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Nature Conservation Monitoring Center

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Conservation Monitoring Centre \ The Royal Society for the Conservation of Nature
Dahiat Al Rasheed, Bulding No. 4, Baker Al Baw Street,
Amman, P.O. Box 1215 Code 11941 Jordan

Jordan Journal of Natural History

Editorial Preface

It is a pleasure to present issue 8 of Jordan Journal of Natural History (JJNH), a journal published by the Conservation Monitoring Centre, The Royal Society for the Conservation of Nature (RSCN). The Jordan Journal of Natural History (JJNH) is an open access international scientific journal publishing original research and reviews in nature history in its broadest sense. This is taken to include conservation biology, botany, geology, paleontology, zoology, and ecology, including a broad range of systematics papers encompassing traditional taxonomic revisions and descriptions, cladistics analyses and molecular phylogenetic. The editorial policy of JJNH will follow the lines of most international journals. All manuscripts received by the editor will be examined by referees, who will be instructed to judge the papers by the significance and novelty of the results reported and to favour briefness of presentation.

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We would like to reaffirm that the success of the journal depends on the quality of reviewing and, equally, the quality of the research papers published. In addition to being a hard-copy journal, JJNH is an open access journal which means that all contents are freely available for the users and their institutions free of charge. Users are allowed to read, download, copy, distribute, print, search, or link to the full texts of the articles in this journal without asking for prior permission from the publisher or the author. This is in accordance with the BOAI definition of open access.

At the end of this preface, would like to thank our readers and authors for their continuing interest in JJNH, and each member of our editorial and review boards for their continued hard work, support and dedication, which made it possible to bring another new issue of JJNH to the multidisciplinary international audience. We very much appreciate your support as we strive to make JJNH one of the most leading and authoritative journals in the field of Natural History Sciences.

June, 2022

الجمعية الملكية لحماية الطبيعة
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The Jordan Journal of Natural History (JJNH) is an open access international scientific journal publishing original research and reviews in nature history in its broadest sense. This is taken to include conservation biology, botany, geology, paleontology, zoology, and ecology, including a broad range of systematics papers encompassing traditional taxonomic revisions and descriptions, cladistics analyses and molecular phylogenetic. The Jordan Journal of Natural History is published by the Conservation Monitoring Centre at the Royal Society for the Conservation of Nature, Jordan.

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Discussion: Concise discussion without repeating the results with the significance of the present work should be provided. Citations should be given in support of the findings.

Acknowledgment: A brief acknowledgment section may be given after the conclusion section just before the references. The acknowledgment of people who provided assistance in manuscript preparation, funding for research, etc. should be listed in this section.

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Ogunseitan, O A. 1998. Protein method for investigating mercuric reductase gene expression in aquatic environments. *Applied and Environmental Microbiology*, 64 (2): 695-702.

Rabia, B and Attum O. 2018. Shoreline encounter and stranding rates of cetanceans and loggerhead turtles *Caretta caretta* in North Sinai, Egypt. *Jordan Journal of Natural History*, 5(1): 75-78.

Hamidan, NA, Geiger, MF and Freyhof, J. 2014. *Garra jordanica*, a new species from the Dead Sea basin with remarks on the relationship of *G. ghorensis, G. tibanica* and *G. rufa* (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, 25(3): 223-236.

Reference to a book

Brown WY and White SR.1985. The Elements of Style, 3rd ed. MacMillan, New York.

Reference to a chapter in an edited book

Mettam, GR and Adams, L B. 2010. How to prepare an electronic version of your article. *In*: Jones, B S and Smith, R Z. (Eds.), Introduction to the Electronic Age. Kluwer Academic Publishers. Netherlands, Pp. 281–304.

Conferences and Meetings

Embabi, N. S. 1990. Environmental Aspects of Distribution of Mangrove in the United Arab Emirates. Proceedings of the First ASWAS Conference. University of the United Arab Emirates. Al- Ain, United Arab Emirates.

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Author/s	An Author and Another(s) the first name and family name should be written in full without abbreviations as (Nashat A. Hmaidan), Centred, Regular, Times New
Affiliation	[1]Department, University, City, Country; Institute, Full Address,
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Abstract	Text smaller, indented both sides, Centred, Regular, Time New Roman, size 12
Key words	word; another word; lower case except names. Position aligned with abstract
Headings	A. Bold initial cap only (size bold), Times New Roman, size 14 B. Bold italic initial cap only (size bold, italic), Times New Roman, size 14 C. Italic initial cap only (size italic), Times New Roman, size 14 D. Italic initial cap only (size italic) Text runs on after a punctuation mark, Times New Roman, size 14 All ranged left, numbers to be included if supplied, no indent below
Paragraph	Indented Paragraph: use this for the first paragraph in a section, or to continue after an extract. New paragraph: use this style when you need to begin a new paragraph

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Conservation Monitoring Centre
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Dahiat Al Rasheed, Bulding No. 4, Baker Al Baw Street,
P. O. Box 1215 Al Jubaiha, Amman 11941 Jordan
Email: jjnh@rscn.org.jo

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Further Collection of Scorpions from Saudi Arabia

Abdulhadi Aloufi[1], Bassam Abu Afifeh[2], Zuhair S. Amr[3]*

[1] Department of Biology, Taibah University, Al-Madinah Al-Munawwarah, Kingdom of Saudi Arabia; [2] Ministry of Education, Al-Rumman Secondary School, Amman; [3] Department of Biology, Jordan University of Science and Technology, Irbid, Jordan

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Abstract

Additional distributional data on the scorpions of Saudi Arabia are presented for eight species, covering 31 localities in Al Madinah Al Monawwarah, Jazan, Riyadh, and Tabuk provinces. In addition, high resolution images are provided for each species. Such data are useful for mapping the scorpions of Saudi Arabia.

Key words: Scorpions, Saudi Arabia, distribution, Buthidae, Scorpionidae.

Introduction

In the past two decades, growing interest in the scorpions of Saudi Arabia resulted in several publications (Al-Asmari *et al.*, 2007, 2009a, b, 2013; Desouky and Alshammari, 2010; El-Hennawy, 2009; Lowe *et al.*, 2014; Alqahtani *et al.*, 2019). Most of these studies did not include high quality images for the scorpions. Abu Afifeh *et al.* (2021) described *Compsobuthus khaybari* from Khaybar area. Recently Aloufi *et al.* (2021) reported on the scorpions of Tabuk including high resolution images for eight species.

The main purpose of this paper is to provide high quality images for the scorpions of Saudi Arabia, along with major diagnostic characteristics for eight species, as well as to document recent records from Al Madinah Al Monawwarah, Jazan, Riyadh, and Tabuk provinces.

Materials and Methods

Scorpions were collected from 31 localities in Al Madinah Al Monawwarah, Jazan, Riyadh,

*Corresponding author: amrz@just.edu.jo

Table 1. Localities from where the scorpions were collected.

Locality	N	E
Ain Al Akhdhar	27° 38' 18.53"	36° 49' 13.46"
Al Atafeah village	24° 27' 28.10"	39° 53' 58.20"
Al Auruf village	24° 12' 07.30"	40° 26' 55.60"
Al Boqa'a	17° 20' 29.04"	43° 09' 43.90"
Al Dyear	25° 00' 52.04"	39° 51' 10.75"
Al Fegrah	24° 21' 44.34"	38° 57' 44.75"
Al Makhrameah	28° 53' 43.08"	36° 07' 28.94"
Al Mendasah	24° 37' 50.93"	39° 19' 12.84"
Al Mulaeleeh	24° 48' 58.65"	39° 09' 05.80"
Al Qarnaen	19° 07' 58.45"	45° 08' 27.06"
Alaab	24° 06' 13.08"	38° 55' 48.13"
Buwat	24° 43' 45.23"	39° 12' 45.23"
Dhabua'h	24° 26' 51.00"	39° 29' 21.00"
Herma	24° 34' 16.83"	40° 20' 51.30"
Jabal Al Ward	26° 24' 06.78"	37° 17' 02.97"
Jabal khasher	17° 20' 08.57"	43° 10' 09.46"
Mughera'a	26° 23' 55.40"	38° 03' 21.20"
Nofoud Al Thumamah	25° 21' 14.00"	46° 29' 37.90"
Quraeah	28° 47' 05.35"	36° 00' 14.93"
Rowdhat Malham	25° 10' 20.70"	46° 29' 34.50"
Sha'eeb Huraymila	25° 05' 34.10"	46° 03' 27.40"
Shajwa	25° 02' 51.77"	38° 59' 47.24"
Sultan Al Feridi farm	24° 21' 58.78"	39° 32' 57.15"
Wadi Al Fara'a	23° 19' 22.14"	39° 36' 42.56"
Wadi Al Garhan	17° 21' 14.33"	43° 05' 57.96"
Wadi al Jal a'b	24° 44' 25.80"	39° 42' 57.29"
Wadi Al Muataf	17° 19' 19.50"	43° 08' 40.50"
Wadi Awed	17° 20' 32.30"	43° 10' 39.80"
Wadi Jora	17° 21' 54.90"	43° 07' 46.10"
Wadi Reem	24° 10' 13.58"	39° 19' 50.03"
Wadi Reem (Al Aseel)	23° 55' 06.50"	39° 18' 05.50"

and Tabuk provinces (Table 1) either by flipping stones or by using ultraviolet torches at night. Specimens were photographed while being alive, and then preserved in 75% ethyl alcohol with glycerol for further identification. The species were identified based on taxonomic keys according to Hendrixson (2006) and Alqahtani and Badry (2021).

Results

In this study, nine species of scorpions belonging to two families (Buthidae and Scorpionidae) were reported from 31 localities from several provinces in Saudi Arabia. High quality images are provided.

Family Buthidae

***Androctonus crassicauda* (Olivier, 1807) (Figure 2).**

Material examined: 2 ♀♀, 1 subadult ♂, Quraeah (Tabuk Province), 23.7.2017, *leg*. A. Aloufi. 1 ♂, Buwat (Al Madinah Al Monawwarah Province), 11.5.2017, *leg*. A. Aloufi. 1 ♂ juv., Al Mendasah (Al Madinah Al Monawwarah Province), 9.8.2018, *leg*. A. Aloufi. 1♂, Wadi Al Fara'a (Al Madinah Al Monawwarah Province), 1.4.2018, *leg*. A. Aloufi. 1 ♀ subadult, Dhabua'h (Al Madinah Al Monawwarah Province), 17.9.2017, *leg*. A. Aloufi. 2 ♀♀, 3 ♂♂ subadults, 1 ♀ subadult, 5 juv. Rowdhat Malham (Riyadh Province), 26.11.2021, *leg*. A. Aloufi. 2 ♂♂ subadults, 1 ♀ subadult, Sha'eeb Huraymila (Riyadh Province), 30.9.2021, *leg*. A. Aloufi. 1 ♀ subadult, 1 ♂, Al Atafeah village , Al Suedrah city (Al Madinah Al Monawwarah Province), 12.4.2022, *leg*. A. Aloufi. 1 ♂, Al Auruf village , Al Suedrah city (Al Madinah Al Monawwarah Province), 20.4.2022, *leg*. A. Aloufi. 1 ♀, Sultan Al Feridi farm (Al Madinah Al Monawwarah Province), 12.5.2022, *leg*. A. Aloufi. 1 ♀, Jabal Al Ward (Al Ula Governorate, Al Madinah Al Monawarah Province), 14.5.2017, *leg*. A. Aloufi. 1 ♀, Hermah, Al Suedrah city (Al Madinah Al Monawwarah Province), 3.6.2022, *leg*. A. Aloufi. 2 ♂♂,1 ♀, Al Dyear, Al Suedrah city (Al Madinah Al Monawwarah Province), 8.6.2022, *leg*. A.

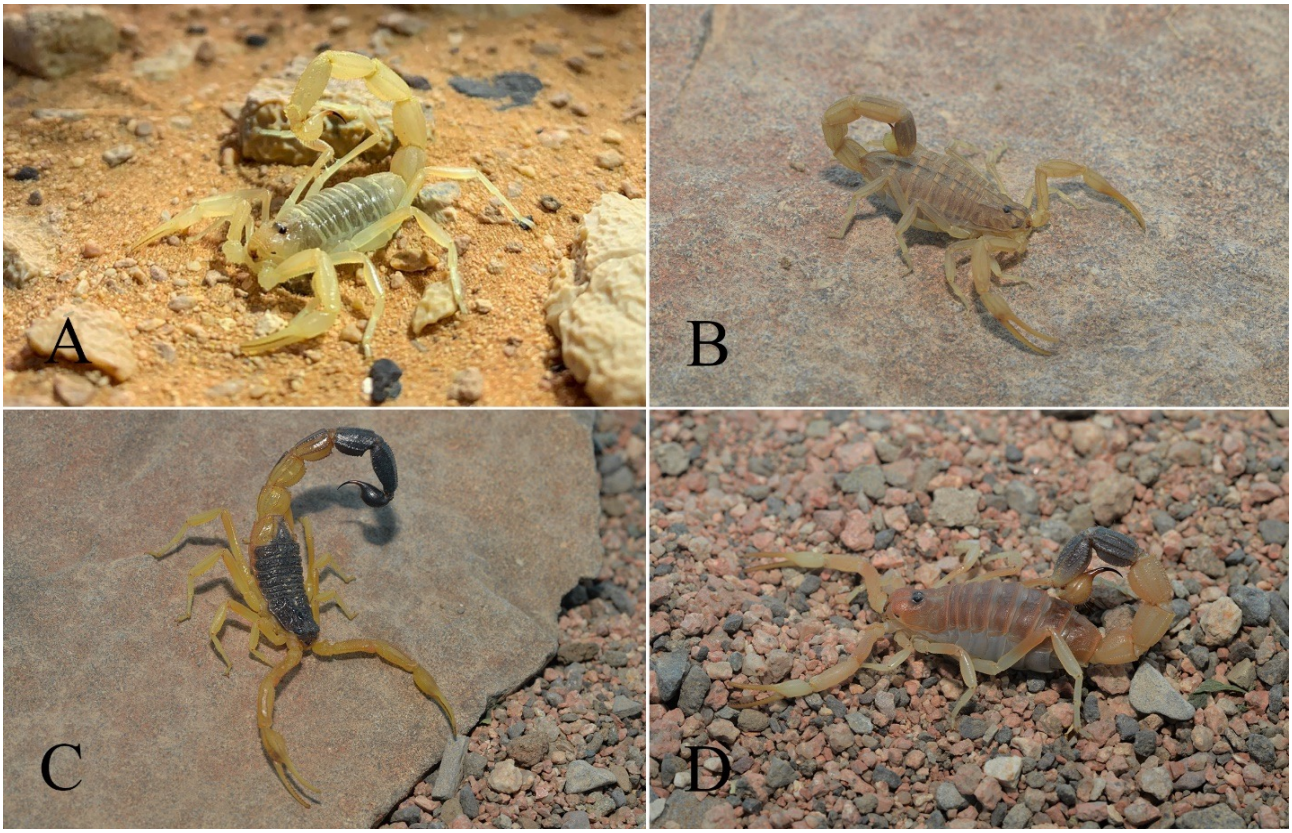

Figure 1. A. *Buthacus* sp. **B**. *Compsobuthus manzonii.* **C**. *Hottentotta scaber.* **D**. *Parabuthus liosoma.*

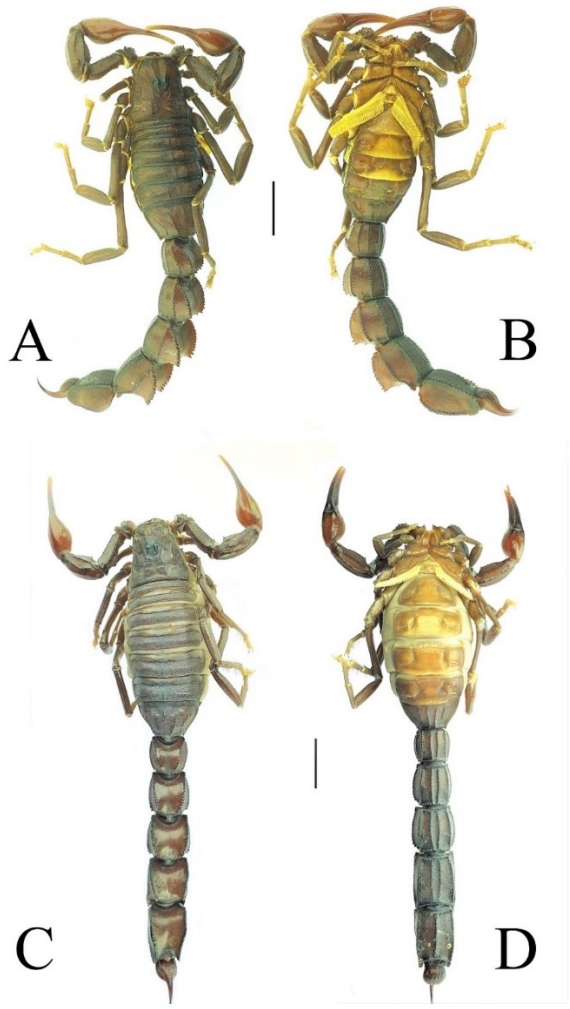

Figure 2. *Androctonus crassicauda.* Male. **A**. Dorsal aspect. **B.** ventral aspect. Female. **C**. Dorsal aspect. **D.** ventral aspect. Scale bar = 10 mm

Aloufi.

Diagnosis: Colour of adults is golden brown to nearly black, pale yellow in juveniles; metasomal segment III wider than long; pedipalp manus broad and stout; outer tooth of basitarsal spur on leg IV generally not bifurcated, mesosomal tergites I and II with at most three carinae (Hendrixon, 2006).

Remarks: This is a widely distributed species across Saudi Arabia (Hendrixon, 2006; Alqahtani and Badry, 2021). Its distribution range extends across all of the Middle East and reaches as far as Armenia and Azerbaijan (Hendrixon, 2006). Alqahtani *et al.* (2022) showed that three distinct clusters of *A. crassicauda* in Saudi Arabia and Iran based on molecular studies.

Figure 3. Dorsal and ventral views of *Apistobuthus pterygocercus* female.

***Apistobuthus pterygocercus* Finnegan, 1932 (Figure 3).**

Material examined: 1♀, Nofoud Al Thumamah (Riyadh Province), 2.12.2021, *leg*. A. Aloufi.

Diagnosis: Carapace with distinct carina, metasomal segment II widely flared, much wider than other segments, pedipalp chela fingers extremely elongated with 13-14 rows of granules, pectinal tooth counts 36-50 in female, 52-57 in males.

Remarks: This species was originally described from Uruq Dhahiqah, Saudi Arabia (Finnegan, 1932). This is a sand dwelling species associated with sand dunes around Hail, Riyadh and Ash Sharqiyah (Alqahtani and Badry, 2021). Widespread throughout the Arabian Peninsula including Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen (Hendrixon, 2006).

***Buthacus* sp. (Figures 1A, 4).**

Material examined 1 ♂ subadult, Sha'eeb Huraymila (Riyadh Province), 30.11.2021, *leg*. A. Aloufi.

Diagnosis: External surface of pedipalp patella with seven trichobothria; pedipalp femoral trichobothrium **d**5 proximal to **e**2; metasomal segments very hirsute; metasomal segment V and/or telson often black; pedipalp chela fingers with inner and

Figure 4. Dorsal and ventral views of *Buthacus* sp. male.

outer accessory granules.

Remarks: The validity of this species is still doubtful. It seems that *Buthacus nigroaculeatus* is the common species, however our specimens do not fit with the description of *B. nigroaculeatus*. For the mean time, we refer to these specimens as *Buthacus* sp.

***Compsobuthus manzonii* (Borelli, 1915) (Figures 1B, 5).**

Material examined 1♀, Wadi al Jal a'b. Al Wahaj farm (Al Madinah Al Monawwarah Province), 6.8.2017, *leg*. A. Aloufi. 1 ♀, Shajwa (Al Madinah Al Monawwarah Province), 8.4.2018, *leg*. A. Aloufi. 2 ♂♂, 2 ♀♀, Alaab (Al Madinah Al Monawwarah Province), 21.3.2019, *leg*. A. Aloufi. 1 ♂, 1 ♀, Ain Al Akhdhar, Harat Al Rahah (Tabuk Province), 5.7.2021, *leg*. A. Aloufi. 1♀, Wadi Al Garhan (Al Dayer Governorate, Jazan Province), 5.12.2021, *leg*. A. Aloufi. 2 ♂♂, 2 ♀♀, Wadi Jora, (Al Dayer Governorate, Jazan Province), 2.5.2022, *leg*. A. Aloufi. 1♀, Al Boqa'a, (Al Dayer Governorate, Jazan Province), 4.5.2022, *leg*. A. Aloufi. 1♂, Wadi Al Muataf , (Al Dayer Governorate, Jazan Province), 5.5.2022, *leg*. A. Aloufi. 4 ♂♂, 1 ♀, Al Fegrah (Wadi Mzaber), (Al Madinah Al Monawwarah Province), 25.5.2022, *leg*. A. Aloufi.

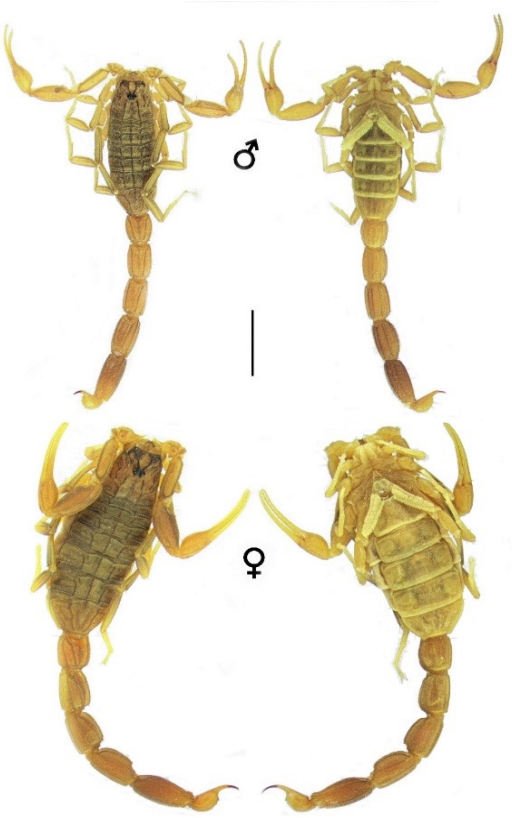

Figure 5. *Compsobuthus manzonii*. Male. **A**. Dorsal aspect. **B.** ventral aspect. Female. **C**. Dorsal aspect. **D.** ventral aspect. Scale bar = 5 mm.

Diagnosis: Adult females to 45 mm in length; body surfaces generally underlined with dusky pigment; pedipalp chela fingers with outer accessory granules; pedipalp chela fingers with 9-11 rows of granules along dentate margin; pectinal tooth counts 19-23 in males, 17-19 in females; median lateral carinae on metasomal segments II and III present at least on posterior three-fourths; pedipalp chela fingers not extremely elongated.

Remarks: This species was firstly recorded from Saudi Arabia as a new species under the name *Compsobuthus fuscatus* Hendrixson, 2006, with its holotype male from Jabal Qishayradh, 21°17' N 40°17› E, this particular form of *Compsobuthus* is distributed throughout the south-western of Saudi Arabia (Hendrixson, 2006, Fig. 13 : 70), and

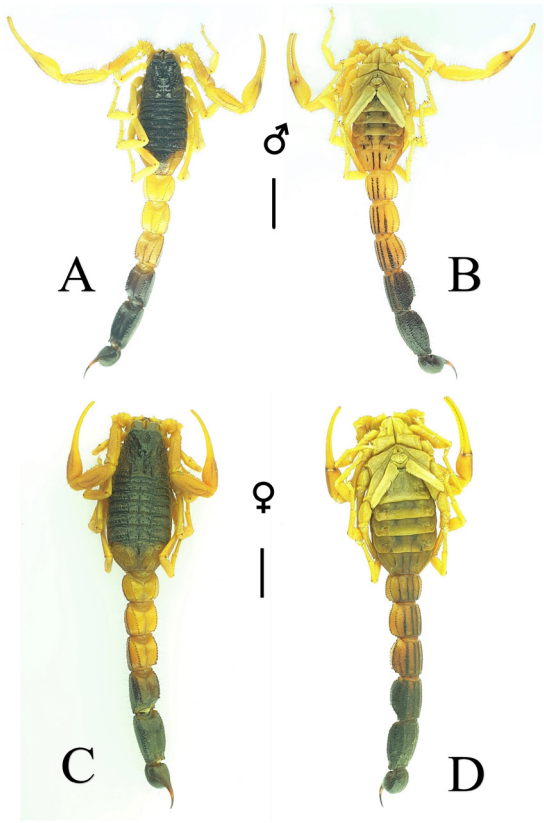

Figure 6.- *Hottentotta scaber*.Male. **A**. Dorsal aspect. **B.** ventral aspect. Female. **C**. Dorsal aspect. **D.** ventral aspect. Scale bar = 10 mm.

throughout the mountainous areas of north-west Yemen (Sissom, 1994, Fig. 13 : 70)
This species was recorded from Asir, Jazan and Mecca (Alqahtani *et al.*, 2019). The present records extend its distribution range further into northwestern Saudi Arabia. According to Kovařík, (2013), *Compsobuthus fuscatus* Hendrixson, 2006 is synonymized with *Compsubuthus manzonii* (Borelli, 1915).

***Hottentotta scaber* (Ehrenberg, 1828) (Figure 1C, 6).**

Material examined: 1♂, Jabal khasher, (Al Dayer Governorate, Jazan Province), 5.12.2021, *leg*. A. Aloufi. 1 subadult ♂, Wadi Al Garhan, (Al Dayer Governorate, Jazan Province), 1.5.2022, *leg*. A. Aloufi. 1 ♀, 1 ♂ juv., Wadi Jora, (Al Dayer Governorate, Jazan Province), 2.5.2022, *leg*. A. Aloufi. 2 subadult ♀, Wadi Awed, (Al Dayer Governorate, Jazan Province), 3.5.2022, *leg*. A. Aloufi. 2 ♂♂, 2 ♀♀, Al Boqa'a, (Al Dayer Governorate, Jazan Province), 4.5.2022, *leg*. A. Aloufi. 2 ♂♂, 2 ♀♀, 2 subadults ♂♂, 5 subadults ♀♀, Wadi Al Garhan, (Al Dayer Governorate, Jazan Province), 2.7.2022, *leg*. A. Aloufi.

Diagnosis: Total length 60–85 mm. Male with slightly longer and narrower metasomal segments. Pectinal teeth number 34–37 in males, 28–33 in females. Pedipalps and legs densely hirsute, metasoma sparsely hirsute, fifth metasomal segment more hirsute than first. The hairs on patella of pedipalps are long. Carapace, mesosoma except seventh tergite (or its posterior part), fifth metasomal segment and telson black. First three metasomal segments, legs and pedipalps including fingers uniformly pale yellow. Ventral carinae on metasomal segments also black. Movable fingers of pedipalps with 14–15 rows of granules and 5 terminal granules. First and second metasomal segments with 10 carinae; third and fourth segments with 8 carinae; fifth segment with 5 carinae, 3 ventral (1 median, 2 lateral) and 2 dorsal. First and second metasomal segments of both sexes wider than long.

Remarks: *H. scaber* has three characters unusual for the genus. It differs from all other species in coloration, with the carapace, mesosoma, the fifth metasomal segment and telson black and all other parts pale yellow. Exceptional is also the combination of densely hirsute pedipalps and sparsely hirsute metasoma, which indicates closeness to *H. jayakari* and *H. salei* inhabiting the same areas. Most unusual are the very broad first and second metasomal segments in relation to the fourth metasomal segment, namely in females. This unusual feature is otherwise present only in *H. jalalabadensis*, which is easily distinguished by other noted characters (pubescence and color).
This African species was first recorded in Saudi Arabia from Seir Farasãn Kebir (Kovařík and Whitman, 2005; Kovařík, 2007), the second record were from Khasher and Al Aridhah (Jizan Province) by Alqahtani *et al*. (2019).

***Leiurus haenggii* Lowe, Yagmur & Kovarik, 2014 (Figure 7).**

Material examined 1 ♂ subadult, Mughera'a (Al Ula Governorate, Al Madinah Al Monawarah Province), 19.7.2017, *leg*. A. Aloufi. 3♂♂, 1♀, 3 ♂♂ subadults, Wadi al Jal a'b, Al Wahaj farm (Al Madinah Al Monawwarah Province), 6.8.2017, *leg*. A. Aloufi. 1 ♂, Al Mulaeleeh, Al Madinah Al Monawwarah Province), 13.9.2017, *leg*. A. Aloufi. 1♀, 1 ♂ subadult, 1 ♀ subadult, Wadi Reem (Al Madinah Al Monawwarah Province), 5.5.2018, *leg*. A. Aloufi. 2 ♂♂, 2 ♀♀, 3 ♂♂ subadults, 2 ♀♀ subadults, Alaab (Al Madinah Al Monawwarah Province), 21.3.2019, *leg*. A. Aloufi. ♂♂, 1♀, Wadi Reem (Al Aseel), (Al Madinah Al Monawwarah Province), 22.5.2022, *leg*. A. Aloufi.

Diagnosis: Mesosomal tergites I and II with five carinae, pedipalp patella in females with L/W less than 3.20, female sternites III–IV with weak to obsolete median carinae (Lowe *et al.*, 2014).

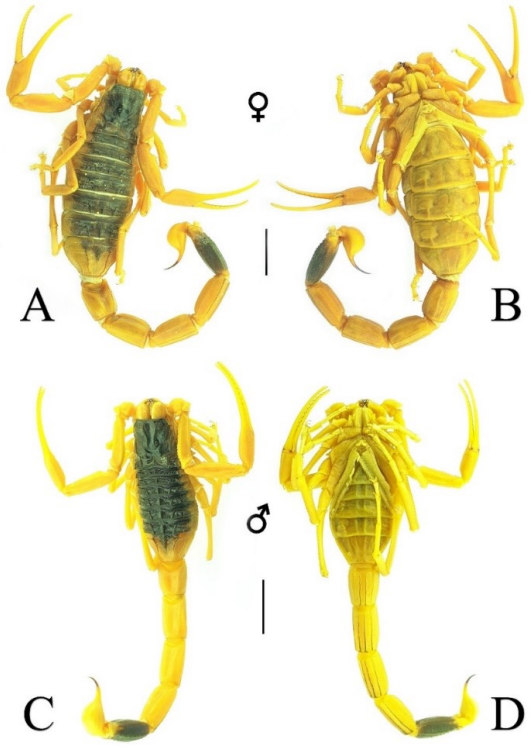

Figure 7. *Leiurus haenggii*. Female. **A**. Dorsal aspect. **B.** ventral aspect. Male. **C**. Dorsal aspect. **D.** ventral aspect. Scale bar = 10 mm.

Remarks: Lowe *et al.* (2014) revised the genus *Leiurus*; all previous records of *Leiurus quinquestriatus* (Ehrenberg, 1828) in Saudi Arabia are described as either: *Leiurus brachycentrus* (Ehrenberg, 1829) known along the southern Red Sea coast of Saudi Arabia and Yemen, *Leiurus arabicus* Lowe, Yagmur & Kovarik, 2014 in central Arabia reaching as far as the southwest of Makkah, and *Leiurus haenggii* Lowe, Yagmur & Kovarik, 2014 extending along the coastal mountains of the Red Sea reaching as far as Yemen and western Oman (Lowe *et al.,* 2014).

***Parabuthus liosoma* (Ehrenberg, 1828) (Figures 1D, 8).**

Material examined: 3 ♂♂, 1♂ juv., Wadi Al Garhan (Al Dayer Governorate, Jazan Province), 5.12.2021, *leg*. A. Aloufi. 1♂, Wadi Al Garhan (Al Dayer Governorate, Jazan Province), 2.7.2022, *leg*. A. Aloufi.

Diagnosis: Pedipalp femoral trichobothria arranged in alpha-configuration; a stridulatory patch present on the dorsal surface of metasomal segments I-III (Hendrixon, 2006).

Remarks: The genus *Parabuthus* is represented by several species in the Horn of Africa (Kovařík *et al.*, 2016). In their study, Kovařík *et al.* (2016) split *P. liosoma* into three sibling species; *P. abyssinicus* Pocock, 1901 confined to Eritrea, Djibouti, central and north-eastern parts of Ethiopia), *P. liosoma* (Ehrenberg, 1828) known from Yemen and Saudi Arabia and *P. maximus* Werner, 1913 from Tanzania and Kenya). Recorded previously from southwestern Saudi Arabia including Jeddah and Jizan (Hendrixon, 2006), Al Baha. Jazan and Mecca (Alqahtani *et al.*, 2019) and Tabuk (Aloufi *et al.*, 2021).

***Vachoniolus globimanus* Levy, Amitai & Shulov, 1973 (Figure 9).**

Material examined: 1♀, Al Makhrameah (Al Wabari Farm, Tabuk Province), 23.7.2017, *l*eg. A. Aloufi. 1 ♂, Al Qarnaen

(Uruq Bani M'arid Protected Area, Yadamah Governorate, Najran Province), 5.5.2019, *leg*. A. Aloufi.

Diagnosis: Carapace lacking distinct carinae; external surface of pedipalp patella with eight or nine trichobothria; pedipalp femoral trichobothrium d_5 distal to e_2; male pedipalp chela swollen and globular (Hendrixon, 2006).

Figure 8. Dorsal and ventral views of *Parabuthus liosoma* male.

Remarks: This species is widely distributed across Oman, Saudi Arabia and the United Arab Emirates (Lowe, 2010; Alqahtani & Badry, 2021). It was previously recorded from Riyadh and El-Baha (Hendrixson, 2006; Al-Asmari *et al.*, 2009a). The present record extends its distribution range to the northwest of Saudi Arabia in Tabuk. Both Al Makhrameah in Tabuk and Al Qarnaen in Najran have extensive sand plains.

***Scorpio kruglovi* Birula, 1910 (Figure 10, Figure 11A-C).**

Material examined: 1♀, 1♂, Quraeah, (Tabuk Province), 23.7.2017, *leg*. A. Aloufi.

Diagnosis: Adults greater than 5 cm long , general color of the body straw yellow or light brown; fingers of pedipalp chela darkened, anterior margin of carapace with shallow median notch, median eyes located in the middle of carapace, three pairs of lateral ocelli, pedipalps orthobothriotaxic, with 26 trichobothria, pedipalp chela trichobothrium ***it*** placed basally along fixed finger near ***ib***, chela rather narrow (its maximum width is smaller than the length from the basal joint

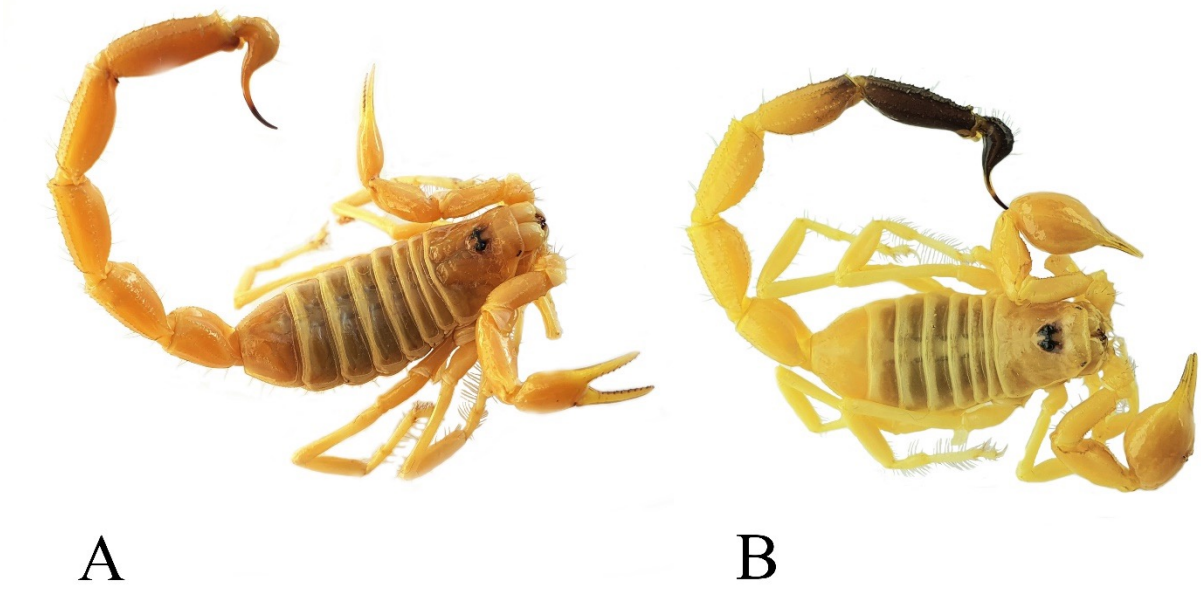

Figure 9. A. Dorsal view of *Vachoniolus globimanus* female. **B.** Dorsal view of *Vachoniolus globimanus* male.

to the edge of the fixed finger, in females the external surface of chela almost smooth mostly with a sculptural structure of barely raised punctate fine whorls; the internal surface almost smooth; only covered with barely noticeable, very finely dotted small spots; in males the external surface of chela with rather unequal small, isolated, covered with rounded, somewhat pointed granules, internal surface of chela is rather sparsely covered with pointed granules over almost two-thirds of its surface. Sternite VII with paired ventrosubmedian and ventrolateral carinae, metasomal segments I-IV each with paired ventrosubmedian and ventrolateral carinae; ventrosubmedian carinae of metasomal segment IV smooth, telson lacking subaculear tubercle; telson vesicle granular ventrally; telson vesicle rather narrow, elongated, almost as long as the moderately curved aculeus, female pecten with long narrow basal median lamella; of the same length the untoothed area as the region bearing the teeth. Pectinal tooth count 9-10, tibial spurs absent, tarsi armed only with prolateral pedal spurs, tarsi ending in rounded lateroapical lobes; 6 spines on the external surface of the tarsi of legs IV and 9 on the internal surface (the formula being 6-7/8-10), stridulatory organs absent.

Remarks: *S. kruglovi* was first recorded from Wadi Hanifa and near Riyadh by Vachon (1979). The characters of the 5 females examined by Vachon, whose size is about 5 cm, correspond well to those possessed by the subspecies *kruglovi* Birula whose type locality is Deir-Al Zur, upper Euphrates / Syria. The important and special character to this form is, in his opinion, that drawn from the structure of the pectines; the basal median lamella of which is long and narrow (Fig. 10A), the untoothed region of pecten of the same length as the region bearing the teeth. All examined females with pectinal tooth count 9 or 10. Talal *et al.* (2015) elevated this subspecies to the species level as *Scorpio kruglovi* Birula, 1910.

In their identification keys Barahoei *et al.* (2020) and Alqahtani & Badry (2021) reversed the character "*Base of pectin with or without denticle*" to distinguish between *S. kruglovi* and *S. palmatus*. According to Birula (1910) plates and figures; females of *S. kruglovi* has a slender basal median lamella of pecten devoid of denticles basally (Fig. 11A). In contrast, *S. palmatus* has a stocky, basal median lamella with more denticles (Fig. 11D).

Figure 10. Dorsal and ventral view of female *Scorpio kruglovi*.

Discussion

The scorpions of Saudi Arabia are still in dire need for further studies. With the large area of Saudi Arabia, many species are awaiting exploration that will certainly results in additional new species. Recent studies by Abu Afifeh *et al.* (2021) and Alqahtani *et al.* (2022) added more to our knowledge on the scorpions of Saudi Arabia.

The scorpions of the southwestern region

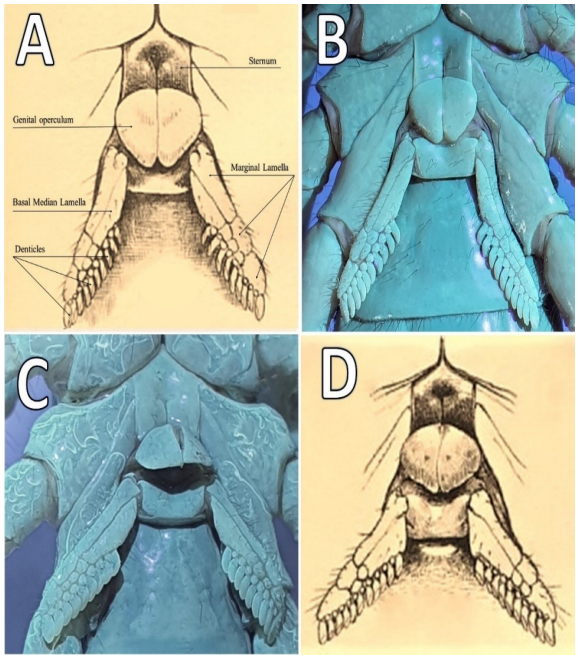

Figure 11. Pectines, genital operculum and sternum. **A.** Female *Scorpio kruglovi* (Birula, 1910, Fig. 14, plate XIII). **B.** Female *Scorpio kruglovi* (Quraeah, Tabuk). **C.** Male *Scorpio kruglovi* (Quraeah, Tabuk). **D.** Male *Scorpio palmatus* (Birula 1910, Fig. 7, plate XII).

of Saudi Arabia are still to be investigated, especially the status of species of the genus *Nebo*. It is anticipated that a new species of this genus will be described based on our personal observations. We have collected specimens from many parts of the country that are still under investigation. Species of the genus *Scorpio* are still a challenge to reveal their identity, and certainly new species of this genus will be described shortly. On the other hand, species of the genus *Compsobuthus* are still to be explored due to high variations between the different populations in Saudi Arabia.

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Snakes from Jazan Province, Saudi Arabia

Abdulhadi Aloufi[1], Zuhair S. Amr[2*], and Mohammad A. Abu Baker [3]

[1] Department of Biology, Taibah University, Al-Madinah Al-Munawwarah, Kingdom of Saudi Arabia; [2] Department of Biology, Jordan University of Science and Technology, Irbid, Jordan, [3] Department of Biology, the University of Jordan, Amman, Jordan

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Abstract

Eleven species of snakes belonging to six families (Colubridae, Psammophiidae, Lamprophiidae, Viperidae, Elapidae and Atractaspididae) are reported herein from Jazan Province. Data on their ecology are presented along with a zoogeographical analysis of species of African affinities.

Keywords: Jazan, Snakes, *Psammophis aegyptius, Boaedon fuliginosus*

Introduction

Despite the additions of new records to the herpetofauna of Saudi Arabia over the last decade (Aloufi and Amr, 2015, Aloufi *et al*., 2019, 2020, 2021, 2022), some areas remain poorly known in terms of herpetological studies. The most southwestern corner of Saudi Arabia, close to the Yemeni frontiers was subject to few studies. Schätti and Gasperetti (1994) recorded twenty-two species of snakes from southwestern Arabia. Masood (2012) listed thirty-six species of snakes from Jazan area, several are of doubtful presence (i.e. *Pesudocerastes persicus fieldi* [Sic.], *Cerastes vipera, Naja nigricollis*, and *Platyceps ventromaculatus*), while Masood and Asiry (2012) removed these species from the list of Jazan snakes. Busais *et al*. (2019) listed seven species of venomous snakes from the Jazan area.

Jazan Province has an area of 12.435 km^2 and is located on the most southwestern part of Saudi Arabia, adjacent to Yemen. It includes about one-hundred islands in the Red Sea, among which is the largest, Farasan Island. Its coastline extends along the Red Sea for 280 km. The annual rainfall is less than 100 mm, with mean maximum temperatures ranging from 40 ˚C in July to 31 ˚C in January. Different types of habitats are found within Jazan Province ranging from high mountains such as Al-Sarawat mountains with an altitude reaching up to 3000 m asl, to dense forests and pasture lands such as Al-hazoun forest, and Tihamah plains that are extensively planted with coffee beans, cereal grain crops and fruits. In addition to having many forms of wetlands (i.e., Wadi Lajab and Wadi Jazan Dam) as well as salt marches "*sabkhas"* along the coastal plains (King Abdulaziz Public Library 2011). In this communication, eleven species of snakes are reported from Jazan Province, Saudi Arabia.

Materials and Methods

Field trips were conducted between October 2021 and January 2022. Reptiles were visually observed and captured during day and night times by a group of wildlife biologists from five sites representing different habitats in Jazan Province. Transects of about one km length were surveyed during daytime with at least 3 hrs. of total effort for each site. Scale counts include ventral, caudal, and midbody scales. Measurement were taken for snout-vent and tail.

Study area

Five areas were studied within Jazan Province; Al-Kheshabeah, Wadi Al-Heiad, Wadi Al- Mejasess, Wadi Al-Meqtabah and Wadi Jazan. Habitats in these sites varied considerably (Figure 1 and 2). Below are descriptions of each study site.

*Corresponding author: amrz@just.edu.jo

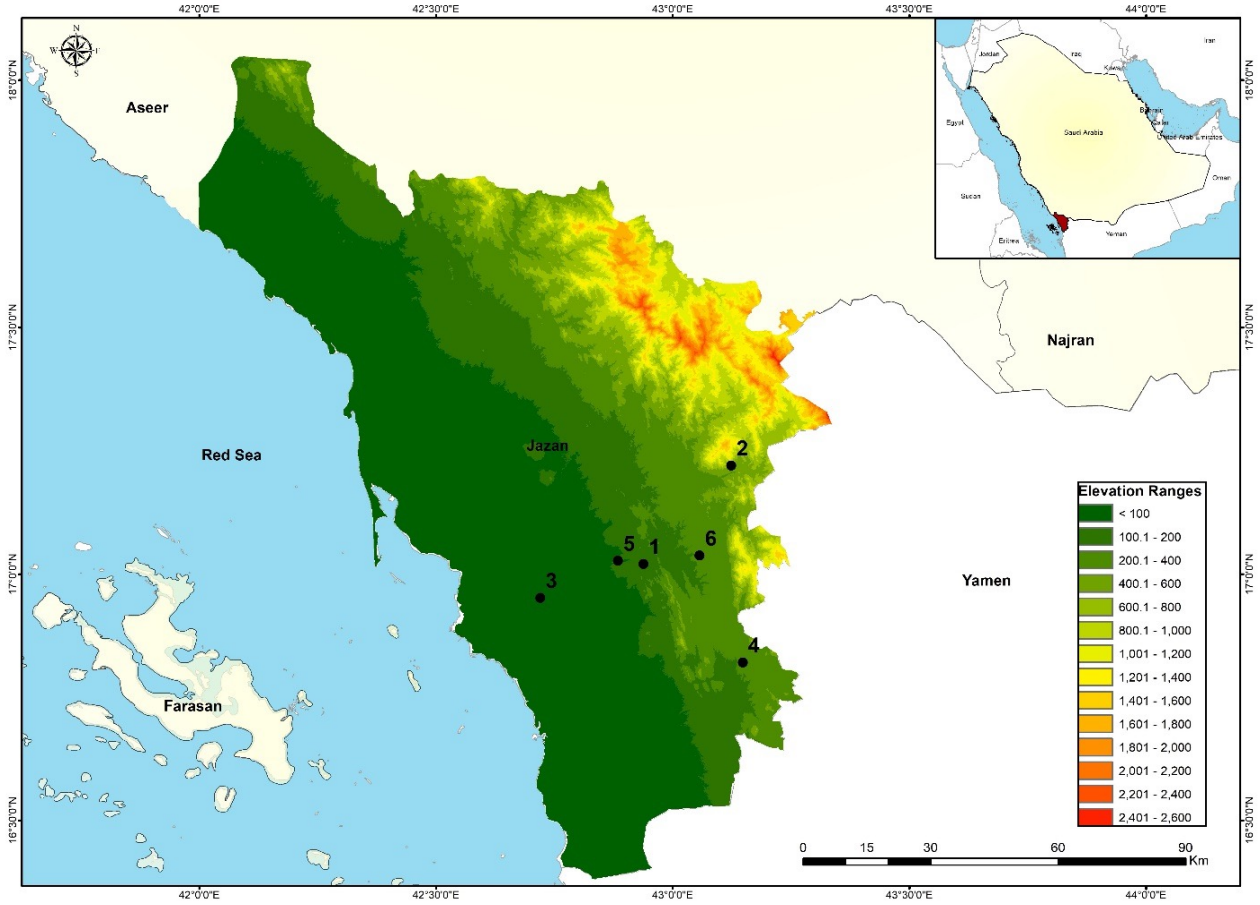

Figure 1. Map of Jazan showing studied localities. 1. Wadi Jazan. 2. Fifa mountains. 3. Al-kheshabeah. 4. Wadi Al-Meqtabah. 5. Wadi Al-Mejasess. 6. Wadi Al-Heiad.

Al-kheshabeah (16°57'6.66" N, 42°43'14.84" E): Located within Abu ʿArish Governorate. This site is part of a sandy plain that is 95 m asl, densely covered with *Panicum turgidum*.

Wadi Al-Heiad (17° 02' 11.55" N 43° 6'50.73" E): Located within Al-Aridhah Governorate. A large valley descending from Mount Al-Abadil, characterized by rocky cliffs with large rocks at the mountainside, some of which block the wadi to create large pools of water. It is about 270 m asl. *Ficus cordata salicifolia* trees are scattered on its sides on the upper slopes, however, there is a scattered presence of *Dobera glabra* trees. At the foothill of the valley, *Ziziphus spina-christi*, *Acacia gerrardii*, and *Anisotes trisulcus* grow densely in the form of a forest.

Wadi Al-Mejasess (17° 1'38.12" N 42°53'4.99" E): Located within Abu ʿArish Governorate. A large valley that is about 110 m above sea level. On its high rocky sides, the *Delonix elata* trees are scattered, while in the depth and middle of the valley there is a forest of *Acacia ehrenbergiana* and some Doum palms, *Hyphaene thebaica*.

Wadi Al-Meqtabah (16°49'13.76" N 43° 8'55.78" E): Located within Al-Hurath Governorate. A large valley that is about 220 m above sea level. It is densely covered with *Ocimum tenuiflorum* and *Abutilon sp.* On its rocky sides, there are clusters of *Adenium obesum* and *Acacia* sp.

Wadi Jazan (17° 1'14.51" N 42° 56' 18.36" E): Wide wadi systems in Jazan province with seasonal water forming a stream-like water body, ending with a big lake. The dominant plant communities consist of *Acacia ehrenbergiana, Acacia johnwoodii, Typha elephantina, Saccharum spontaneum,*

Figure 2. Sites from which collections were made. **A**. Al-kheshabeah. **B**. Wadi Al-Heiad. **C**. Wadi Al-Mejasess. D. Wadi Al-Meqtabah. E. Wadi Jazan (Photo by Mohamed Fetini).

Calotropis procera and some *Hyphaene thebaica*.

Results

Eleven species of snakes belonging to six families (Colubridae, Psammophiidae, Lamprophiidae, Viperidae, Elapidae and Atractaspididae) were reported from Jazan Province during the study period. Families Colubridae, Psammophiidae and Viperidae were represented by three, two, and three species respectively, while the families Lamprophiidae, Elapidae and Atractaspididae were represented by a single species for each family, Table 1 shows scale counts and

measurements for the collected specimens.

Family Colubridae

***Platyceps variabilis* (Boulenger, 1905) Figure 3A**

Material examined: JZC002 and JZC007, Wadi Al-Meqtabah, 28.11.2021.

Remarks: Two specimens were collected for this species. Both are uniformly black, whereas the head is darker than the rest of the body. Table 1 shows measurements and scale counts. Scalation of collected specimens falls within the range (153-174 ventral scales, 80-90 caudal scales) given by Gasperetti (1988) and Schätti and Gasperetti (1994). Schätti and Gasperetti (1994) suggested a new combination for this species; *Platyceps variabilis manseri* Leviton, 1986. They noted specimens from Hakimah, Malakiyah, Wadi Shadhan, and Wadi Damad. Gasperetti (1988) postulated that *P. manseri* and *P. variabilis* might integrate in Yemen.

This species was originally described from Yemen and is considered a highly polymorphic species (Boulenger, 1905). He described seven different colour morphs with remarkable variations. Al Aloufi *et al.* (2020) reported on a specimen collected from the vicinity of Al-Madinah Al- Monawrah Province. Its distribution range is confined to western Oman, western Saudi Arabia and Yemen (Boulenger 1905; Schätti and Gasperetti, 1994; Šmíd, 2010).

Figure 3. **A**. P*latyceps variabilis*. **B**. *Spalerosophis diadema cliffordii*. **C**. T*elescopus dhara,* **D**. *Boaedon fuliginosus*. **E.** *Psammophis aegyptius*. **F**. *Psammophis schokari*.

Table 1. Scale counts and measurements for the collected specimens from Jazan Province.

Species	Specimen No.	SV (mm)	TL (mm)	VS	CS
Boaedon fuliginosus	JZC011	375	65	229	57
Echis borkini	JZC008	450	55	160	33
Echis coloratus	JZC006	350	45	131	47
Psammophis aegyptius	JZC003	1035	475	188	104
Psammophis aegyptius	JZC004	1950	370	177	99
Platyceps variabilis	JZC002	320	120	167	80
Platyceps variabilis	JZC007	335	115	174	70
Spalerosophis diadema cliffordii	JZC001	1400	180	216	70
Psammophis schokari	JZC005	1000	265	185	79
Telescopus dhara	JZC012	790	150	233	71

***Spalerosophis diadema cliffordii* (Schlegel, 1837) Figure 3B**

Material examined: JZC001, Al-kheshabeah, 28.11.2021.

Remarks: The Diadem Snake has a wide range of distribution across North Africa reaching the Middle East. It was reported from several localities across Saudi Arabia (Gasperetti, 1988), covering a wide range of habitats. Scale counts and measurements are given in Table 1.

***Telescopus dhara* (Forskål, 1775) Figure 3C**

Material examined: JZC012, Wadi Al-Heiad, 28.12.2021.

Remarks: The Arabian Cat Snake is distributed along the Arabian Peninsula, Jordan, Palestine and Sinai (Sindaco *et al*., 2013). According to Gasperetti (1988), it exhibits several colour morphs within its populations. The specimen in this work is uniformly brown-red without markings. Scale counts fall within the range (235-274 ventral scales, 66-72 caudal scales) given by Gasperetti (1988). This species is associated with arid mountains, with many records along western Saudi Arabia including Jazan area, and few in central Saudi Arabia (Gasperetti, 1988).

Family Psammophiidae

***Psammophis aegyptius* Marx, 1958 Fig. 3E, Figure 4A and B**

Material examined: JZC003 and JZC004, Wadi Al-Mejasess, 30.11.2021.

Remarks: Aloufi *et al*. (2022) recorded *P. aegyptius* for the first time from Saudi Arabia. This species is distributed across Egypt, reaching southern Algeria and Libya, Chad and Niger (Sindaco *et al.,* 2013). Rato *et al.* (2007) stated that *P. aegyptius* is a sister species of *Psammophis schokari*, however, genetic divergence is high which permits considering *P. aegyptius* as a distinct species.

***Psammophis schokari* (Forskål, 1775) Figure 3F, Figure 4C and D**

Material examined: JZC005, Wadi Al-Mejasess, 30.11.2021.

Remarks: The Forskål Sand Snake has a wide range of distribution across North Africa, the Middle East reaching as far as Iran (Sindaco *et al*., 2013). This is a highly polymorphic species; striped, non-striped and rear-striped (Kark *et al.,* 1997). Marx (1988) stated that three Arabian groups of *P. schokari* occur in the Arabian Peninsula; western, central and eastern based on scale counts and morphological features. The

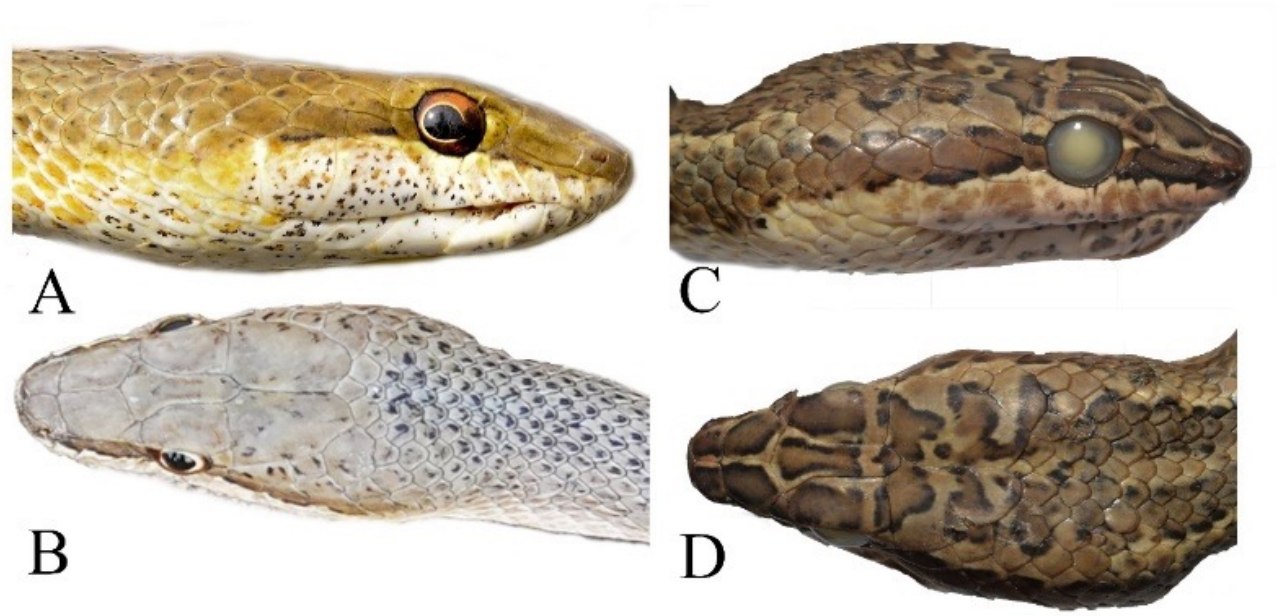

Figure 4. A. Lateral aspect for the head of *P. aegyptius*. **B.** Dorsal aspect for the head of *P. aegyptius*. **C**. Lateral aspect for the head of *P. schokari*. **D.** Dorsal aspect for the head of *P. schokari*.

presence of a dark stripe from the snout through the eye reaching the temporal region (Figure 3D) is a distinctive feature of *P. schokari* (Schleich *et al.,* 1996).

This is a common species in Saudi Arabia and is known all over the country. The locals make a distinction between *P. aegyptius* and *P. schokari,* calling the first "*Al-Gubry*" which means the dusty snake, and the second "*Al-Shajary*" meaning the tree-dweller. Table 1 shows scalation and measurements for a specimen collected from Wadi Al-Mejasess.

Family Lamprophiidae

***Boaedon fuliginosus* (Boie, 1827) Figure 3D, Figure 6**

Material examined: JZC011, Wadi Al-Heiad, 29.12.2021.

Remarks: Aloufi *et al*. (2022) recorded the Common African House Snake for the first time from Saudi Arabia. Also, it was reported from two localities in Yemen; Dathla, and Wadi Warazan in the Arabian Peninsula (Parker, 1930; Schätti and Gasperetti, 1994). This is an African species with a distribution range extending from West and Central Africa reaching Sudan, Ethiopia, and Eritrea (Sindaco *et al.,* 2013). This species is apparently common; a snake vendor collected fourteen specimens from Wadi Al-Heiad. The species is sought after by snake collectors in Saudi Arabia. Another vendor collected specimens from Fifa Mountains (Figure 6), and a local scientist sent some photos for this species from Athreb Mountains in Asir Province.

Family Viperidae

***Cerastes gasperettii* Leviton & Anderson, 1967**

Remarks: One specimen was observed in Al-kheshabeah. The Arabian Horned Viper is widespread across the Arabian Peninsula inhabiting sand-covered areas (Gasperetti 1988; Schätti and Gasperetti, 1994; Aloufi and Amr, 2015).

***Echis borkini* Cherlin, 1990 Figure 6B**

Material examined: JZC008, Wadi Al-Mejasess, 30.11.2021.

Remarks: The taxonomic status of this

Figure 5. A snake vendor from Fifa holding three common African house snakes.

species remains obscure. Cherlin (1990) described this species from East Africa. Other authorities placed "*borkini"* under the *Echis pyramidium* complex (Pook *et al*., 2009). They assigned several haplotypes from southern Yemen and southwestern Saudi Arabia to *E. pyramidum*. The specimen from Wadi Al-Mejasess has oblique crossbars rather than rounded blotches seen in *E. coloratus,* and with a higher number of ventral scales (Table 1).

***Echis coloratus* Günther, 1878 Figure 6A**

Material examined: JZC006, Wadi Al-Mejasess, 30.11.2021.

Remarks: The distribution of this Saw-scaled Viper extends along Eastern Egypt, Yemen, Saudi Arabia, Palestine, and Jordan (Sindaco *et al.,* 2013). The specimen has 131 and forty-seven ventral and caudal scales respectively. The color pattern of *E. coloratus* is very distinctive in that it forms rounded blotches.

Family Elapidae

***Naja arabica* Scortecci, 1932 Figure 6C**
Material examined: JZC009, Wadi Al-Heiad, 30.11.2021.

Remarks: This is a rather common species in southwestern Saudi Arabia (Gasperetti, 1988). Aloufi *et al.* (2021) found the Arabian Cobra to be common around Al-Madinah Province, inhabiting wadi systems with scarce vegetation as well as mountains. Different color morphs were noted, ranging from a yellow body with a black head and neck to entirely golden yellow or red (Aloufi *et al*., 2021).

Family Atractaspididae
***Atractaspis andersonii* Boulenger 1905**

Remarks: One dead specimen was observed in Wadi Al-Mejasess. This species is confined to Oman, Yemen, and southwest Saudi Arabia (Sindaco *et al.,* 2013). *Atractaspis engaddensis* Haas, 1950 occur in the northwestern and central parts of the country (Aloufi *et al.,* 2019).

Discussion

Eleven species of snakes belonging to six families are reported. All previous records of Masood (2012) from the Jazan area should

Figure 6. A. *Echis coloratus*. **B**. *Echis borkini*. **C**. *Naja arabica.*

be scrutinized, since many of his records are doubtful and inconsistent with the known distribution ranges of many species. For example, he listed *Platyceps ventromaculatus* (Gray, 1834) which is distributed in Iraq, Iran, the eastern part of the Arabian Peninsula reaching as far as Pakistan. Also, he listed *Pseudocerastes persicus fieldi* [Sic.] now recognized as two separate species; *Pseudocerastes fieldi* Schmidt, 1930 has a distribution range extending from northern Saudi Arabia, Jordan, Syria, and Iraq, while *Pseudocerastes persicus* (Duméril, Bibron and Duméril, 1854) is distributed across Eastern Arabia and Iran reaching also Pakistan . By now, three species of the genus *Psammophis* are known to occur in Saudi Arabia; the very well-known and widely distributed *P. schokari, Psammophis sibilans* (Linnaeus, 1758) recently reported from the vicinity of Al-Madinah Province (Aloufi *et al*., 2021), and the new record of *P. aegyptius* in the present work. *Psammophis sibilans* is known in eastern Egypt, Eritrea, Ethiopia, and Somalia (Baha El Din, 1994), while *P. aegyptius* is distrusted across southern Egypt, reaching southern Algeria and Libya, Chad, Niger, and the Sudan (Sindaco *et al*., 2013).

The taxonomic status of *Platyceps variabilis* requires further investigation to reveal the identity of this species complex. Schätti *et al*. (2014) considered *P. insulanus, P. manseri* and *P. thomasi* to be conspecific with *P. variabilis*. A molecular study on this species morphs should be conducted.

The Common African House Snake, *B.*

fuliginosus, was reported from Yemen (Gasperetti, 1988) and Djibouti, Somaliland, Somalia, and Ethiopia (Largen and Spawls, 2010; Trailin, 2022). This species is very common in Wadi Al-Heiad owing to the large number of snakes found by snake collectors in the area. They were usually found in forested habitats with a relatively dense vegetation cover.

Both *P. schokari* and *P. aegyptius* were sympatric and were recovered from the same habitat at Wadi Al Mejasess. In Eritrea and Ethiopia, *P. schokari* and *P. sibilans* were found in sympatry (Largen, 1997; Largen and Spawls, 2010). Similarly, *E. borkini* and *E. coloratus* were collected from the same locality at Wadi Al Mejasess. Gasperetti (1988) reported both *E. coloratus* and *Echis pyramidium* (=*Echis borkini*) from southwestern Arabia.

It is evident that several African species integrated in southwestern Arabia, including Yemen. *Bitis arietans* Merrem, 1820, *Dasypeltis scabra* (Linnaeus, 1758), *Pelomedusa barbata* Petzold *et al*. 2014*,* and *Trachylepis brevicollis* (Wiegmann, 1837) are examples of East African reptile species reported from southwestern Saudi Arabia (Aloufi *et al*., 2019). This is attributed to the temporary formation of the southwestern land bridge between the Arabian Peninsula and the Horn of Africa around 10 to 5.3 Ma (Bosworth *et al*., 2005, Tejero-Cicuéndez *et al*., 2021).

Hopefully, further future studies will focus on other reptiles of Jazan including lizards and other suspected snakes that have not been recorded in this study.

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Different Evolutionary Causes of Clutch Size in the *Asaccus/Haemodracon* Cluster (Squamata: Gekkota: Phyllodactylidae)

Herbert Rösler[1*] and Wolfgang Wranik[2]

[1]Naturkundemuseum Erfurt, Große Arche 14, D 99084 Erfurt, [2]Annette Kolb-Ring 5, D 18106 Rostock, Germany

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Abstract

Gekkota differ in their clutch sizes. This phenomenon is particularly evident in the variable double-egg clutches and practically invariant single-egg clutches. The clutch size developed from a selection of different life history characteristics. The reduction to a single egg is the most recent evolutionary adaptation of gecko's clutch size. In the *Asaccus/Haemodracon* cluster, both clutch sizes are known for geckos. The single-egg clutches developed convergently in the lineage and are (1) a generic feature (*Asaccus*) and (2) an intraspecific feature (*Haemodracon*). As biotic selection factors, possibly (1) predator-prey relationships and (2) food net patterns have contributed to the miniaturization of the invariant clutch size in the selected species. The regulated reproductive efforts have led to a reduction in adult mortality and an increase in the survival rate of offspring.

Key words: *Asaccus*, *Haemodracon*, different clutch sizes, natural selection factors, predator-prey system, food resources.

Introduction

As for the early reduction of the clutch sizes in the geckonid lineage and its subsequent fixation, the causal relationships to the life-history characteristics are largely unknown. The researchers recorded and analyzed the reproductive properties of species within two phyllodactylid sister genera *Asaccus* (Dixon and Anderson, 1973) and *Haemodracon* (Bauer, Good and Branch, 1997), in which the two known clutch-sizes of geckos occur. The aim of the present investigation is to examine the basis of intraspecific reproductive characteristics, and to determine which morphological or ecological factors led to the development of the smallest possible clutch size in these related groups.

*Corresponding author: herbertroesler@aol.com

Material and methods

Two species of the genera *Asaccus* from Oman and *Haemodracon* from the Island of Socotra (Yemen) were made available for the present study of reproductive biology. The researchers examined specimens of *Asaccus caudivolvulus* (Arnold and Gardner,1994) and *Asaccus montanus* (Gardner, 1994) each in the sex ratio 1/2 (male/female); *Haemodracon riebeckii* (Peters, 1882) in the sex ratio 3/5 (male/female) and *Haemodracon trachyrhinus* (Boulenger, 1899) in the sex ratio 3/3 (male/female). The species of both genera differ in size and body shape but share similar toe structures (Figures 1–6).

The reproductive data on both of the *Asaccus* species that were determined and logged were from 2008 to 2019, while the data on the two *Haemodracon* species were from 1999 to 2019.

The geckos were kept in pairs in terrariums of different sizes and were differently arranged according to the natural habitats. All couples were temporarily separated, and the sexes were housed individually. The geckos were mainly fed with various bred insects and their larvae (e.g. *Tenebrio molitor*, *Gryllus assimilis*, *Galleria mellonella*). Sporadically, they were also offered hand-captured spiders (non det.) and millipedes (non det.). In addition, several varieties of fruit porridge, yoghurt, and various vegetables were offered regularly. The foods were enriched with

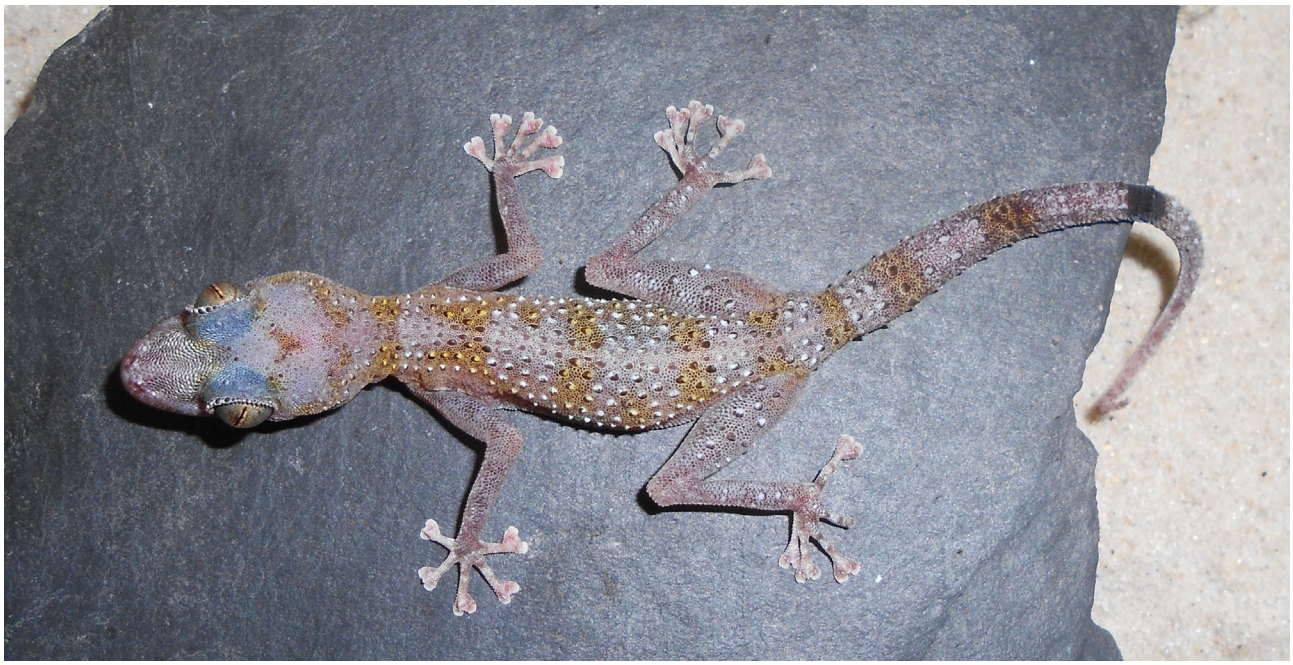

Figure 1. Adult female of *A. caudivolvulus*. ©Herbert Rösler

Figure 2. Portrait of *A. caudivolvulus*. ©Konrad Kürbis

Figure 3. Ventral view of hind foot of *A. caudivolvulus*. ©Konrad Kürbis

Figure 4. Adult female of *A. montanus*. ©Herbert Rösler

Figure 5. Adult male of *H. riebeckii* and some toe details. ©Konrad Kürbis

Figure 6. Adult female of *H. trachyrhinus*. ©Herbert Rösler

mineral and vitamin supplements.

During the period of examination, all living adult geckos were measured and weighed several times, and the average values were calculated from the individual data. The size and weight of the eggs were recorded immediately after the oviposition, and the size and weight of the young animals were recorded on the day of hatching (Figures 7–11).

The following abbreviations are used:

SVL = snout-vent length
FM = female mass
EL = egg length
EW = egg width
CV = clutch volume
CM = clutch mass
JM = juvenile mass

All morphometric data are from living specimens. Their snout-vent length (distance between tip of snout and cloacal slit) and the egg size were measured with a digital caliper. The adult geckos were weighed with a laboratory scale, and the eggs and young specimens were weighed using a pharmaceutical analysis scale.

In terms of the clutch sizes, two categories were distinguished: invariant single-egg clutches and variable double-egg clutches. The egg volume was calculated according to the formula: $V = 4/3 \times \pi \times EL/2 \times EWh/2 \times EWv/2$ (EL = egg longitudinal axis, EWh = egg width axis horizontal, EWv = egg width axis vertical). The formula: clutch mass immediately after ovipositon/female live weight was used to calculate the relative clutch mass (CM/FM = RCM). Data analyses were carried out with multivariate statistics (analysis of variance [one-way ANOVA], principal components analysis [PCA]), and significant ranges were determined with the Mann-Whitney-U-Test. The normal distribution of the data on clutch size, clutch mass and mass of juveniles was checked with the Shapiro-Wilk test. A Spearman's rank correlation was used to test the relationships between female snout-vent length and clutch volume (SVL/CV), female mass and clutch mass (as RCM), as well as juvenile mass and female mass (JM/FM). Violin plots with embedded boxplots were generated for continuous morphometric characters to visualize the same plus the distribution frequency of the data. A hierarchical cluster analysis (CA) was performed to determine which taxa were the most similar morphologically and in terms of clutch-size based on the unweighted pair group method with arithmetic mean (UPGMA). For all the analyses, the statistics program PAST, Version 3.22 (Hammer 2010) was used.

Results

Reproduction-specific characteristics: *A. caudivolvulus*: female (n=2) SVL 68.0–69.0 mm (68.5±0.50), mass 5.44–5.99 g (5.72±0.28); male (n=1) SVL 69.0 mm, mass 5.89 g.

A. montanus: female (n=2) SVL 37.0–39.0 mm (38.0±1.00), mass 1.26–1.55 g (1.41±0.15); male (n=1) SVL 40.5 mm, mass 1.65 g.

H. riebeckii: female (n=5) SVL 106.0–116.5 mm (110.7±4.0), mass 32.48–45.08 g (40.06±5.02); male (n=3) SVL 125.0–128.5 mm (127.2±1.9), mass 57.30–59.14 g (58.35±0.95). *H. trachyrhinus*: female (n=3) SVL 40.0–43.0 mm (41.0±1.7), mass 1.62–3.09 g (2.43±0.75); male (n=3) SVL 40.0–41.0 mm (40.7±0.3), mass 2.01–2.34 g (2.00±0.17).

The two *Asaccus* species glued fertile eggs to both solid inorganic materials (glass, slate slabs) and organic material (wood, cardboard) (Figures 12–13). Mostly, they were placed hidden in crevices, but *A. caudivolvulus* also glued some eggs visibly to the top of stone slabs. In both *Asaccus* species, some of the unfertilized eggs were also glued, while others were deposited freely on the soil substrate. The two *Haemodracon* species always buried fertile eggs in the substrate (Figures 14–15), while unfertilized eggs were either buried glued to pieces of decoration or simply placed on the ground. In both of the *Haemodracon* species, the eggshells were adhesive, and all the eggs had densely-packed substrate incrustations.

Figure 7. Hatching of *A. caudivolvulus*. ©Herbert Rösler

Figure 8. Hatching of *H. riebeckii.* ©Herbert Rösler

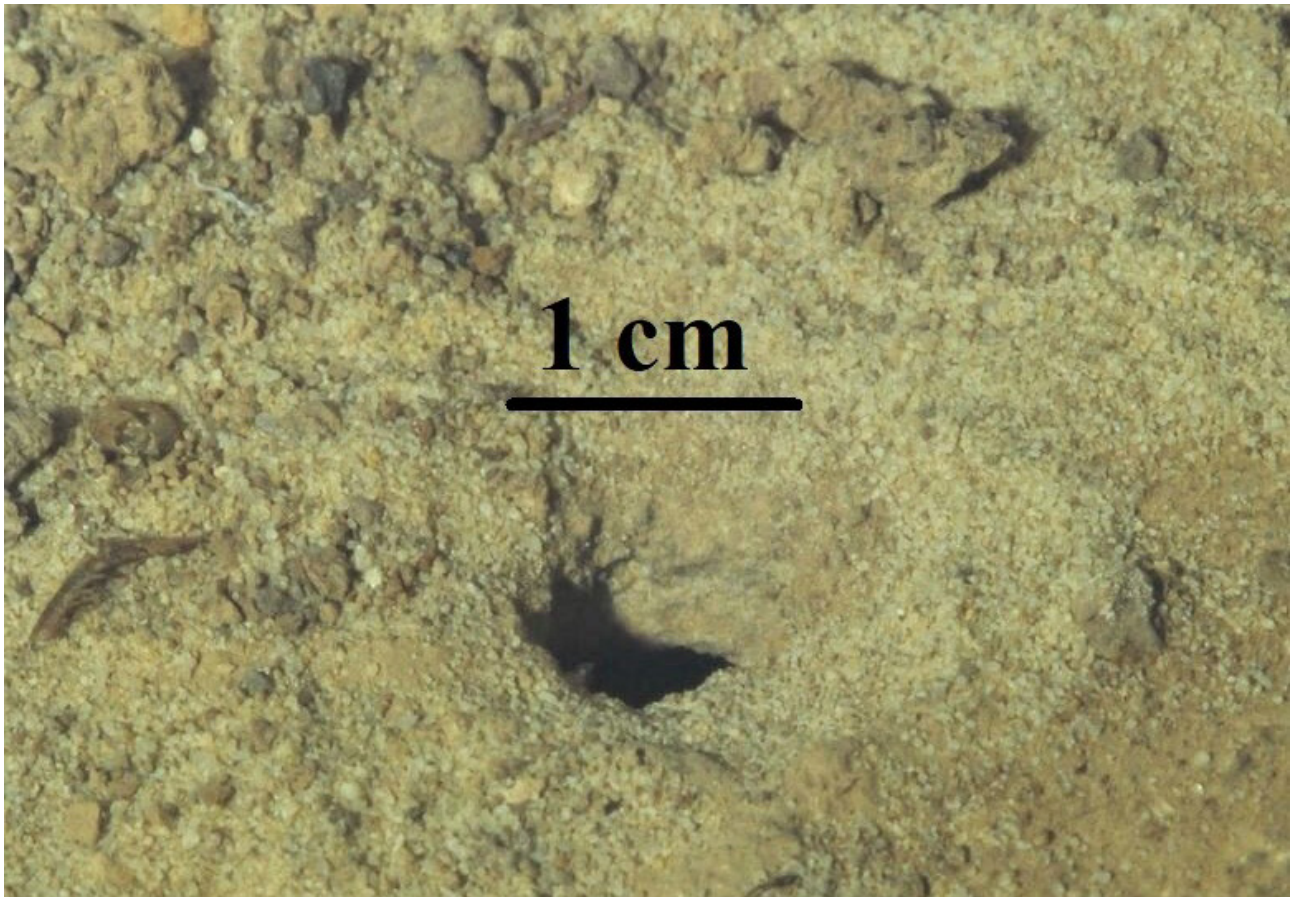

Figure 9. Hatched juveniles of *H. riebeckii* independently burrow a narrow exit from the ground. ©Herbert Rösler

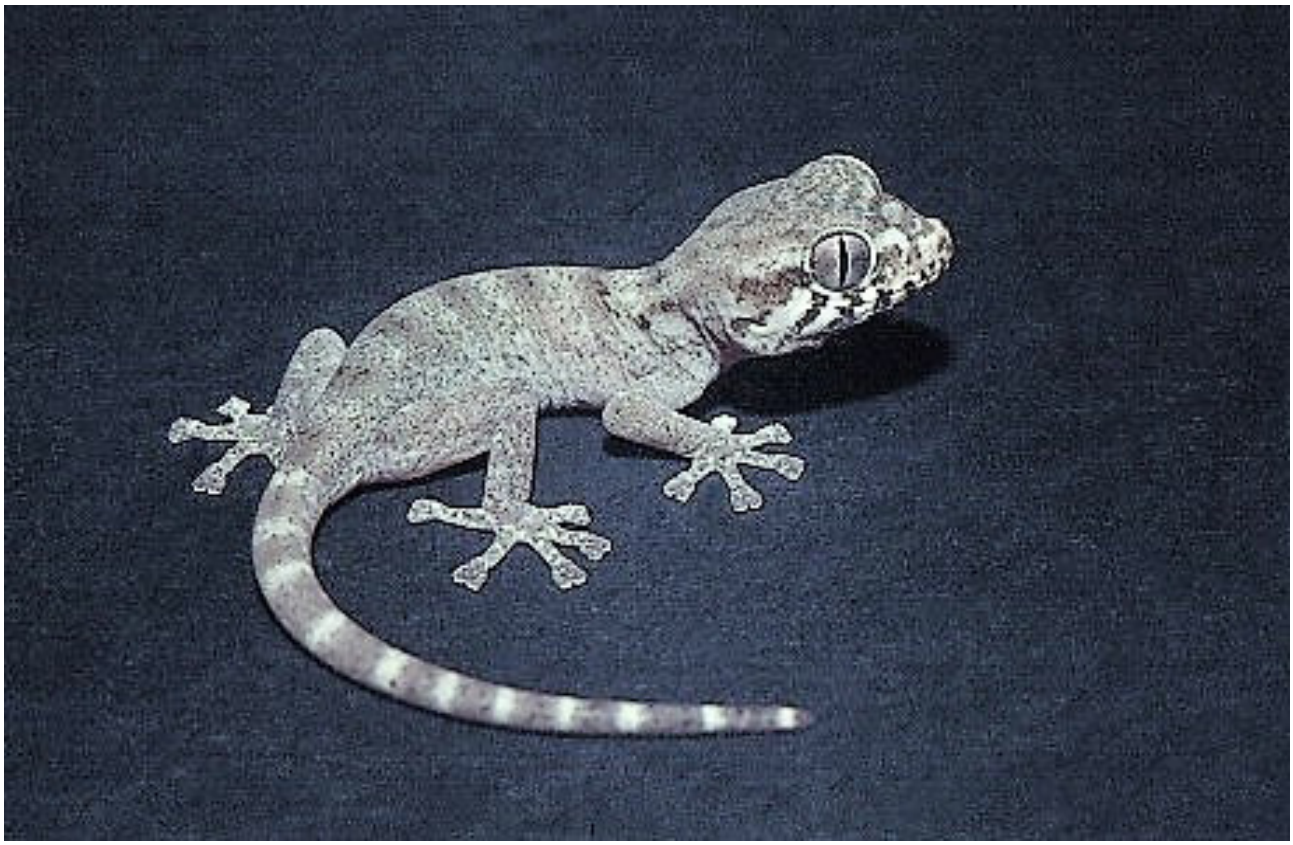

Figure 10. Hatchling of *H. riebeckii,* one week old. ©Herbert Rösler

Figure 11. Hatchling of *H. trachyrhinus*, two days old. ©Herbert Rösler

Figure 12. Fertilized egg of *A. caudivolvulus* four days after oviposition. ©Herbert Rösler

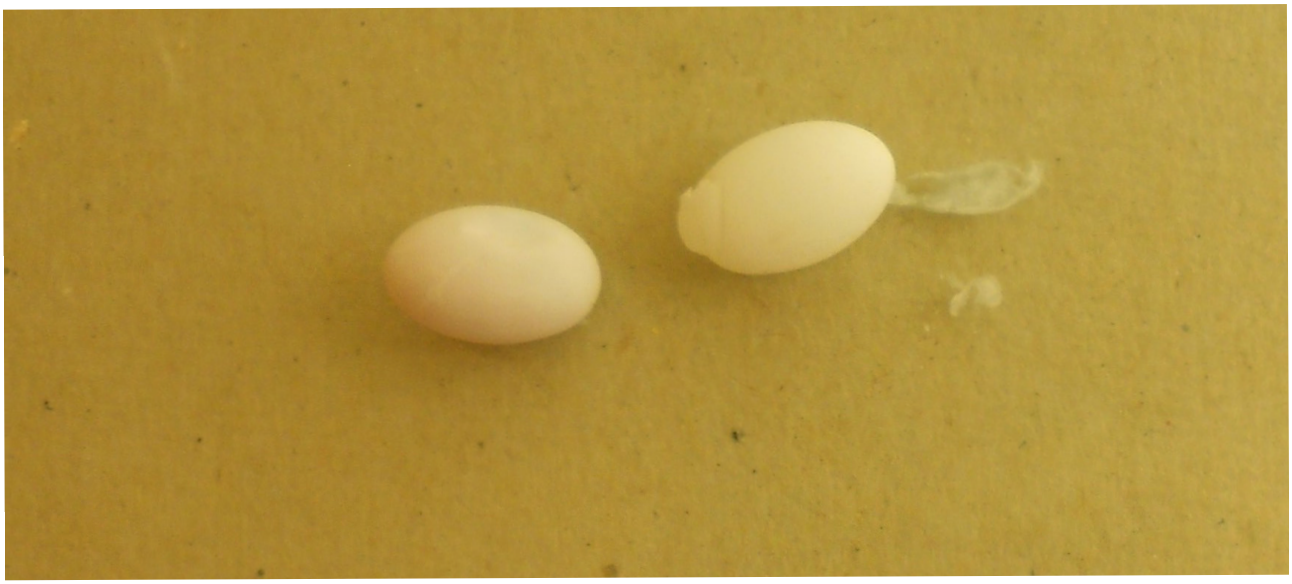

Figure 13. Eggs from two females of *A. montanus*, from the right egg hatchling hatched. ©Herbert Rösler

Figure 14. Nest pit for a clutch of *H. riebeckii*, vertically about 5 cm deep in the ground. ©Herbert Rösler

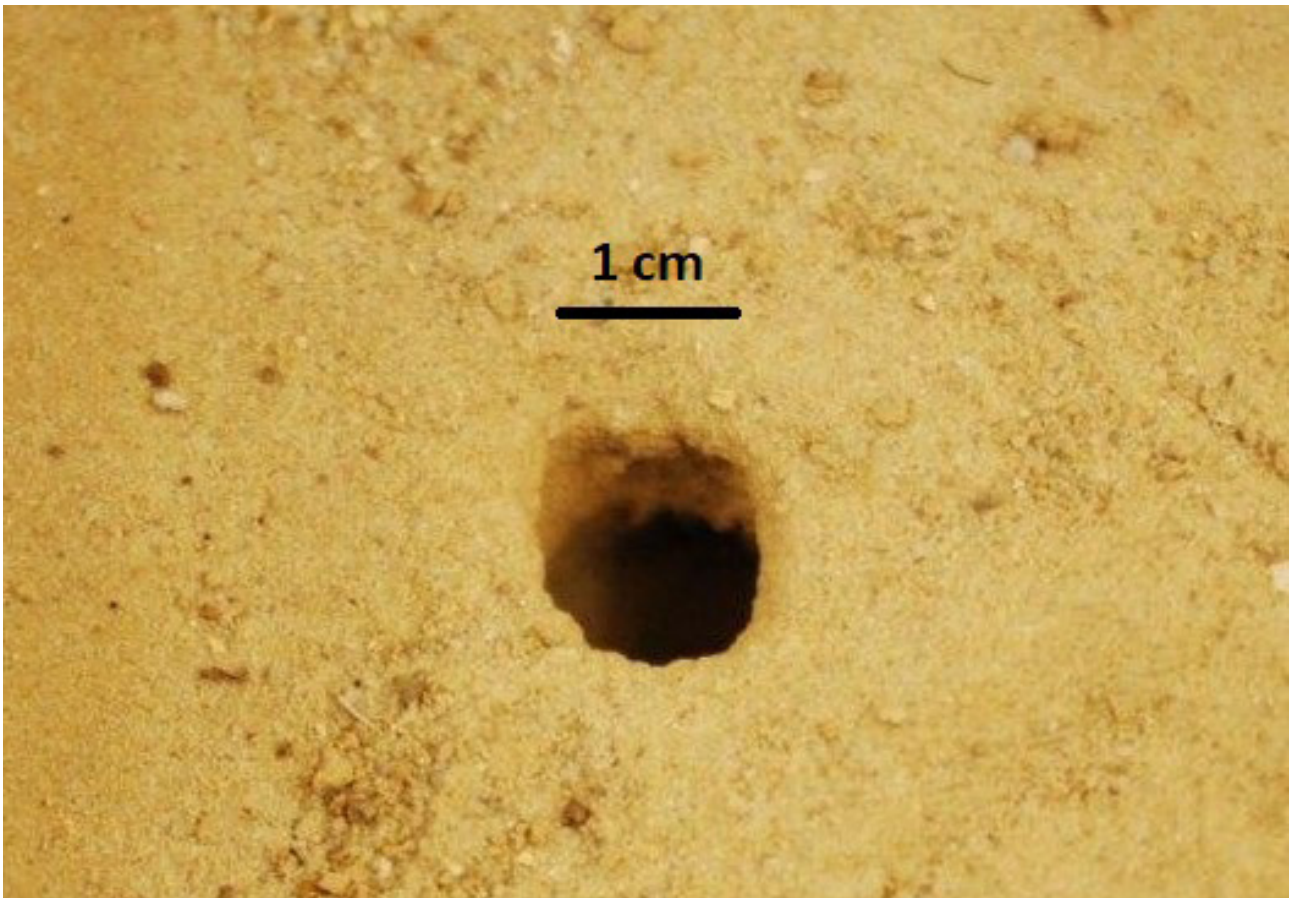

Figure 15. Nest pit for a clutch of *H. trachyrhinus*, vertically about 2 cm deep in the ground. ©Herbert Rösler

Data analysis of reproductive characteristics: The females of the four studied species differ considerably in morphological parameters. Significant differences between them were found to be in snout-vent lengths (ANOVA, F 460.3461, p <0.01) but not in body weight (ANOVA, F 104.7094, p >0.05). In the snout-vent length, *H. trachyrhinus* does not differ significantly from *A. montanus*, but in all other pairwise comparisons, the species differ significantly. In body weight, only *H. riebeckii* differs significantly from the other three species (see supplement).

The intraspecific reproductive data clutch size, clutch volume, clutch mass, and hatching weight were used for the interspecific comparison. The results observed were related to the snout-vent length and body weight of the females. The parameters of reproduction of the four species are summarized in Table 1.

The species differ significantly in clutch size. Only single-egg clutches were produced by *A. caudivolvulus* (n=79), *A. montanus* (n=59) and *H. trachyrhinus* (n=128). *H. riebeckii* produced a total of 346 clutches. About a third of these contained one egg (33.5 %), the remaining ones had two eggs (mean clutch size 1.66±0.47).

The normal distribution of the intraspecific clutch volumes was examined. The clutch volume of *A. caudivolvulus* and *H. trachyrhinus* was normally distributed; non-normal distribution was found in *A. montanus* and in *H. riebeckii*. The volumes of both clutch-sizes were also not normally distributed (see supplement). In all four species, the clutch volume was correlated with the female snout-vent length (Spearman rank correlation: *A. caudivolvulus* rs 0.099, *A. montanus* rs 0.125, *H. trachyrhinus* rs 0.079, and *H. riebeckii* single-egg clutch rs 0.069, double-egg clutch rs 0.223). The lowest value of the SVL/CV index was found in *H. riebeckii* for the double-egg clutches, compared to the other three species with single-egg clutches. Significantly, in *H. riebeckii*, the volume of eggs from the single-egg clutch is almost exactly the same as that of a single egg from a double-egg clutch (Table 1). The clutch volumes of the four species are correlated with the snout-vent length and are distributed isometrically. Interspecifically, there is an increase in egg proportions with the snout-vent length decreasing (Figure 16). As for the clutch volume, all four species differ significantly in pairwise comparisons (ANOVA, F 1560.631, p <0.01, see supplement).

For the calculation of the relative clutch mass, the clutch weights of the four species were verified for normal distribution. The clutch weights of *A. caudivolvulus*, *A. montanus*, *H. trachyrhinus*, and the weight of the double-egg clutches of *H. riebeckii* were normally distributed. There was no normal distribution in the case of the single-egg clutches of *H. riebeckii* (see supplement). In all four species, the relative clutch mass was not correlated with the weight of the females (Spearman rank correlation: *A. caudivolvulus* rs -0.171, *A. montanus* rs -0.655, *H. trachyrhinus* rs -0.818, and the *H. riebeckii* single-egg clutch rs -0.698, double-egg clutch rs -0.644). The greatest energy effort (RCM) among the four species for the development of a clutch is for *H. trachyrhinus* and the lowest was for *H. riebeckii*. *H. trachyrhinus*, *A.caudivolvulus*, and *A. montanus* invest more in the production of a single-egg clutch than *H. riebeckii* in a double- egg clutch (Figure 17). The cost saving for the development of a single egg compared to two eggs is over 50 % for *H. riebeckii* (Table 1). In the relative clutch mass, the pairs of species differ partially significantly (ANOVA, F 107.8593, p <0.01). *A. montanus* is not significantly different from *A. caudivolvulus* and H. *trachyrhinus* (see supplement).

For the calculation of the JM/FM index, the hatch weights of the four species were checked for normal distribution. In *A. caudivolvulus* and *A. montanus*, there was a normal distribution for the hatching weight, while the hatching weights of the young animals of *H. riebeckii* from double-egg clutches and *H. trachyrhinus* were not normally distributed (see supplement).

Table 1. Summary statistics of reproductive characteristics of *A. caudivolvulus*, *A. montanus*, *H. riebeckii*, and *H. trachyrhinus*.

species	**clutch volume (mm³)**	
	single egg clutch	double egg clutch
A. caudivolvulus	911.6±129.3 (n=32)	
	647.7-1256.0	
A. montanus	263.2±90.2 (n=27)	
	197.2-689.9	
H. riebeckii	2208.4±232.5 (n=89)	4352.5±414.5 (n=157)
	1552.8-2654.0	3065.2-5277.2
H. trachyrhinus	347.3±42.0 (n=59)	
	255.1-436.8	
	clutch mass (g)	
	single egg clutch	double egg clutch
A. caudivolvulus	0.8309±0.1552 (n=12)	
	0.5289-1.0056	
A. montanus	0.2251±0.0178 (n=4)	
	0.2117-0.2508	
H. riebeckii	2.1645±0.2919 (n=93)	4.3632±0.3674 (n=177)
	1.4425-2.5973	3.1528-5.3779
H. trachyrhinus	0.3315±0.0474 (n=52)	
	0.2041-0.4248	
	snout-vent length/clutch volume	
	single egg clutch	double egg clutch
A. caudivolvulus	0.077±0.011 (n=32)	
	0.055-0.107	
A. montanus	0.154±0.027 (n=27)	
	0.054-0.193	
H. riebeckii	0.050±0.006 (n=89)	0.025±0.003 (n=157)
	0.041-0.072	0.021-0.036
H. trachyrhinus	0.117±0.015 (n=59)	
	0.092-0.157	
	relative clutch mass	
	single egg clutch	double egg clutch
A. caudivolvulus	0.147±0.027 (n=12)	
	0.097-0.185	
A. montanus	0.171±0.026 (n=4)	
	0.137-0.200	
H. riebeckii	0.052±0.007 (n=93)	0.107±0.015 (n=178)
	0.032-0.069	0.054-0.161
H. trachyrhinus	0.179±0.050 (n=52)	
	0.079-0.262	

	juvenile mass/female mass	
	single egg clutch	double egg clutch
A. caudivolvulus	0.099±0.009 (n=23)	
	0.084-0.123	
A. montanus	0.107±0.016 (n=41)	
	0.070-0.141	
H. riebeckii	0.032±0.006 (n=31)	0.064±0.009 (n=65)
	0.022-0.042	0.046-0.095
H. trachyrhinus	0.118±0.037 (n=66)	
	0.063-0.192	

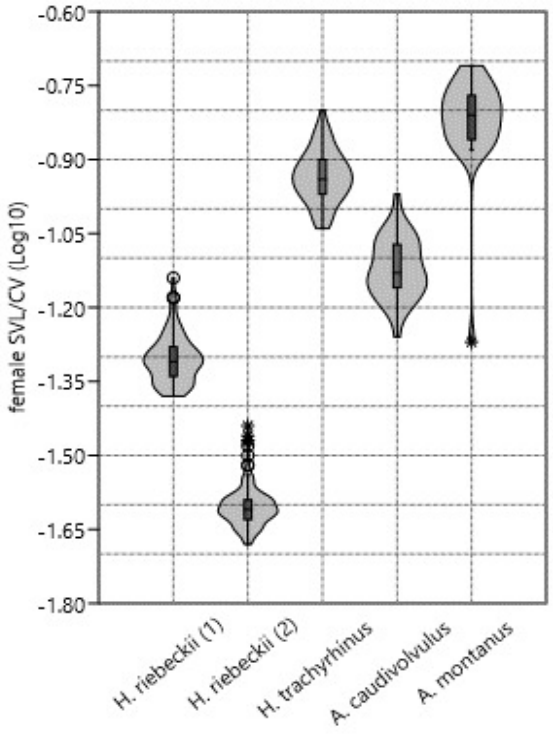

Figure 16. Comparisons of female SVL and CV in the *Asaccus/Haemodracon* cluster. Abbreviations: (1) = single egg clutch, (2) = double egg clutch.

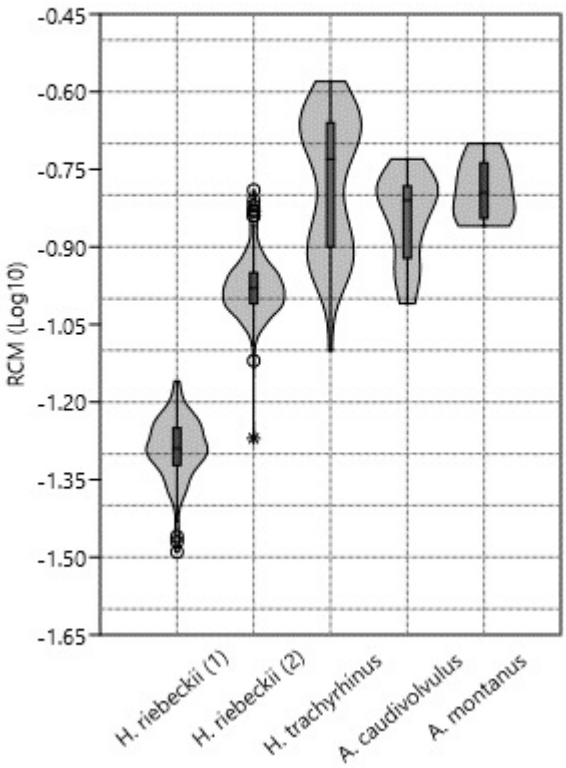

Figure 17. Comparisons of RCM in the *Asaccus/Haemodracon* cluster. Abbreviations: (1) = single egg clutch, (2) = double egg clutch.

The hatching weight of the young was only correlated with the weight of the females in one species (Spearman rank correlation: *A. caudivolvulus* rs 0.304). In the remaining three species, the hatching weight was not correlated with the weight of the females (Spearman rank correlation: *A. montanus* rs -0.005, *H. trachyrhinus* rs -0.321, *H. riebeckii* juveniles from single-egg clutches -0.357, juveniles from double-egg clutches -0.199). The JM/FM results largely correspond to the species-specific RCM values (Figure 18). The lightest juveniles were produced by *H. riebeckii* and the heaviest were produced by *H. trachyrhinus*.

The young animals of all of the three species that produce single-egg clutches were relatively heavier (ANOVA, F 485.7438, p <0.01). Statistically, as expected, the JM/FM index of the four species examined, hardly differed from the RCM values, however, there are significant differences between *H. trachyrhinus* and *A. montanus* (see supplement). In *H. riebeckii*, there is no significant difference in weight between the juveniles of the single-egg clutches (mean mass 1.3207±0.1779 g, n=31) and the double-egg clutches (mean mass 1.3196±0.1689 g, n=187) (Man-Whitney-U-Test, z -0.0984,

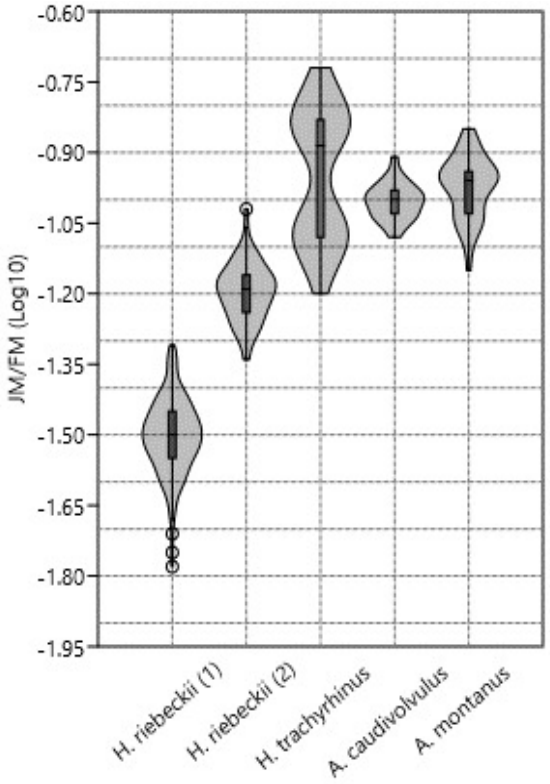

Figure 18. Comparisons of JM and FM in the *Asaccus/ Haemodracon* cluster. Abbreviations: (1) = single egg clutch, (2) = double egg clutch.

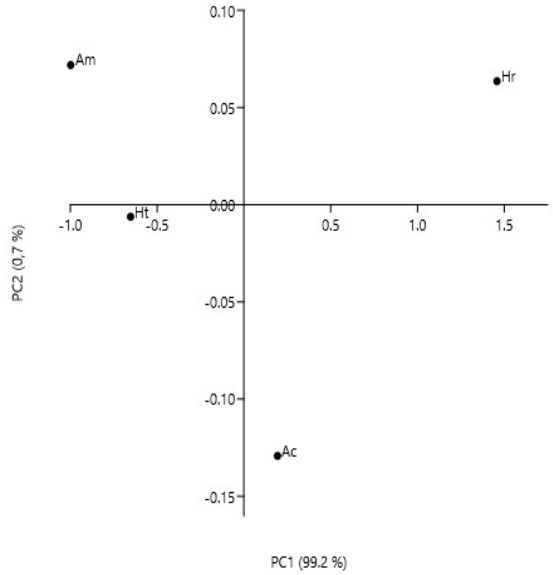

Figure 19. PCA of the shape related reproduction specific data of four species from the *Asaccus/ Haemodracon* cluster. Abbreviations: Hr = *Haemodracon riebeckii,* Ht = *Haemodracon trachyrhinus,* Ac = *Asaccus caudivolvulus*, Am = *Asaccus montanus.*

p >0.05). With successful hatching of the young animals of both clutch sizes (two vs one juvenile), the two indices JM/FM differ significantly (Whitney-U-Test, z -7.8941, p <0.01). However, the ratio between the costs and the resulting benefits of both types of clutch sizes is assessed as neutral because *H. riebeckii* can only achieve the efficiency limit of reproduction through a proportional increase in energy expenditure.

A PCA was performed with six variables: female SVL (mm/Log10), FM (g/Log10), clutch size (one or two eggs/Log10), CV (mm³/Log10), CM (mg/Log10), and JM (mg/Log10). The PCA demonstrates that *A. montanus/H. trachyrhinus* and *A. caudivolvulus* as well as *H. riebeckii* occupy non-overlapping positions in morphospace among the collective ordination of the first two principal components (Figure 19). Principal component 1 accounts for 99.2 % of the variation and loads most heavily for FM, CV, CM and JM (Figure 20). Principal component 2 accounts for an additional 0.7 % of the variation and loads most heavily for FM, clutch size, and JM (Figure 21). Principal component 3 accounts for an additional 0.1 % of the variation, respectively (Table 2). Although *A. caudivolvulus*, *A. montanus* and *H. trachyrhinus* do not differ significantly in clutch size, they do differ in several other characteristics. The ANOVAs of the data recovered four characters bearing statistically significant mean differences among them, illustrating that *A. caudivolvulus* has a significantly greater snout-vent length, and lesser RCM, SVL/CV, JM/FM than *H. trachyrhinus*; *A. montanus* has a significantly greater SVL/CV and lesser JM/FM than *H. trachyrhinus* respectively (see supplement). ANOVAs also demonstrated that *H. riebeckii* has significantly greater female SVL and FM than *H. trachyrhinus*, *A. caudivolvulus*, and *A. montanus* but significantly lesser RCM, SVL/CV, and JM/FM (see supplement).

The CA shows grouping compatible with PCA (Figure 22). *A. montanus* and *H. trachyrhinus* form a common cluster with a relatively small distance to *A. caudivolvulus* and were finally grouped with *H. riebeckii*.

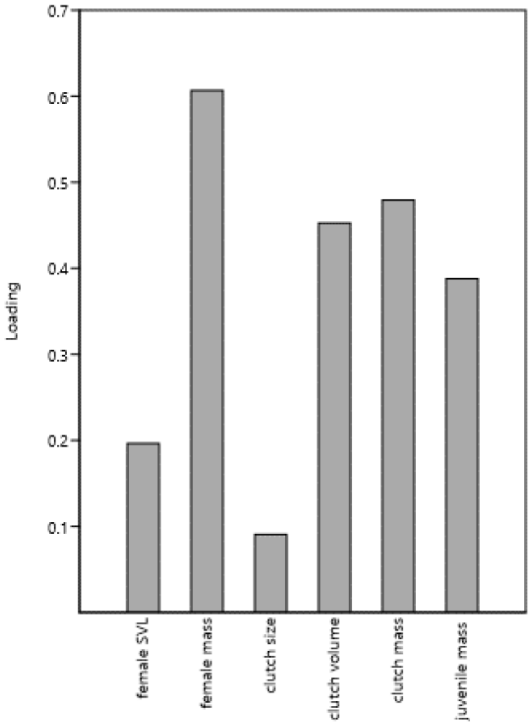

Figure 20. PCA of *Asaccus/Haemodracon* cluster, bar plots loading scores of PC1.

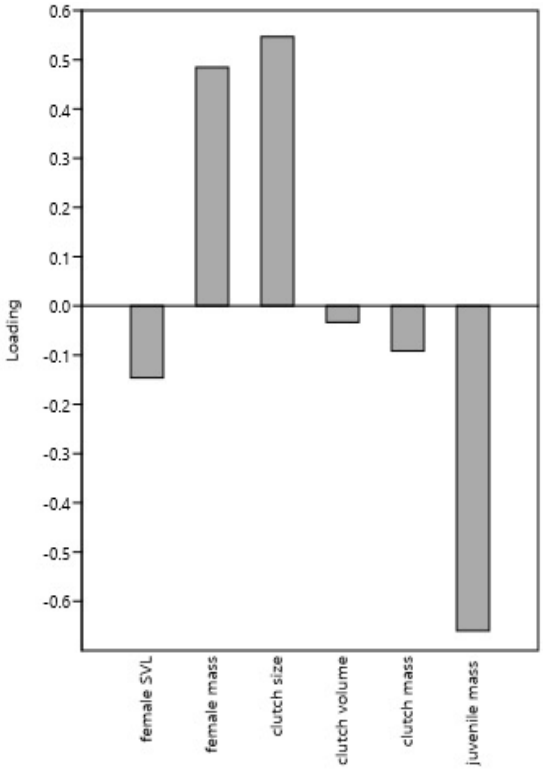

Figure 21. PCA of *Asaccus/Haemodracon* cluster, bar plots loading scores of PC2.

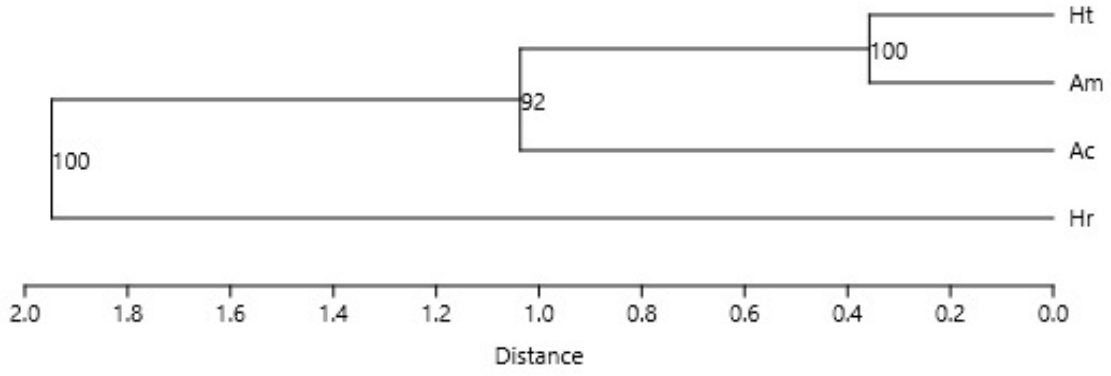

Figure 22. Cluster analysis of the shape related reproduction specific data (1000 Bootstrap replicates) of four species from the *Asaccus/Haemodracon* cluster. Abbreviations: see Figure 19.

Table 2. Statistics of principal component analysis scores for the reproductive characters of *A. caudivolvulus, A. montanus, H. riebeckii,* and *H. trachyrhinus.*

Character	PC 1	PC 2	PC 3
female SVL	0.19644	-0.14617	0.66372
FM	0.60663	0.48465	-0.13301
clutch size	0.090664	0.54657	-0.16253
CV	0.45268	-0.033226	0.5446
CM	0.47943	-0.091452	-0.2907
JM	0.38784	-0.65996	-0.36643

Discussion

Clutch sizes in the *Asaccus*/*Haemodracon* cluster: *Asaccus* and *Haemodracon* are sister genera of the family Phyllodactylidae (Gamble *et al.* 2008, 2012, 2015, Pyron *et al.* 2013). Both genera are distributed allopatrically in the Near East (Bauer *et al.* 1997, Sindaco and Jeremčenko 2008). It is believed that the common ancestor of the *Asaccus/Haemodracon* cluster lived in the Eocene further west in East Africa, although this hypothesis requires further studies (Arnold and Gardner 1994, Carranza *et al.,* 2016, Simó-Riudalbas *et al.* 2018). According to (Tamar *et al.* 2019), *Asaccus* and *Haemodracon* separated in the middle Eocene about 42–48 Ma on the Arabian Peninsula. The speciation in *Asaccus* began earlier than in *Haemodracon*. According to the molecular mtDNA and nDNA data, the oldest *Asaccus* branch occurred in the Oligocene (ca. 24.6 Ma) and the youngest in the Pliocene (approx. 4 Ma), but the family tree reconstruction of *Asaccus* does not yet consider all species of the genus (Carranza *et al.* 2016). Socotra separated from the Arabian Peninsula 30-17,6 Ma ago (Autin *et al.* 2013). The in-situ speciation of *Haemodracon* took place in the middle Miocene about 15.5 Ma ago (Tamar *et al.* 2019).

In the *Asaccus/Haemodracon* cluster, both clutch sizes known from Geckos are represented (Rösler 2020). the researchers hypothetically assumed a production of double-egg clutches in the *Asaccus/ Haemodracon* ancestor and that *H. riebeckii* is the only species from the cluster which retained the plesiotypic clutch size. According to the speciation sequences in the *Asaccus/ Haemodracon* cluster, the clutch sizes were modified convergently. Infragenerically, the *Asaccus* ancestor developed single-egg clutches earlier and independently from the intraspecific *H. trachyrhinus* which developed these later. The alternative hypothesis, which is based on a clutch-size reduction to a single egg already secondarily acquired by the common ancestor, would mean that the diversification of the clutch size did not take place at a staggered time in the *Asaccus/Haemodracon* cluster, but *H. riebeckii* may have decreased the egg size again in order to increase the number of eggs to two. In view of the generally low tendency of clutch enlargement of single-egg producing geckos, this conversion process seems unrealistic (Rösler 2020).

The two *Asaccus* species used in this study, *A. caudivolvulus* and *A. montanus*, produced only single-egg clutches. A literature search revealed that the clutches of *A. andersoni*, *A. gallagheri*, *A. granularis*, *A. kurdistanensis*, *A. platyrhynchus* and *A. tangestanensis* also contained only a single egg (Arnold and Gardner 1994, Leptien *et al.* 1994, Torki and Sharifi 2007, Parsa *et al.* 2009, Torki 2010, Torki *et al.* 2011a, b, Gardner 2013). If the reduction of the left oviduct is a generic feature of *Asaccus,* it can be assumed that all other species of the genus, for which the clutch size is not yet known, also lay single-

egg clutches only (Carranza *et al.* 2016). *Haemodracon* belongs to a larger number of genera in which a combination of invariable clutch sizes (single-egg and double-egg clutches) occurs (Rösler 2020).

Reduction of clutch size depending on snout-vent length and body weight: Numerous authors describe a variability of the clutch sizes of lizards of different development lines correlated with the snout-vent length (Fitch 1970, 1985, Tinkle *et al.* 1970, Turner 1977, Vitt and Congdon 1978, James and Shine 1988, Henle 1991, Shine and Greer 1991, Thompson and Pianka 2001, Du *et al*. 2005, Galdino and Van Sluys 2011, Kiefer *et al.* 2008, Winck and Rocha 2012). The ability to adjust the number of eggs and the egg size to the body size is necessary for the development of invariant clutch sizes. A prerequisite for the historical assessment of the correlation of the two parameters is that the current conditions correspond to those that were decisive for the evolution of invariant clutch sizes. This study can only speculate on whether the evolutionary reduction of snout-vent length correlated with an increase in maternal stress was the driving force, which led to the development of the invariant clutch size of two eggs in the Gekkota. However, fossil records from the Cretaceous to the late Neogen (97–5.3 Ma) support the early predisposition of small body sizes in them (Daza *et al.* 2014 and references cited therein). Some recent gecko species belong to the smallest land-dwelling vertebrata, e.g. *Sphaerodactylus ariasae*, adult snout-vent length 17.9 mm, mass 0.14 g (Hedges and Thomas 2001) and *S. parthenopion* adult snout-vent length 17–18 mm, mass 0.15 g (Thomas 1965, Mc Lean 1985).

From a linear order of snout-vent lengths of the geckos combined with their clutch sizes, however, it is clear that the reduction of the clutch size to a single egg cannot be explained by morphometric modifications only (Rösler 2020), if phylogenetic inertia is excluded as the cause. The latter means that the reduction of the clutch size to a minimum of one egg was acquired by a small ancestor and was then maintained by the descendants independently of an evolutionary increase in snout-vent length ('bottlenecking' hypothesis, Shine and Greer 1991, Kratochvil and Kubiska 2007).

The authors do not have any valid information on the snout-vent length of the *Asaccus/ Haemodracon* ancestor. The snout-vent length of recent *Asaccus*-species (unsexed) varies between 33.6 mm (*A. arnoldi*) and 70.7 mm (*A. gardneri*) (Carranza *et al.* 2016, Simo-Riudalbas *et al.* 2018) and the mean generic SVL is 56.98±11.41 mm (n=19), close to the mean of 57.55 mm calculated for recent geckos (species n=1115, Meiri 2008). The SVL of both *Haemodracon* species may have been influenced by the 'island effect' (Mertens 1934, Case 1978, Pregill 1986, Meiri 2007, 2008, Tamar *et al.* 2019). Of the *Haemodracon* species (unsexed), *H. riebeckii* reaches a maximum SVL of 140 mm (Peters 1882) and probably deviates much more from the size of the *Asaccus/ Haemodracon* ancestor than the smaller *H. trachyrhinus* with a snout-vent length with a maximum size of 50 mm (Boulenger 1899).

Numerous gecko species with snout-vent length <40 mm from the genera *Cnemaspis*, *Ebenavia*, *Lygodactylus*, *Matoatoa* and *Phelsuma* are able to produce double egg clutches (Spawls *et al*. 2002, Branch 2005, Glaw and Vences 2007, Hallmann 2008, Grismer *et al*. 2014). Adult females of *A. montanus* and *H. trachyrhinus* correspond to this size range, but due to their robust physique, they are proportionally much heavier compared to the females of many other small gecko species (e.g., *Ebenavia inunguis* 0.55 g, *Lygodactylus conraui* 0.75 g, *Matoatoa brevipes* 0.75 g, own data). Despite this special type of body constitution, *A. montanus* and *H. trachyrhinus* produce only single-egg clutches instead of double-egg clutches, but this contradicts with the clutch size of many even smaller and lighter gecko species from which this would be expected. The small reproduction-specific differences (e.g., index SVL/CV, cost-benefit ratio) between the two species do not result from

the clutch size, but in the dimorphic character of female snout-vent length and female mass. This study provisionally excludes the bottleneck hypothesis (as seen above) for the development of single-egg clutches in the *Asaccus/Haemodracon* cluster. Instead, the authors assume that the diversification of the clutch size was not triggered in connection with possible evolutionary changes in body size and weight either in the common ancestral form or the ancestors of both genera, but other biotic selection factors were found to be responsible for this.

Reduction of the clutch size depending on the body shape: Morphological adaptations to the habitat can contribute to the reduction of reproductive investments, including the number of eggs (Vitt 1981). In the *Asaccus/ Haemodracon* cluster, there are species with two different body shapes represented. The *Asaccus caudivulus* and both *Haemodracon* species have a voluminous-cylindrical trunk (abdomen more or less flattened) largely common in geckos. In *A. montanus*, the trunk shape is asymmetrical and dorsoventrally compressed, and the body is about three times as wide as height .

Kratochvil and Frynta (2005) found that in the hard-shelled eggs of geckos, the egg length/egg width index (EL/EW) is correlated with the SVL. The EL tends to increase with the SVL decreasing. The researchers have determined some egg proportions of different small-growing gecko species (SVL <40 mm) and compared them with the species of the *Asaccus/Haemodracon* cluster. The index EL/EW is for the single-egg clutch species *Gonatodes fuscus* 1.19±0.03 (n= 9), *Sphaerodactylus ruibali* 1.26±0.04 (n=16), *Sphaerodactylus torrei* 1.28±0.06 (n=43) and for the double-egg clutch species *E. inunguis* 1.06±0.12 (n=23), *Hemidactylus adensis* 1.11±0.06 (n=14), *Lepidodactylus planicaudus* 1.35±0.10 (n=28), and *Matoatoa brevipes* 1.38±0.17 (n=6). According to the variation range of these species, the eggs of both *Haemodracon* species have similar egg parameters (*H. riebeckii* 1.25±0.07, *H. trachyrhinus* 1.22±0.07).

The *Asaccus* species with voluminous physique also produce more spherical to oval eggs (e.g., index EL/EW *A. caudivolvulus* 1.31, *A. kurdistanensis* 1.20, *A. nasrullahi* 1.15), while those with the dorsoventral flattened physique produce more elliptical eggs (e.g., Index EL/EW at *A. montanus* 1.58, *A. gallagheri* 1.50) (Leptien *et al.* 1994, Torki and Sharifi 2007, Torki *et al*. 2010, this study).

Regarding the cause for the infrageneric development of single-egg clutches, the study provisionally excludes a direct connection with the different body shapes of *Asaccus* species. Probably, more flattened body shapes developed in them only after speciation in new microhabitats, later than the previously fixed clutch size. If the volume of hard-shelled gecko eggs increases, an increase in the length of the egg is expected (Werner 1989). The hypothesis of the limited width of the pelvic aperture (Sinervo and Licht 1991a, b, Kratochvil and Frynta 2005, 2006) does not seem to account for the significantly larger egg length in relation to the egg width of some *Asaccus* species; however, an adaptive compromise in which the egg shape adapted to the body shape serves to produce larger offspring.

Possible reduction of the clutch size depending on the climate: Meiri *et al.* (2020 and references cited therein) find that due to short seasonal activity periods, combined with abundant resources, lizards produce at higher latitudes and in highly seasonal regions few clutches with relatively many eggs. On the other hand, longer reproductive periods in tropical and subtropical habitats support increased clutch production in lizards, correlated with a lower number of eggs (Tinkle *et al.* 1970, Andrews and Rand 1974, James and Shine 1988).

The climatic influence on clutch sizes of recent gecko species is weaker compared to other Squamata (Rösler 2020). *Gymnodactylus* is a genus common in the equatorial zone, in which the two

known clutch sizes of geckos occur. Colli *et al.* (2003) discuss the interrelationships between climate, food supply, reproductive periodicity, and the clutch size of two species of this genus. *Gymnodactylus amarali* produces in unpredictable environments cyclically double-egg clutches and *G. geckoides* produce in predictable environments acyclical single-egg clutches. The reproductive cycle of *Homonota darwini*, which is common in the southern hemisphere to reach up to 45°S, is significantly dependent on climatic conditions. In this species, vitellogenesis up to ovulation can extend to twelve months, and it produces single-egg clutches without exception, usually in a two-year cycle (Ibargüengoytía and Casalins 2007). The form of reproduction is an adaptation to boreal climates, and the survival of the species would be impossible without a low mortality in both parents and their offspring (Williams 1966, Hirshfield and Tinkle 1975, Henle 1990b).

Globally, a pronounced warming trend occurred in the Canozoic, culminating with a climate optimum on the border between the Paleocene and Eocene. After that, temperatures continued to decline throughout the Eocene (Zachos *et al.* 2001). Jacobs *et al.* 2010; and references cited therein) used macrofossils from the middle Eocene of Tanzania to conclude on forest types in an open landscape, such as those found in seasonally dry and warm climates. The authors suspect that the climatic conditions under which the *Asaccus/Haemodracon* ancestor lived were such, that even with strong seasonality, sufficient time was available for several clutches in one reproductive period (Meiri 2019). The early ancestral forms of *Asaccus* and *Haemodracon* were exposed to interregional climate changes. Changes in the Indian monsoon system occurred in middle and late Miocene and reached into North Africa (De Menocal 1995, Gupta and Thomas 2003, Gupta *et al.* 2004). Since the period, in which *H. trachyrhinus* changed to produce only single eggs instead of two eggs, cannot be defined more precisely, no environment-related conclusions on the development of the single egg-clutch type are possible. Climatic factors for another life-history feature, the size diversification in the in-situ speciation of *Haemodracon*, are largely excluded by Garcia-Porta *et al.* (2016). Recently, a molecular diversification of both *Haemodracon* species during the Pleistocene was found (Tamar *et al.* 2019), but this did not affect the intraspecific clutch size.

According to the study's hypothesis, a convergently acquired ability to produce single-egg clutches in the *Asaccus/ Haemodracon* cluster does not correspond to epochal climatic processes. Even with a theoretically assumed regional cooling or regional contrasts (Ethiopian-Yemeni plateau to coastal lowlands) in different phases of evolution, the reduction of two eggs to a single egg would not have been directly caused by the climate (reduction of reproduction time) but may be correlated with the associated changes in other biotic factors.

Possible reduction of the clutch size depending on the predator-prey relationship: A reduction in the number of eggs contributes in general to an increase in the hatchling size of the young animals, reducing the risk of predation and mortality (Andrews and Rand 1974, Fitch 1985, Henle 1990a, Meiri 2019). It is well known that a size-dependent mortality exerts a strong selection pressure in lizards (Lacertidae see Kramer 1946, Diplodactylidae and Gekkonidae see Henle 1988, 1990b, 1991), which can be buffered by an increase in the SVL of the young. In the assessment of the life-history characteristics of the Squamata, Vitt (1981), Tinkle and Dunham (1986) and Henle (1988, 1990a) agree that ground-dwelling lizards are exposed to greater predation pressure compared to tree- or rock-dwelling species.

In the hatchlings of *A. caudivolvulus*, the mass is 9.9 % of that of the mother's, and in the *A. montanus*, the mass is10.8 %, while in *H. trachyrhinus*, it is11.8 %. With a similar single-egg fixed clutch size, the newly

hatched young e.g., of *Aristelliger georgensis* 3.3 % (n=2) and *Aristelliger lar* 3.4 % (n=4) are relatively lighter, but in the SVLs, they are significantly larger than the *Asaccus* and *Haemodracon* hatchlings. Based on the low RCM values, similar ratios can be expected for *Thecadactylus rapicauda* (Vitt and Zani 1997). The interspecific differences show that the risk of being eaten is lower for the young of larger species than it is for smaller species. Small species are forced to produce larger young to reduce the number of potential predators.

If predator-prey relationships are assumed to be a possible trigger mechanism for the development of single-egg clutches in the *Asaccus/Haemodracon* cluster, then the clutch size must be interpreted interspecifically, as (1) an optimal adjustment of the reproduction performance, based on the available abdominal volume of the mother, and (2) as an increase in the hatchling size of the young, which should serve to reduce size-dependent mortality.

The Irano-Arab *Asaccus* species have a largely montane distribution (Hadschar Mountains, Zagros Mountains) and are saxicolous (Rösler 1995, Gardner 2013, Šmid *et al.* 2014, Carranza *et al.* 2016, 2018). The present study depends on assumptions about their former way of life. A terrestrial *Asaccus* ancestor may have been forced to move to vertical rock surfaces due to increased predation pressure. The new locomotor requirements could then have had a counterproductive effect on pregnancy with two large eggs in the females and led to a reduction in the clutch size. The one-sided oviduct loss in *Asaccus* may be a consequence of this development. A left-sided regression or reduction of the paired organ is typical of Squamata (Blackburn 1998). A single egg follicle or mature egg was always found in the right oviduct of *Ptenopus garrulus* (Hibbits *et al.* 2005, Goldberg 2008). Furthermore, the researchers believe that the *Asaccus* ancestor already glued its eggs. The risk of predation during the search and preparation of a suitable egg storage site on the ground is greater than when laying eggs in natural crevices and cavities of vertical rock formations. However, females require less energetic cost for gluing compared to burying the eggs. The pregnant female is not forced to leave her residential area in search of a site with suitable nesting conditions to bury her eggs. Furthermore, optimal nest sites for burying eggs can be difficult to find in natural habitats.

Two characteristics presumably found in the ancestor of the *Asaccus/Haemodracon*, namely the production of double-egg clutches and the burial of eggs, have been preserved in the genus *Haemodracon.* Tamar *et al.* (2019) assume that the *Haemodracon* ancestor lived on vertical surfaces. If this hypothesis is correct, *H. riebeckii* has retained the original way of life (as rock- and tree-dweller) while *H. trachyrhinus* has developed into a soil dweller. As a possible scenario for the stability *vs* reduction of the clutch size in *Haemodracon,* the researchers suggest that a very strong increase in body size in *H. riebeckii* interacted with the growth of the egg size which explains why the resulting larger young animals could only be caught by fewer predators. This would eliminate the selection pressure to reduce the number of eggs from two to one in favour of lower mortality. *H. trachyrhinus,* in which the extent of diversification of the body size is likely to be less than in its sister species (Meiri 2007, 2008), was faced with an increased number of potentially dangerous predatory arthropods by entering a free ecological niche. Under island conditions, taxa usually increase the speed of change and adjustment, and in the context of low predation pressure, they quickly colonize ecological niches which were not present in their area of origin (Schluter 2000, Harmon *et al*. 2008, Losos and Ricklefs 2009, Tamar *et al.* 2019). Starting from an oligocene insular isolation of the *Haemodracon* ancestor and the later sympatric or allopatric Miocene speciation, the start-up effect of a fast ecological incorporation is eliminated. From a common micro-habitat (rocks, caves, crevices and cliffs) *H. riebeckii* with the increasing body size may have pushed the sister species *H.*

trachyrhinus into a horizontal microhabitat (areas with low vegetation, shrub areas) (Tamar *et al.* 2019).

The population dynamics and demographics of small soil geckos are affected by a disproportionately high mortality rate in juveniles, and this ultimately would lead to the extinction of the species. In general, the number of potentially dangerous predatory arthropods on juveniles of ground-dwelling lizards with small SVL is increased (McCormick and Polis 1982, Bauer 1990, Reyes-Olivares *et al.* 2020, Valdez 2020). The invertebrate fauna of Socotra is rich in species (Wranik 2000, 2003). Among them are also numerous predatory arthropods dangerous for lizards, e.g. *Araneae, Scolopendridae*. The researchers found that Socotra‘s most dangerous predator for terrestrial lizards to be *Scolopendra valida* occurring synoptically with *H. trachyrhinus*. The centipede is able to overwhelm and eat adult skinks (*Hakaria simonyi*). A strong selection pressure caused by predation-related mortality may have provoked an increase in the SVL of juveniles in *H. trachyrhinus,* which subsequently led to a reduction in the number of eggs in order to produce larger eggs and offspring.

Possible reduction of the clutch size depending on prey acquisition strategies and food resources: Ecological niche models have different food web structures (Williams and Martinez 2000, Woodward and Hildrew 2002). Various studies on resource use patterns have shown that animals normally have a proportionality of body size and prey size (Warren and Lawton 1987, Fisher and Dickman 1993, Moen and Wiens 2009, Alcantara *et al.* 2019). Cocilio *et al.* (2016) described the ontogenetic variation of the food composition of *Homonota fasciata*. The food spectrum of the adult specimens included fourteen different species of arthropods, compared to only five of juveniles. Transformations of prey acquisition strategies, changes in activity patterns and new micro-habitats are closely linked to changes in food resources. Niche diversity, coupled with specifically and ontogenetically different dietary preferences, can, in a limited or absence of supply of size-specifically adapted prey species in certain habitats, force animals to produce larger young, which provides a better chance of survival in the interspecific competition for small food animals.

The *Asaccus/Haemodracon* complex includes species of different microhabitats and activity patterns. The two *Asaccus* species are saxicolous, *H. riebeckii* saxicolous and arboricolous and *H. trachyrhinus* terricolous; the first three species are cathemeral and the latter nocturnal (Rösler and Wranik 2005, Gardner 2013, Tamar *et al.* 2019). All four species are insectivore (Weber 1960, Torki and Sharifi 2007, Torki *et al.* 2010, 2011a, Martin *et al*. 2017). Only *H. riebeckii* is additionally frugivorous and herbivorous (Rösler and Wranik 2007). Furthermore, all four species are cannibalistic and differ in their preying strategies. *H. trachyrhinus* is a more active forager when seeking food (Schätti and Desvoignes 1999, Martin *et al.* 2017), while the other three species use a sit-and-wait strategy. The average energy-production cost per clutch (based on RCM values) for the sit-and-wait predators is higher (25 %) than that of the search hunters (18 %) as measured by Dunham *et al.* (1988) and is not detectable in the *Asaccus/Haemodracon* complex (see also Vitt and Congdon 1978). *H. trachyrhinus* has an effort of 18 %, *A. montanus* 17 %, *A. caudivolvulus* 15 % and *H. riebeckii* 11 %.

Interspecifically, contrasting trophic niches can be assumed in *Asaccus* and *Haemodracon*. The researchers assume that *Asaccus* sp. and *H. riebeckii* are dependent on a high percentage of food introduced via the air (Torki and Sharifi 2007, Torki *et al*. 2011b and own observations). *A. montanus* can catch prey up to the size of ant maids (myrmeleontid, wing lengths >40 mm, B.M. Zwanzig personal communication). The food composition of *H. riebeckii* and *H. trachyrhinus* (Martin *et al.* 2017) differs according to the different habitats and hunting strategies. Normally, the larger young ones eat large prey species, but also

do not despise the tiny species of arthropods. The smaller young ones are dependent on a size-specific adapted and sufficiently large prey potential. The proportion of the available prey is extended by the size of the young of *H. riebeckii* and is being more limited in *H. trachyrhinus.* In addition to the intraspecific predation-related mortality, *H. trachyrhinus* may also have been forced to develop individual large eggs if the death rate of the too small juveniles increased as a result of too few adequate prey potentials in its microhabitat.

Reproductive-specific effects of clutch-size reduction: *Haemodracon riebeckii* is the only species of the *Asaccus/Haemodracon* complex with a variable clutch size, wherein the percentage of double-egg clutches produced in the course of an egg-laying season predominates (as seen above).

If the abdominal volume of the female is assumed as a limiting factor for the maximum clutch volume (Shine 1992), then more abdominal space is available in the vitellogenesis of one instead of two eggs. A theoretically resulting possible egg enlargement did not occur in *H. riebeckii*. The average of the egg volume from single-egg clutches is 2212±228 (n=96), while in the eggs from the double-egg clutches, it is 2175±259 (n=337). The volumes of the eggs of both clutch sizes do not differ significantly (Mann-Whitney-U-Test, z -1.8933, p >0.05). This means that in the vitellogenesis of an egg (whether in the right or left oviduct), no unilaterally disproportionate expansion of the oviduct occurs, which corresponds to the results in other gecko species (Kubička and Kratochvil 2009, Weiser *et al.* 2012 and references cited therein).

In the species of the genus *Tarentola* from the Canary Islands and the Cape Verde Islands, alternating clutch sizes are also found (Nettmann and Rykena 1985, Hielen 1993). The researchers collected and statistically analyzed reproduction data from *T. nicolauensis* in captivity and found that 47.1 % of the clutches contained a single egg (mean clutch size 1.27±0.45, n=51). The volume of the eggs from single-egg clutches is 1339±196 (n=26) while in the eggs from double-egg clutches, it is 1039±139 (n=24). The egg volume of both clutch sizes differs significantly (Mann-Whitney-U-Test, z -4.6902, p <0.01). Similar results apply to *Tarentola angustimentalis*, *T. delalandii* and *T. rudis* (Hielen 1991, Rösler 2020).

Tarentola nicolauensis is scansorial and lives on gravel plains with granular substrate (Wranik and Rösler 2007). The eggs from the single-egg clutches of *T. nicolauensis* are larger and heavier than those of *H. riebeckii*. The reason for the positive allometric enlargement of the eggs of single-egg clutches in *T. nicolauensis* could be intraspecific competition. Larger juveniles are able to build food territories faster and to be more effective in resource competition (Nettmann and Rykena 1985). The tendency to enlarge single eggs could be a stage of development, which ultimately results in the relative increase in costs in the development process of invariant single-egg clutches in geckos (see below). The affine egg dimensions in both clutch sizes of *H. riebeckii*, on the other hand, are conservative. Lower intraspecific competition may have reduced intraspecific selection pressure to produce larger eggs and juveniles, or the egg conformity of the two types of clutches is fixed in the way of life as rock- and tree-dwellers (Andrews and Rand 1974, Shine *et al*. 1998, Schwarz and Meiri 2017, Meiri *et al*. 2020).

In the evolutionary process of reduction from two eggs to a single egg per clutch, geckos have applied different strategies, their results can be interpreted by comparing the egg dimensions proportional to the SVL, RCM, or other parameters. For the time being, the eggs from single-egg clutches are placed interspecifically into two weight classes. A small group of specialized arboricol taxa miniaturized the total clutch mass (as seen above *Aristelliger* and *Thecadactylus*), probably like the Dactyloidae for reasons of reducing the physical reproduction stress of females in difficult habitats (Kratochvil and Kubička 2007 and references cited therein). The opposite strategy, an increase in total

clutch mass combined with the development of single-egg clutches, includes the second, larger group of gekkonid taxa. This strategy compensates for a lower reproduction rate by more competitive offspring. This work concludes that the growth limitation of the egg size in the double-egg clutches of geckos is primarily regulated by the maximum available abdominal volume of the female and secondly by the pelvic opening, while for the proportionally larger eggs from the single-egg clutches, mainly, the width of the pelvic passage is the decisive factor.

The single-egg-producing species of the *Asaccus/Haemodracon* complex belong to the group of egg-enlargement strategists. Interspecifically, subtle differences can be observed within this group, which are noticeable in the correlation of egg volume and egg mass to the female size and female weight. *A. montanus* produces eggs that are relatively larger than *H. trachyrhinus;* intraspecifically reversed, the eggs of the former are relatively lighter than the latter, but how to explain this discrepancy?

It is assumed that both species have adjusted the resource investment per clutch in an equilibrium ratio (used maternal resource to offspring fitness). Cox and Calsbeek (2009) have experimentally shown that the locomotor abilities (endurance, speed) of productive (gravid) *Anolis* females deteriorate measurably compared to unproductive ones, even if they only carry a single small egg. This effect increases exponentially with an increase in egg proportions. Compared to the tree- and branch-dwelling *Anolis* species with low RCMs (0.051-0.128, medium 0.074±0.024, n=10) (Andrews and Rand 1974, Ramirez-Batista and Vitt 1997, Ramirez-Batista 2003, Vitt and Zani 2005, Johnson *et al.* 2010), the rock-dwelling *Anolis montanus* has enlarged its eggs but is inferior in direct proportional comparison to *H. trachyrhinus* in the RCM (Table 1). *A. montanus* and *H. trachyrhinus* are scansorial and have morphologically similar toe structures (Gamble *et al.* 2012) but inhabit various ecological niches. A plausible explanation for the inter-specific differing RCMs would be a relation to ecological parameters. In addition to predation intensity and food availability (as seen above), staying on vertical surfaces correlated with the fitness of pregnant females could allow a regulated increase in egg size, while in gravid females on horizontal surfaces, it depends on other parameters (e.g., pelvis passage). The theory, however, has a caveat. It cannot be applied to geckos in general. Relatively higher RCM values can also reach small-growing rock-living species (e.g., *Pristurus* cf. *rupestris* 0.217±0.020, n=14) and comparatively larger ground-dwelling can also reach relatively lower values (e.g., *Homonota horrida* 0.124±0.022, n=5). Probably, several mutually influencing factors are responsible for the interspecific differences in the modification of the relative clutch mass.

Conclusion

To sum up, this work concludes that the *Asaccus/Haemodracon* ancestor produced double-egg clutches and the species of both genera reduced their clutches convergently to a single egg. The aim of the present study is to investigate which earlier selective forces led to the development of single-egg clutches. In the comparison of ancestral and derived reproductive traits, the researchers have reconstructed relationships with predation risk and food acquisition as biotic selection factors for the allometries of clutch size. This work concludes that *Asaccus* and *Haemodracon* possibly independently developed single-egg clutches for various reasons. The authors are aware that the analysis only considers part of the functional feedbacks for the evolutionarily eligible miniaturized clutch size in the *Asaccus/ Haemodracon* cluster, but they do believe it will offer approaches for further research into the developmental phenomenon of invariant single-egg clutches within the Gekkota.

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Supplement

Summary of statistics of the normal distribution tests of *Asaccus/Haemodracon* cluster. Shaded cells are those characters bearing significantly different means p <0.05.

character, species	W	p
clutch volume		
A. caudivolvulus	0.97687	0.70489
A. montanus	0.49373	0.00000
H. riebeckii (single egg clutch)	0.96665	0.02173
H. riebeckii (double egg clutch)	0.96263	0.00030
H. trachyrhinus	0.98914	0.87775
clutch mass		
A. caudivolvulus	0.91213	0.22715
A. montanus	0.95091	0.74763
H. riebeckii (single egg clutch)	0.94816	0.00129
H. riebeckii (double egg clutch)	0.98756	0.12079
H. trachyrhinus	0.97156	0.18974
hatchling weight		
A. caudivolvulus	0.97956	0.89861
A. montanus	0.96201	0.18488
H. riebeckii (single egg clutch)	0.96467	0.38547
H. riebeckii (double egg clutch)	0.97379	0.00138
H. trachyrhinus	0.94535	0.00577

Summary of statistics of Tukey HSD results for the reproductive characters of *Asaccus/Haemodracon* cluster.

snout-vent length

Tukey HSD p-value

	H. riebeckii	*H. trachyrhinus*	*A. caudivolvulus*	*A. montanus*
H. riebeckii	-	** p<0.01	** p<0.01	** p<0.01
H. trachyrhinus	0.0010053	-	** p<0.01	insignificant
A. caudivolvulus	0.0010053	0.0010053	-	** p<0.01
A. montanus	0.0010053	0.6923274	0.0010053	-

Tukey HSD inferfence

female mass

Tukey HSD p-value

	H. riebeckii	*H. trachyrhinus*	*A. caudivolvulus*	*A. montanus*
H. riebeckii	-	** p<0.01	** p<0.01	** p<0.01
H. trachyrhinus	0.0010053	-	insignificant	insignificant
A. caudivolvulus	0.0010053	0.7234100	-	insignificant
A. montanus	0.0010053	0.8999947	0.6725777	-

Tukey HSD inferfence

snout-vent length/clutch volume

Tukey HSD p-value

	H. riebeckii	*H. trachyrhinus*	*A. caudivolvulus*	*A. montanus*
H. riebeckii	-	** p<0.01	** p<0.01	** p<0.01
H. trachyrhinus	0.0010053	-	** p<0.01	** p<0.01
A. caudivolvulus	0.0010053	0.0010053	-	** p<0.01
A. montanus	0.0010053	0.0010053	0.0010053	-

Tukey HSD inferfence

relative clutch mass

Tukey HSD p-value

	H. riebeckii	*H. trachyrhinus*	*A. caudivolvulus*	*A. montanus*
H. riebeckii	-	** p<0.01	** p<0.01	** p<0.01
H. trachyrhinus	0.0010053	-	** p<0.01	insignificant
A. caudivolvulus	0.0010053	0.0011277	-	insignificant
A. montanus	0.0010053	0.8999947	0.3742620	-

Tukey HSD inferfence

juvenile mass/female mass

Tukey HSD p-value

	H. riebeckii	*H. trachyrhinus*	*A. caudivolvulus*	*A. montanus*
H. riebeckii	-	** p<0.01	** p<0.01	** p<0.01
H. trachyrhinus	0.0010053	-	** p<0.01	* p<0.05
A. caudivolvulus	0.0010053	0.0010053	-	insignificant
A. montanus	0.0010053	0.0269861	0.3279569	-

Tukey HSD inferfence

First Record of the Poplar Lace Bug, *Monosteira unicostata* (Mulsant & Rey, 1852) (Hemiptera: Tingidae), from Jordan

Ahmad Katbeh Bader [1*] and Ibrahim Al-Jboory [2]

[1]Department of Plant Protection, School of Agriculture, The University of Jordan, Amman, Jordan; [2]Department of Plant Protection, College of Agriculture, University of Baghdad, Baghdad, Iraq

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Abstract

The poplar lace bug, *Monosteira unicostata* (Mulsant & Rey, 1852) (Hemiptera: Tingidae) is recorded for the first time from Jordan. It was found in many localities in Amman associated with the predator *Oenopia conglobata* (Linnaeus, 1758) (Coleoptera: Coccineliidae) which is also recorded for the first time in Jordan. In addition, a predatory bug, *Anthocoris* sp. (Hemiptera: Anthocoridae) was observed consuming the immatures of the lace bug.

Key words: New records, Coccineliidae, Anthocoridae.

Introduction

Monosteira unicostata is found in the Euro-Mediterranean region, North Africa, and parts of Asia (Drake and Ruhoff, 1965, Péricart 1983, Tolga and Yoldas 2019). It is a major pest of almond trees growing Euro-Mediterranean region, but it is not established so far in the United States and Australia. Since it was reported in British Columbia, Canada (Scudder 2013), in Argentina (Carpintero *et al.,* 2017), and in Chile (Campodonico *et al.,* 2021), it could be a potential threat to almonds worldwide (Rijal *et al.,* 2021). Costas *et al.,* (2020) recorded *M. unicostata* from the Iberian Peninsula, Balearic Islands and Canary Islands. Djazouli *et al.,* (2009) recorded it on *Populus nigra* L. in Algeria and Talhouk (1977) recorded it from Lebanon. Gennaro and Giorcelli (2019) mentioned that it was found in Italy since 1970s causing defoliations in nurseries and young plantations. Pfiricart *et al.,* (1993) listed fifty-four species of Tingidae from Palestine considering *M. unicostata* as a noxious species. They recorded the lace bug on *Populus, Salix, Amygdalus, Crataegus, Cydonia, Prunus, Pyrus* and mentioned that it occurred from April to October on *Populus* and *Salix*.

Mustafa *et al.,* (2020) studied the population density of *M. unicostata* in Istanbul Province (Turkey) on *Populus deltoides* Bartr., white poplar, *Poplar alba* L. and black poplar, *Populus nigra* L. Adults appeared at the beginning of June,and their numbers continued to increase until they disappeared in the middle of October during 2019. Its population peak was in July. *Populus deltoides* Bartr. was the most susceptible followed by *Populus nigra* L., and white poplar, *Populus alba* L.

González-Núñez (2015) studied the use of Kaolin and potassium soap with thyme essential oil to control *Monosteira unicostata* and other phytophagous arthropods of almond trees in organic orchards in Spain.

Arab (1996) studied the life cycle of *M. unicostata* and its control under field conditions in Syria. Lace bugs emerged from the winter diapause during early spring when the average temperature was around 16°C. They had three-four generations per year. Bolu (2007) studied the population dynamics of lace bugs and their natural enemies in almond orchards of Turkey. He recorded *Monosteira lobulifera* Reuter, 1888, *M. unicostata* (Mulsant and Rey, 1852) and *Stephanitis pyri* (Fabricius, 1775) and twenty-four predatory beetle (Coleoptera: Coccinellidae) species and five predatory

*Corresponding author: ahmadk@ju.edu.jo

bugs (Hemiptera: Lygaeidae, Anthocoridae, Nabidae, and Mioridae). Mustafa *et al.,* (2014) studied the population density of *Monosteira unicostata buccata* Horváth, 1902 in a field study at Koysinjaq city (Iraq, Erbil Province) during 2013 on the black poplar, *Populus nigra* L., Euphratic poplar, *Populus euphratic*a Oliv. and Willow trees, *Salix acmophylla*. Adults appeared in the middle of May, and its population increased to a peak in July and August and then disappeared in the second week of December. *Salix acmophylla* was the most susceptible species followed by *Populus euphratica* Oliv. and *Populus nigra* L.

The objective of this paper is to officially record the poplar lace bug, *Monosteira unicostata* (Mulsant and Rey, 1852) in Jordan, and its associated predators: the ladybird beetle, *Oenopia conglobata* (Linnaeus, 1758), and a minute pirate bug, *Anthocoris* sp. (Hemiptera: Anthocoridae).

Materials and Methods

Infested poplar leaves were first collected on 30/6/2021 from Al Rabiya, Amman. Observations on other poplar trees in several areas in Amman were conducted. Natural enemies associated with poplar lace bug were also collected. Adult insects of the pest and its natural enemies were mounted on cards to take digital images by a sixty-five mm Macro lens attached to Canon (Canon Inc., Tokyo, Japan) 5D Mark IV. A continuous light source was used from a LED ring light. Helicon Focus (HeliconSoft, Kharkiv, Ukraine) Stacking software was used to reach the required depth of field. Voucher specimens were preserved at the University of Jordan Insects Museum.

Results

The bugs feeding on the poplar leaves were identified as the poplar lace bug, *Monosteira unicostata* (Mulsant and Rey, 1852) (Hemiptera: Tingidae) (Figures 1 and 2). This species is recorded from Jordan for the first time.

Adults are 2.0 - 2.8 mm long, 0.65 - 0.70 mm wide, and pale brown with black ventral side. The head is reddish-brown, with prominent eyes, and four-segmented antennae. The hemelytra are heavily reticulated and with small brownish spots along their margins. First and second instar nymphs dark-brown, while third to fifth instars are lighter in color and have wing pads (Figure 3) (Talhouk 1977, Neal and Schaefer 2000).

The predator, *Oenopia conglobate* (Linnaeus, 1758) (Coleoptera: Coccineliidae), was frequently observed on leaves infested with the poplar lace bug (Figure 4). This species is recorded for the first time in Jordan. This lady bird beetle was identified according to the key of Khormizi and Nedvěd (2020) and following Oldřich *et al.,* (2020) description: the elytral background pink or ochraceous, with the black pattern consisting of up to eight pairs of spots in five transverse rows (pattern 2-2-1-2-1) and a narrow black stripe at the suture. The spots are often confluent or fused in European individuals, while they are mostly small and separated in Middle Eastern individuals. The pronotum is white with seven black spots (Oldřich *et al.,* 2020). *Oenopia conglobata* is found in Asia (China -Xinjiang, Iraq, Lebanon, Syria, Turkey, and Uzbekistan), Europe (Bulgaria, Czechia, Federal Republic of Yugoslavia, France, Germany, Greece, Italy, Lithuania, Norway, Poland, Serbia, and Montenegro), and North America (United States-Texas) (CABI, 2022).

In addition, a minute pirate bug, *Anthocoris* sp. (Hemiptera: Anthocoridae) was seen consuming the immatures of the lace bug (Figure 5).

Discussion

Monosteira unicostata is a major pest of almonds growing in the Euro-Mediterranean region (Scudder 2013) so searching for this pest in all almond-producing areas is required. The insect life cycle and losses affecting almond trees have been studied in Portugal. The peak of eggs was observed during June and July. The peak of nymphs was recorded

Figure 1. An Adult of *Monosteira unicostata* (Mulsant and Rey, 1852).

Figure 2. *Monosteira unicostata* (Mulsant and Rey, 1852) feeding on poplar.

Figure 3. Fifth nymphal instar of *Monosteira unicostata* (Mulsant and Rey, 1852).

Figure 4. *Oenopia conglobata* (Linnaeus, 1758) (Coleoptera: Coccineliidae) associated with *Monosteira unicostata* (Mulsant and Rey, 1852).

in the first two weeks of August. The peak of adults was observed at the end of July and beginning of August (Pereira *et al.,* 2008). The poplar lace bug annual generations, its distribution, degree of infestation, damage caused, and other natural enemies need full investigation in Jordan. The susceptibility of poplar clones in Jordan for the poplar lace bug should be evaluated. The susceptibility of five poplar clones (*Populus deltoides*

Figure 5. *Anthocoris sp*. (Hemiptera: Anthocoridae) (Dorsal and lateral views) which was seen consuming the immatures of the lace bug.

Batr. —Lux clone; *Populus nigra* L.—58-861 clone and *Populus* × *canadensis* Mönch. —Luisa Avanzo, I-214 and Adige clones) to *Melampsora* sp. fungus and the poplar lace were investigated. Adige and Lux were most tolerant (Fernàndez-Martínez *et. al*. 2013).

The poplar lace bug is expected to reproduce faster in warmer regions in Jordan such as the Jordan Valley and the adjacent areas. Sánchez-Ramos *et al.,* (2017) studied the reproduction, longevity, and life table parameters of *M. unicostata* at constant temperatures of 22, 25, 28, 31, 34 and 37ºC, 60 ± 10% relative humidity, and under a L16:D8 photoperiod. The optimum temperature for population increase was predicted at 34.1ºC, at which the population doubling time was found to be 3.6 days. Lower and upper thresholds for *M. unicostata* were 14.8 and 38.8ºC, respectively. Accordingly, the poplar lace bug is considered a serious pest in the Mediterranean basin with a high-potential risk in a global warming scenario.

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Short Communication

The Geranium Bronze Butterfly, *Cacyreus marshalli* (Butler, 1898) (Lycaenidae: Lepidoptera), A New Invasive Species and Additional Records to the Butterfly Fauna of the Palestinian Territories - West Bank

Elias Nabil Handal
Palestine Institute for Biodiversity and Sustainability, Palestine Museum of Natural History, Bethlehem University, Bethlehem, Palestine

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Abstract

This is the first report on the Geranium Bronze Butterfly, *Cacyreus marshalli* from the Palestinian Territories. This invasive species was collected from Bethlehem city from two locations in house gardens feeding on *Pelargonium* sp. and *Geranium* sp.

Keywords: Invasive, *Cacyreus marshalli*, Geranium Bronze, West Bank, Palestine.

Introduction

Cacyreus marshalli Butler, 1898 (Lycaenidae: Lepidoptera) commonly known as the Geranium Bronze, Pelargonium Butterfly, or Sardinian Zebra, is a native species to South Africa, and is considered the first non-indigenous species introduced to the Mediterranean region (John *et al.,* 2018). It was initially documented by Eitschberger and Stamer (1990) from the Islands of Mallorca, Spain, from western Turkey (Başbay and John, 2021) and Crete, Greece (John *et al.,* 2018) as a result of imported food plants and *Geraniums* sp. to these countries. *Cacyreus marshalli* could be a serious destructive pest to its geranium hostplant (John *et al.,* 2018).

According to the European and Mediterranean Plant Protection Organization (EPPO) database, it is distributed in several African countries (Algeria, Botswana, Egypt, Eswatini, Lesotho, Morocco, Mozambique, and Zimbabwe. In Asia, it was recorded from historic Palestine (not including the West Bank), Turkey and Uzbekistan. In Europe, the insect was observed in many countries including Albania, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Guernsey, Italy, Latvia, Malta, Montenegro, Netherlands, North Macedonia, Norway, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Switzerland, Ukraine, and the United Kingdom.

In historic Palestine, over 120 species of butterflies belonging to five families (Papilionidae, Pieridae, Lycaenidae, Hesperiidae, and Nymphalidae) have been reported (Comay *et al.,* 2021; Benyamini, 1990). Few studies were carried out on the butterfly fauna from the West Bank area, including fifty-five species reported (Abu Sarhan *et al.,* 2016; Qumsiyeh, 2016; PIBS, 2017). The butterflies of Gazza consist of twenty-five species (Dardona *et al.,* 2015). Benyamini and Kurman (2020) recorded this species for the first time from Jerusalem, which was the first record of this invasive species in the East Mediterranean.

Cacyreus marshalli (Figure 1) was collected from Bethlehem city (in the Mediterranean region) from two different locations; two specimens were collected on the 5th of June 2022 from a house garden (31°42’48.7”N 35°12’13.9”E) flying around ornamental

Corresponding auther: Email: eliashandal93@gmail.com

Figure 1. Dorsal and ventral views of the Geranium Bronze, *Cacyreus marshalli*. (Wing span: 21.3 mm).

plants, and further three specimen were collected on the 7th of June 2022 from the Palestine Museum of Natural History (PMNH) Botanical Garden (31°43'04.4"N 35°12'20.0"E) in Bethlehem on *Pelargonium* sp. ornamental Plants. The distribution and host plants of *C. marshalli* should be intensively studied to understand its effect on the Palestinian environment.

Cacyreus marshalli biology was not well-studied over the years due to the lack of serious damage in its native area in South Africa (Eitschberger U, Stamer P, 1990). After it was recorded in Italy, some studies started to appear (Favilli and Manganelli, 2006; Trematerra and Parenzan, 2003). According to Tawfeek *et al.* (2021) *Cacyreus marshalli* larvae feed on the host plant leaves, flower and nectar then borrow in the host plant stem, so this butterfly pest can feed on plant parts. The female is larger than the male. The average length of the male is 12 mm with an average wingspan of 19 mm, and the female average length is 13 mm and with average wingspan of 23 mm. The larvae need thirty days to reach the pupal stage which lasts for seventeen days before emergence to the adult (Sarto i Monteys and Masó, 1991).

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Short Communication

First Record of *Milnesium* Doyère, 1840 (Tardigrada: Apochela) from the Western Ghats, India.

Elssa Ann Koshy[1,2] and Raveendranathanpillai Sanil[1*]

[1]Molecular Biodiversity Lab, Department of Zoology, Government Arts College, Udhagamandalam -643002, The Nilgiris, Tamilnadu; [2]Postgraduate Department of Zoology, Christian College (University of Kerala), Chengannur - 689 122, Alappuzha District, Kerala, India.

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Abstract

Tardigrades are the strongest micro-invertebrates on the planet, and their ability to thrive in climatic and pressure extremes is currently gaining attention. The researchers report for the first time the presence of *Milnesium* (Order: Apochela, Class: Eutardigrada) from mosses in the high-altitude of the Nilgiris (2500 msl) in the Western Ghats, as well as observations on its clutch size and egg-laying behaviour. *Milnesium* is a highly tolerant species that has been offered as a candidate for space travel. Until now, just one *Milnesium* species has been documented in India, making the present observation extremely significant. The genus is distinguished by its cuticle sculpture, cuticular characteristics, six peribuccal papillae and two lateral ones, six peribuccal lamellae, and a bucco-pharyngeal bulb devoid of placoids or septum, in addition to its distinctive claws. By providing rotifers and ciliates to the species, the researchers were able to cultivate them successfully in the hay infusion medium. *Milnesium* was observed moulting and laying between one to seven eggs per clutch, which were always found adhered to the exuvia. In this instance, a high-altitude sighting of this species during extreme weather is crucial because the genus is able to withstand harsh conditions such as low temperatures and ionising radiation.

Key words: Tardigrades, *Milnesium*, Eggs, Exuvia, Moulting

*Corresponding author: sanilravi@live.in

Introduction

Due to their ability to survive in hostile conditions, tardigrade research has recently gained a great deal of scientific attention (Devasurmutt and Arpitha, 2016). They are classified as a different phylum, Tardigrada, with morphological similarities to arthropods and onychophorans, and molecular similarities to nematodes (Richards, 2018). They thrive in a variety of terrestrial and aquatic habitats, including cryptograms (mosses and liverworts), lichens, leaf litter, beaches, sand dunes, and soil, among others (Nelson *et al.,* 2018). They live by slowing down their metabolism, a mechanism known as cryptobiosis, and reviving on a thin layer of water. Tardigrades can survive dehydration and high stress by entering a dormant state known as the tun stage. Various bioprotectants, such as trehalose, LEA proteins, antioxidants, heat shock proteins, tardigrade specific proteins (TDPs), Aquaporin proteins (AQPs), etc., are involved in the stress response (Kamilari *et al.,* 2019; Neves *et al.,* 2020). Due to this ability, the species are appropriate study models for a variety of industries, including agriculture, biotechnology, biomedicine, ecology, and astrobiology (Clegg, 2001; Jonsson *et al.,* 2008).

Milnesium Doyère, 1840, is a genus of the Order Apochela (Class: Eutardigrada) with a great tolerance to harsh environments like ionising radiation (Beltrán-Pardo *et al.,* 2013), desiccation (Schill and Fritz, 2008), and sub-zero temperatures (Hengherr *et al.,*

2010). *Milnesium tardigradum*, a species with a high tolerance, was flown to space for research and has recently attracted notice for demonstrating its enormous capacity to withstand vacuum and solar radiation (Jonsson *et al.,* 2008). *Milnesium* is widely found in mosses and lichens in temperate temperatures and high-altitude locations (Hengherr *et al.,* 2010). *Milnesium* is represented globally by forty-eight species, excluding one subspecies and a species (Rocha *et al.,* 2022). India is home to only one species of *Milnesium tardigrade,* the *Milnesium longiungue* (Tumanov, 2006) discovered from Himachal Pradesh. This paper reports for the first time the presence of *Milnesium* sp. in the high-altitude region of the Nilgiris in the Western Ghats, together with observations of its clutch size and egg-laying habit.

Methodology

The Western Ghats are an ancient mountain range on the west coast of the Indian peninsula. The Nilgiri Hills, located in the southern portion of the Western Ghats, are a very biodiverse region due to their altitude (2500 m asl) and climate conditions. *Milnesium* was identified from mosses growing at high altitudes in the Nilgiris. The genus is characterised by smooth, pseudoporous, or reticulated cuticle sculpturing; cuticular structures (gibbosities, spines, or pseudoplates); six peribuccal papillae and two lateral ones; six peribuccal lamellae; a bucco-pharyngeal bulb devoid of placoids or septum. The secondary branch is distinguished from the long primary branch by the presence of small supplementary points on all claws, which aided in identifying the genus, and by the presence of a spherical thickening at its base.

For this study hay was collected from the market, cut it into pieces, and was washed twice with tap water and distilled water. In a conical flask, hay was cooked after being autoclaved. The hay infusion was stored under sterile conditions for three days. Utilizing hay infusion aliquots, tardigrades and their food sources were cultured. Initially, moss samples were collected in a Petri dish and soaked in distilled water for twelve to twenty four hours. The extra water in the petri dish was drained, and the moss clump was squeezed to a watch glass. Using a micropipette, isolated tardigrades, rotifers, nematodes, and ciliates were put into hay infusion media. After a month, aliquots of tardigrades were examined under an Olympus stereomicroscope. Before being put on Hoyer's medium, the existing tardigrades were fixed in Carnoy's fluid, dehydrated in alcohol, and cleared in lactic acid. The species was identified using the aforementioned identifying characteristics (Moreno-Talamantes *et al.,* 2020) and photographed using an NLCD-307 Lawrence and Mayo microscope. The species of *Milinesium* that were observed living under a microscope in the extract were subcultured in a medium containing an infusion of hay and studied.

Results

Within a month, the medium demonstrated ecological succession through a high density of rotifers (50 per drop) and ciliates on which tardigrades fed. *Milnesium* tardigrades were isolated from the culture and grown individually in scratched plastic petri dishes with ciliates and rotifers as prey. The observed *Milnesium* species displayed notable differences from *M. tardigraum* and modest differences from *M. longiungue,* but the species status cannot be determined. (Figure 1). The researchers watched *Milnesium* moulting and made the observation that it lays between one to seven eggs at a time, with the eggs always seen attached to the exuvia (Figure 2). When separated and cultured in culture plates, the cuticular shed (exuvia) with eggs hatched at a rate of 92%, and the hatched ones were identified as females. Females who had moulted were seen to re-moult after a sixty to seventy day interval.

Figure 1. (a) *Milnesium* observed from the high altitude of the Nilgiris. (b) *Milnesium* ready to moult with eggs

Discussion

The *Milnesium* species found in the Nilgiris are distinct from *Milnesium longiungue*, the sole species found in India. However, further research on the specimen is necessary to determine the species status. Limno-terrestrial tardigrades are sexually monogamous with intermittent hermaphroditism (Altiero and Rebecchi, 2001). Self-fertilization and thelytoky have been observed in species found in mosses (Altiero *et al.,* 2018). When parthenogenesis and self-fertilisation do not occur in the same species, self-fertilisation is reported as an evolutionary mechanism (Bertolani, 2001). Female limno-terrestrial

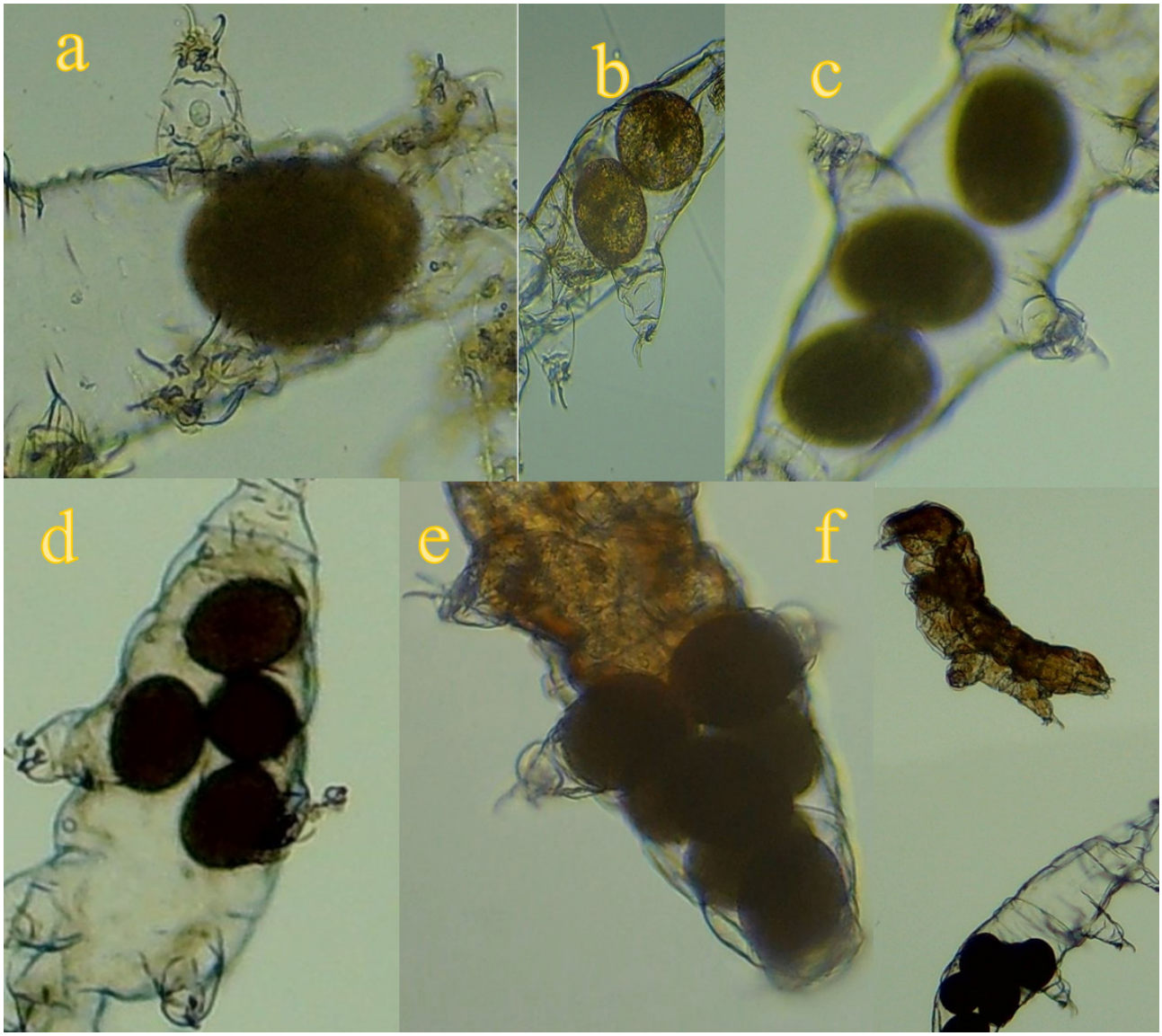

Figure 2. Exuvia of *Milnesium* with eggs (a: Single egg, b: with two eggs, c: with three eggs, d: with four eggs, e: with seven eggs, f: post moulting stage).

tardigrades are said to be iteroparous, which means they can lay eggs freely or in their own exuvia.

Milnesium lives in the moss's upper layer and feeds on ciliates, nematodes, and rotifers (Beasley and Miller, 2007). *Milnesium inceptum* and *Milnesium pentapapillatum* have been shown in the past to reproduce parthenogenetically (Morek *et al.,* 2019-2020). The *Milnesium* species found in the Nilgiris could possibly be parthenogenetic, as only females were observed in the culture. Ontogenetic variation in claw configuration has been reported between instars and adults (Morek *et al.,* 2016). Instar identification was not attainable in this study and requires additional observations under controlled settings. The unique abilities of tardigrades, such as anoxybiosis, cryobiosis, osmobiosis, chemobiosis, and anhydrobiosis (Weronika and Łukasz, 2017), have enabled the development and isolation of biochemicals in industrial and medical applications. At water loss, tardigrades produce a bioprotectant called trehalose, which protects macromolecules such as proteins and nucleic acids from losing their native structure (Kinchin, 2008). Even though tardigrades are extremotolerant, they have a temperature tolerance limit (Neves *et al.*, 2020). Researchers found that a unique protein in tardigrades called the Damage suppressor (Dsup) protein binds to human cells, reducing the amount of DNA damage

caused by radiation up to 40% (Hashimoto *et al.,* 2016). *Milnesium* is a genus that has been extensively used in space research to assess the survival rate. This demonstrates the significance of distinguishing *Milnesium* from climate extremes such as the high altitudes of the Nilgiris.

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Short Communication

Parental Care in the Early Days of a Fledgling of the Clay-colored Thrush (*Turdus grayi*)

Lucía I. Lopez[1] and José Manuel Mora[2,3,*]

[1] Unidad de Ciencias Básicas, Sede Atenas, Universidad Técnica Nacional. Km 34, Ruta 27, C.P. 7-4013, Balsa de Atenas; [2] Carrera de Gestión Ecoturística, Sede Central, Universidad Técnica Nacional, Costa Rica; [3] Department of Biology and Museum of Vertebrate Biology, Portland State University, Portland, Oregon 97207, USA

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Abstract

The clay-colored thrush (*Turdus grayi*) is common in altered habitats (e.g., thickets), artificial (e.g., crop fields), and forest edges. The species nests from March to June in a cup-shaped nest typical of passerines where the female lays two to three eggs. Parents incubate the eggs for twelve to thirteen days and care for the nestlings for twelve to eighteen days. There is no information about what happens to the fledglings just after departure from the nest. On 1 May 2022, the researchers found a fledgling clay-colored thrush on the ground of a garden in a rural area in Carrizal de Alajuela, Costa Rica at 1700 m asl. The fledgling was followed for a week, during which time it was cared for and fed by the parents. This note provides information on the relationship between the fledgling and its parents.

Key words: Costa Rica, fledglings, nesting, open habitats, passerines, yigüirro

Introduction

The clay-colored thrush *Turdus grayi* (Passeriformes: Turdidae), known in Costa Rica as yigüirro, is distributed across Mexico, southwards to northern South America (Vallely and Dyer, 2018), and from sea level to 2400 m elevation (Garrigues and Dean, 2014). It is found and breeds in altered habitats such as gardens and urban areas, agricultural crops, pastureland with scattered trees, forest edges, and secondary forests (Dyrcz, 1983; Stiles and Skutch, 1989). This tropical songbird is visually monomorphic with a monogamous breeding system and a synchronous reproductive season from March to June (Dyrcz, 1983; Sánchez *et al.,* 2018). The nest is an open cup made of rootlets, stalks, moss, sticks, leaves, and other plant material with some mud on its walls (Dyrcz, 1983). Females construct the nests and incubate typically two or three eggs that are blue mottled with brown (Stiles and Skutch, 1989). Incubation lasts twelve to thirteen days (Dyrcz, 1983), and the nestling period lasts twelve to eighteen days (Dyrcz, 1983).

Parental care in passerine birds is defined as the time invested by parents in incubating, feeding the young, defending the nest from predators, and other tasks to ensure the development and survival of their offspring (Winkler, 1987; Sánchez *et al.,* 2018). Parental care is not restricted to the nestling stage but extends beyond the fledgling and even longer than the nestling period (Vega, *et al.,* 2000; Cohen and Lindell, 2004). In many species, parents continue to care for their fledged young, either by leading them to food sources, or feeding them. Birds are vulnerable after they leave the nest, but before they can fly: though once fledged, their chances of

*Corresponding author: jomora@pdx.edu

survival increase dramatically (Gill, 2006). Although the reproductive season and the nesting period of the clay-colored thrush have been studied, the researchers did not find any information on the relationship between the parents and the fledglings just after leaving the nest, being incapable of sustained flight and depending on the adults. Parental care of the fledglings of the white-throated Robin (*Turdus assimlis*) extends for at least three weeks (Cohen and Lindell, 2004). The average age at dispersal for this species was thirty-one days, similar to the ages of independence for two temperate breeding species of Turdidae: the American Robin *Turdus migratorius* (37 days) and the Wood Thrush *Hylocichla mustelina* (28-36 days) (Vega *et al.,* 2000; Cohen and Lindell, 2004). This note provides information on the parental care of a fledgling clay-colored thrush for five days right after it departed from the nest until it became capable of short, sustained flights.

Materials and Methods

The researchers observed the behavior of a family of clay-colored thrush from 01 May to 06 May 2022. The presence of the fledgling was checked on a daily basis four times in the morning (07:00 am, 08:00 am, 09:00 am, and 10:00 am), and four times in the afternoon (03:00 pm, 04:00 pm, 05:00 pm and 06:00 pm), with some additional searches at other times of the day when there was an opportunity for that. At each time, when the researchers found the chick, they observe it for ten minutes and then left. The observations took place in a wooded garden at Carrizal, Alajuela, Costa Rica (10° 06´ 40´´ N, 84° 09´ 53´´ W, Elev. 1700 m). The site is located in the Tropical Lower Montane Wet Forest according to Holdridge´s classification of life zones (Holdridge, 1967). However, the study site was located at a semi-urban areas dominated by agriculture crops and houses. The bird was found in a garden with ornamental plants and fruiting trees.

Results

On 1 May 2022, at 09:00 am, the researchers observed a fledgling clay-colored thrush on the ground close to some herbs just after departure from the nest. Apparently it was the only nestling in the nest that was at 2.4 m high in the fork of a branch of a lemon tree. The fledgling was very noisy, and moving on the ground with clumsy hops as it screeched, though the parents were moving close by. The researchers concluded that the bird was a fledgling based on its plumage, for it was clear the bird has lost nearly all the downy feathers and has quite well developed wings and tail, although they were shorter than those of the adults; also, it has its flight feathers although they were not in adult condition (Figure 1A). At this stage, many birds are weak flyers, and they are cared for by adults, often on the ground (Gill, 2006). Over the period of observation, the bird showed some ability to fly confirming it was a fledgling.

On 2 May 2022, at 8:00 am, the fledging was seen on a small branch about 60 cm above the ground, where it remained for about an hour. During this time, one of the parents approached the fledgling to feed it, and later it descended to the ground and moved with clumsy steps about 2 m towards a site with herbaceous vegetation. At approximately 11:00 am it began to rain; nevertheless, the fledgling remained in the same place under the rain for at least an hour; observation ended after the fledgling hid in the vegetation. On 3 May 2022, at 8:00 am, the fledgling was found on a rock about 70 cm above the ground, where it remained for a little over two hours. During that time, one of the parents (the researchers were unable to determine if it was the same individual or two different ones) fed the fledgling five times: three times with fruits and two with insects (Figure 1C, D). When the researchers approached the young bird trying to photograph it, one of the parents landed next to it and lightly knocked it down behind some plants where it was much less visible. Around 11:00 am it started to rain, and the fledgling stayed on its perch, but

Figure 1. A) Fledgling clay-colored thrush (*Turdus grayi*). B) One parent landed close to the fledgling and pushed it out of rain. C) Fledgling being fed fruits. D) Fledgling being fed insects. Photos © José Manuel Mora.

nearly fifteen minutes later, a parent landed near it making some calls (Figure 1B), and the chick moved under nearby broad leaves that protected it from the rain.

On 4 May 2022, at 10:00 am, the fledgling was spotted on a 2-m-high branch of a lemon tree, where one of the parents fed it on three occasions. Shortly after 11:00 am it started to rain heavily, and it was impossible to observe the chick. The researchers were unable to find the fledgling the following day, although it was found on 6 May 2022 at 10:00 am on a 3.5 -m- high branch of the lemon tree. Upon approaching the position of the chick from below, the fledgling flew without any apparent difficulty to another branch about 2 m away. Two adults began to call (alarm), and some fluttering in the branches was heard. After that, the researchers could no longer observe the birds, even though they looked carefully for the chick for the following two days, searching all branches of the tree.

Discussion

The researchers did not find any reports on the parental care of fledglings by the adults of the clay-colored thrush. Nesting and parental care of the clay-colored thrush on the nest have been studied in Costa Rica as well as in other countries (Lindell *et al.,* 2011; Chanona *et al.,* 2017; Sanchez *et al.,* 2018). However, these investigations stopped after the fledglings left the nests, so they did not generate information about this particular life stage for this species. This is a stage where most studies on avian reproduction cease (Russell, 2000). The post-fledging period is one of the least understood phases of the avian life cycle, mainly because it is difficult to observe young birds after they leave the nest (Cohen and Lindell, 2004). The present observations show that the clay-colored thrush protect their fledglings at least until the time they are capable of sustained

flight. The fact that both parents took care of the fledgling and that the chick responded to their alarm calls was fundamental for its survival showing the appropriate behavior of its age (Magrath *et al.,* 2006).

Nestlings generally leave the nest before they are fully grown, and generally they are helpless for some days and remain cryptic, hidden away until an adult approaches with food, when they beg vociferously (Russell, 2000). On different occasions, the researchers were not able to find the studied fledgling, probably because it was hidden. It was possible to observe it only at times when it was exposed waiting or begging for food. A similar behavior was observed for the fledglings of *Turdus asimilis* who were able to fly five days after they left the nest (Cohen and Lindell, 2004). The fledglings of this species sat still on, or close to, the ground and were rarely observed flying during the first week out of the nest, but they were able to fly distances up to 30 m by the end of the second week (Cohen and Lindell, 2004). These fledglings were seen foraging for the first time during the third week after leaving the nest (Cohen and Lindell, 2004). This means that, probably, the studied fledgling required at least two more weeks of parental care before it was able to feed itself. Besides, the fledging had to be protected from predation during this time. Six fledglings of *Hylocichla mustelina*, another Turdidae, were depredated (within five days after leaving the nest) in Virginia, USA, but 23 (85%) survived to independence (Vega *et al.*, 2000). These fledglings were able to fly at least 30 m in response to parental alarm calls only five days following nest departure; this is the time when they stayed on the forest floor or on bushes (Vega *et al.,* 2000), also similar to the fledgling observed in this work. The researchers did not notice any interaction among potential predators and the family of the clay-colored thrush. Parents provisioning was strongly related to the ambient risk of predation (Ghalambor *et al.,* 2013). this factor could have been favorable in the current study because it allows for the fledgling to be constantly fed by its parents being incapable of flying and looking for its own food. Unfortunately, the researchers were not able to follow the fledging until it became capable of sustained flight and can feed itself. However, it is possible that the parents continued to take care of the fledging for several more days, a behavior that still needs to be documented.

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Short Communication

A Defensive Attack by a Social Carnivore (White-nosed coati) against a Constrictor Predator (Mesoamerican boa constrictor)

Juan de Dios Astorga[1,2] and José Manuel Mora[3,4,*]

[1]Universidad Técnica Nacional, Ingeniería en Manejo Forestal y Vida Silvestre, 7-4013, Atenas, [2]Sistema Nacional de Áreas de Conservación, Área de Conservación Arenal-Tempisque, 50601, Guanacaste, [3]Carrera de Gestión Ecoturística, Sede Central, Universidad Técnica Nacional, Alajuela, Costa Rica. [4]Department of Biology and Museum of Vertebrate Biology, Portland State University, Portland, Oregon, USA.

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Abstract

Ecological interactions are one of the most complex aspects of tropical biodiversity; among these, predation stands out due to the impact it has both on prey and predators. Two of the most prominent groups of predators in the tropics are snakes (Reptilia) and mammalian carnivores. White-nosed coati *Nasua narica* (Mammalia: Carnivora: Procyonidae) and the Mesoamerican boa *Boa imperator* (Reptilia: Squamata: Serpentes: Boidae) interact in cross-predatory events that depend on the size of the individuals involved. On 21 November 2019, at 1637 h, the researchers observed a herd of thirty-seven coatis, where a subgroup of twenty-three individuals, made up of mostly adult females and some young males, were aggressively attacking a large boa. The attack could have been a defensive reaction of the females of the herd who, perceiving a potential threat to their young, reacted aggressively to drive away the predator. This work reviews and places this observation in the context of previous records of interactions between these two species.

Key words: *Boa imperator*, Costa Rica, Ecological interactions, *Nasua narica*, Snake

Introduction

Ecological interactions are one of the most complex aspects of tropical biodiversity (Andresen *et al*., 2018). Among these, predation stands out due to the impact it has both on prey and predators. Predation influences several key aspects of fitness including feeding, breeding, and mortality; as such, it constitutes a fundamental aspect of the lives of wild animals (Humphreys and Ruxton, 2018). Predator-prey interactions are one of the main drivers of natural selection, influencing the structure of ecological communities, and the functioning of ecosystems (Portalier *et al.,* 2019; Valdez, 2020). The observation of predatory events and related aspects of natural history contributes to the understanding of ecological interactions, species behavior, energy transfer in the food chain, and other key aspects required to attain the ecological knowledge necessary as a basis for wildlife management and conservation (Sih and Christensen, 2001; Santos-Filho *et al.,* 2021). Two of the most prominent groups of predators in the tropics are snakes (Serpentes, Squamata) and carnivores (Carnivora, Mammalia). However, several tropical carnivores have specialized in eating fruits and many species are omnivorous (Mora, 2000). An example of these is the White-nosed coati *Nasua narica* (Linnaeus 1766), one of the most gregarious species of the Carnivora (Pérez-Irineo and Santos-Moreno, 2016). The white-nosed coati is diurnal and generally travels in bands of variable size, typically consisting of five to eighteen individuals (Kays, 2009). Most of the males

are solitary and are expelled from family groups or bands formed mainly by females and juvenile individuals (Kays, 2009). A unique case among carnivore species, a lek-like mating system in a population of white-nosed coatis *Nasua narica* was reported in Guatemala (Booth-Binczik *et al.,* 2004). The group works cooperatively in parental care, surveillance, and defense against potential predators, and larger groups have been found to have lower rates of predation (Gompper, 1997; Hass and Valenzuela, 2002). The white-nosed coati is distributed from the southwestern United States to the north and west of Colombia, from 0 to 2,879 m elevation (Kays, 2009). In Costa Rica, it is found mainly in lowlands, although it is also common in midlands (Mora, 2000). It is considered to be a medium-sized mammal, with a maximum length of 680 mm and a weight of 3.5 – 5.6 kg (Kays, 2009). It prefers forested habitats, but is commonly seen on the edges of these habitats and in thickets and disturbed sites in general (Reid, 2009). It feeds on invertebrates, fruits, small vertebrates, eggs and carrion and also takes nectar (Mora *et al.,* 1999). Although the coati is common or even abundant, its population ecology is insufficiently known in various areas (Pérez-Irineo and Santos-Moreno, 2016), even though it is pursued as food or as a nuisance or harmful (Velarde and Cruz, 2015).

The Mesoamerican boa constrictor or Becker (*Boa imperator*) is the largest, heaviest snake in Costa Rica (Leenders, 2019). It has a robust cylindrical body reaching a maximum length of 5 m (Solórzano, 2022). Its tail is short (10 – 15% of total length), and its head is large, wide, and well differentiated from the neck (Savage, 2002). The dorsum is covered with uniformly small, smooth, and iridescent scales (Leenders, 2019). This snake is found in lowlands and adjacent slopes from Northern Mexico to northeastern South America (Hynková *et al.,* 2009). In Costa Rica it is found in the lowlands and on premontane slopes throughout the country in tropical and subtropical shrublands and secondary forests, dry, moist, and wet forests, from sea level to 1,500 m elevation, including the Central Valley (Savage, 2002; Solórzano, 2022). The Boa is terrestrial and arboreal, active mainly at night and crepuscular times (Solórzano, 2022). It frequents cultivated areas and farmlands as well as human buildings, and it tolerates a wide range of temperature and humidity levels (Leenders, 2019). Boas are sit-and-wait predators (Greene, 1983) and feed on a large variety of vertebrate prey, including small to medium-sized mammals such as rats, agoutis, raccoons, and ocelots, birds, and lizards, as well as some domestic animals (Savage, 2002; Brown, 2019; Solórzano, 2022). Prey size is largely dependent on the size of the snake with juvenile snakes taking smaller preys such as rats, mice, bats, and squirrels, and adult large snakes feeding on larger preys including opossums, monkeys and coatis (Leenders, 2019). Large prey such as jaguarundi (*Herpailurus yagouaroundi*; Mammalia: Carnivora: Felidae) and gray fox (*Urocyon cinereargenteus*; Carnivora: Canidae) also have been reported (Monroy-Vilchis *et al.,* 2011; Perez-Alvarado *et al.,* 2019).

The interactions between the White-nosed coati and the Mesoamerican boa are cross-predatory depending on the size of the individuals involved. Adult boas routinely eat coatis (Solórzano, 2022) and coatis take newborn and small boas (Reid, 2009). This note presents a case of a putatively defensive attack by a band of White-nosed coatis on an adult Mesoamerican boa based on observations of an interaction between these two species in northwestern Costa Rica. The paper reviews and places this observation in the context of previous records of interactions between these two species.

Materials and Methods

The researchers' observations were conducted at Taboga Forestry Reserve, Cañas, Guanacaste (10° 20' 17.5" N, 85° 09' 02.6" W, 30 elevation). Taboga is located in Tropical Premontane Moist Forest, basal transition life zone (Holdridge, 1967).

Average annual rainfall in this life zone varies between 1200 and 2200 mm, and mean annual temperature between 23º and 24°C (Bolaños *et al.,* 2005). It is a seasonal habitat with a marked dry season of 3.5 – 5 months between December and May, and a rainy season from June to November (Bolaños *et al.,* 2005). Sites adjacent to the reserve are mainly dedicated to agriculture, with sugarcane and rice as principal crops (Astorga and Mora, 2022). Based on general distribution and habitats, Taboga is a zone of sympatry for the White-nosed coati and the Mesoamerican boa.

Results

On 21 November 2019, at 1637 h, during a routine patrol within the Taboga protected area, the researchers observed a herd of thirty-seven coatis. The group was on the side of a gravel road in a secondary forest, with minimal flow of traffic. A subgroup of twenty-three individuals, made up mostly of adult females and some young males, were aggressively attacking a large boa. During the attack, the rest of the group, made up of the youngest in the group, remained about 10 m from the site, observing the attack. The interaction was observed for a period of twenty minutes, during which time lunges and bites were constant. After that period, the group of coatis began to gradually withdraw from the site. The snake seemed very exhausted, and minutes later it moved towards the forest. The researchers did not observe who initiated the attack or why the attack occurred; however, it could be interpreted as a defensive reaction of the females of the herd who, perceiving a potential threat to their young, reacted aggressively to drive away the predator. A video of the interaction can be seen at https://www.youtube.com/watch?v=_0tpTu-6l6A.

Figure 1. A band of White-nosed coatis (*Nasua narica*) attacking a Mesoamerican boa (*Boa imperator*) in Northwestern Costa Rica. Photo by J. de D. Astorga.

Discussion

Natural history observations constitute the fundamental basis of empirical studies that enable results to be viewed and analyzed in an appropriate context; this is particularly true for antagonistic interactions between predatory species (Morrison, 2018). Although coatis have been studied fairly extensively, there remain numerous gaps with respect to the researchers' knowledge of this carnivore. Similarly, a recent case of parthenogenesis in *Boa imperator*, resulting in all-female offspring, shows how much we still have to learn about this snake species (Leenders, 2019). Boas often are involved in cross-species predatory encounters, even including other snakes such as a Central American Indigo Snake (*Drymarchon melanurus*; Squamata: Colubridae) attempting to prey on an individual in Honduras (Brown and Murcia, 2021). The snakes were in combat for over ten minutes, and assumed defensive postures after intervention and separation (Brown and Murcia, 2021). Some prey defend themselves aggressively from predatory attempts by boas; for example, turkeys fend off predators using their beaks, large bodies, wings, and spurs on the back legs as weapons (Brown, 2019).

The researchers are uncertain in the present instance why the coatis attacked the boa (or even if they initiated the agonistic interaction), because the boas as a prey item was too large for the coatis. A defense mechanism against snakes seems a more plausible behavior on the part of the coatis. Coatis on Barro Colorado Island in Panamá, reacted with mixed alarm, aggressiveness, and curiosity when two large boas were presented to them, and one coati even bit the tail of one of the snakes (Janzen, 1970). Protecting conspecifics from predation is considered a driving force for the development of sociality in many species (Hass and Valenzuela, 2002). There is one report of a 3.4 m boa killing a coati in Taboga, but before the snake asphyxiated the young coati, three adults defended its conspecific in an apparent display of altruistic behavior on the part of the prey coati's companions (Janzen, 1970). The coatis continued to paw and bite the snake for several minutes until they were interrupted (Janzen, 1970). Apparently, only if the snake had been small, could the coatis have caused the release of their band member, or if vulnerable areas of the snake were exposed to the coatis (Janzen, 1970).

Interactions between predators are worth reporting because they help characterize the biology of species involved. However, natural history events involving snakes are difficult to observe in the field because they are discreet and habitually stealthy animals (Steen, 2010). The reporting of these cases helps fill gaps in this area of knowledge and understand the behavior, ecological interactions, and life history, of the species involved (Santos-Filho *et al.,* 2021). The researchers have worked in the field for over three decades, and although boas and coatis are common in their study sites, the interaction reported here has never been observed before. It would be worthwhile to determine whether this is an unusual interspecific interaction between the two species, or whether it is more commonplace. Behavioral studies of the two species in sympatry would help determine which of the two alternative hypotheses is more probable.

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Is a national organization devoted to the conservation of Jordan's wildlife. It was founded in 1966 under the patronage of His Majesty the late King Hussein and has been given responsibility by the government to establish and manage protected areas and enforce environmental laws. As such, it is one of the few non-governmental organizations in the Middle East to be granted such a public service mandate.

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