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Three new species and one new subspecies of *Hemidactylus* Oken, 1817 from Yemen (Squamata, Gekkonidae)

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> Abstract

Based on morphological and molecular characters, three new species and one subspecies of the genus *Hemidactylus* are described from the mainland of Yemen. According to the molecular tree of mitochondrial genes of Cytochrome *b* and 12S (Busais & Joger 2011), *Hemidactylus* species from the mainland were divided into three monophyletic groups: three taxa are members of *H. yerburii* group, two clades are members of *H. robustus* group and three compose a new group of undescribed species. In addition to the molecular results, the morphological analysis revealed that each new species is distinguished from the other species of the genus in some morphological characters. In this study, a detailed description of each new species is presented.

> Zusammenfassung

Mit Hilfe morphologischer und molekularer Merkmale werden drei neue Arten und eine neue Unterart der Gattung *Hemidactylus* vom Festland der Republik Jemen beschrieben. Der molekulare Baum, basierend auf den mitochondrialen Genen Cytochrom b und 12S RNA (Busais & Joger 2011) teilt die *Hemidactylus*-Arten des Festlandes drei monophyletischen Gruppen zu: Drei Taxa gehören der *H. yerburii*-Gruppe an, zwei der *H. robustus*-Gruppe und drei bilden eine neue Gruppe noch unbeschriebener Arten. Die morphologiche Analyse belegt, dass sich jede neue Art von den übrigen Arten der Gattung mindestens durch einige Merkmale unterscheidet.. Detaillierte Beschreibungen der neuen Arten werden präsentiert.

> Key words

Geckos, morphology, molecular tree, new species, taxonomy, Yemen.

Introduction

Yemen has a highly endemic fauna and flora due to its location in the southwest of Asia close to the horn of Africa. This unique geographical position in combination with a mountainous topography has given Yemen different climatic areas. These features are favorable for existence of diverse ecosystems along with a rich biodiversity (CBD, 2009).

Previous studies on the herpetofauna of Yemen have concentrated mainly on recording which species occurred in the country. However, several records need confirmation and a couple of genera need a critical revision. This is notably true for *Hemidactylus*. *Hemidactylus* Oken, 1817 is one of the most species-rich genera of the family Gekkonidae which contains more than 90 species (Bauer & Pauwels, 2002; Sindaco *et al.*, 2007, 2009; Zug & McMahan 2007; Arnold *et al.*, 2008; Giri 2008; Giri & Bauer 2008; Bauer *et al.*, 2008; Giri *et al.*, 2009; Ullenbruch *et al.*, 2010, Agarwal *et al.*, 2011). Molecular phylogenetic work identified a number of undescribed species of this genus in Yemen (Busais & Joger, 2011).

The high level of variation within this genus makes the distinction among the species using superficial features taxonomically difficult. As a result of these systematic problems in *Hemidactylus*, the phylogenetic species approach, using molecular methods, often simplifies distinguishing the species as in other genera that have similar problems (Carranza & Arnold 2006).

In the study of *Hemidactylus* geckos using mitochondrial DNA sequences by Carranza & Arnold (2006), five major clades are discernable that have well-supported value. The positions of the Yemeni *Hemidactylus* species are within two of these clades: the large group is within the arid clade and only one species (*H. flaviviridis*) is within the 'tropical Asian clade'. Our study focuses on the taxonomic status of species inside the arid clades from the mainland of Yemen. The present paper provides description of four taxa belonging to three new species of *Hemidactylus* and one new subspecies.

Materials and Methods

Animals were collected from several localities in Yemen (Appendix 1). The collected samples are deposited in the Natural History Museum in Braunschweig, Germany (NHM-BS) and in the Zoological Research Museum Alexander Koenig, Bonn, Germany (ZFMK).

The morphological analysis for Yemeni geckos was done after defining operational taxonomic units (OTUs) depending on the results of the phylogenetic tree for mitochondrial genes based on 1106 bp of cytochrome *b* and 12S. OTUs were defined as monophyletic clades in the mitochondrial genetic trees. The mitochondrial tree clearly distinguishes eight clades of Yemeni *Hemidactylus* taxa that were found on the mainland of Yemen (fig. 1) (Busais & Joger 2011).

The following measurements were taken with a caliper to the nearest 0.1 mm by using a Vernier® ROYAL. Scales and scansors counts were measured directly from the target by using a binocular microscope.

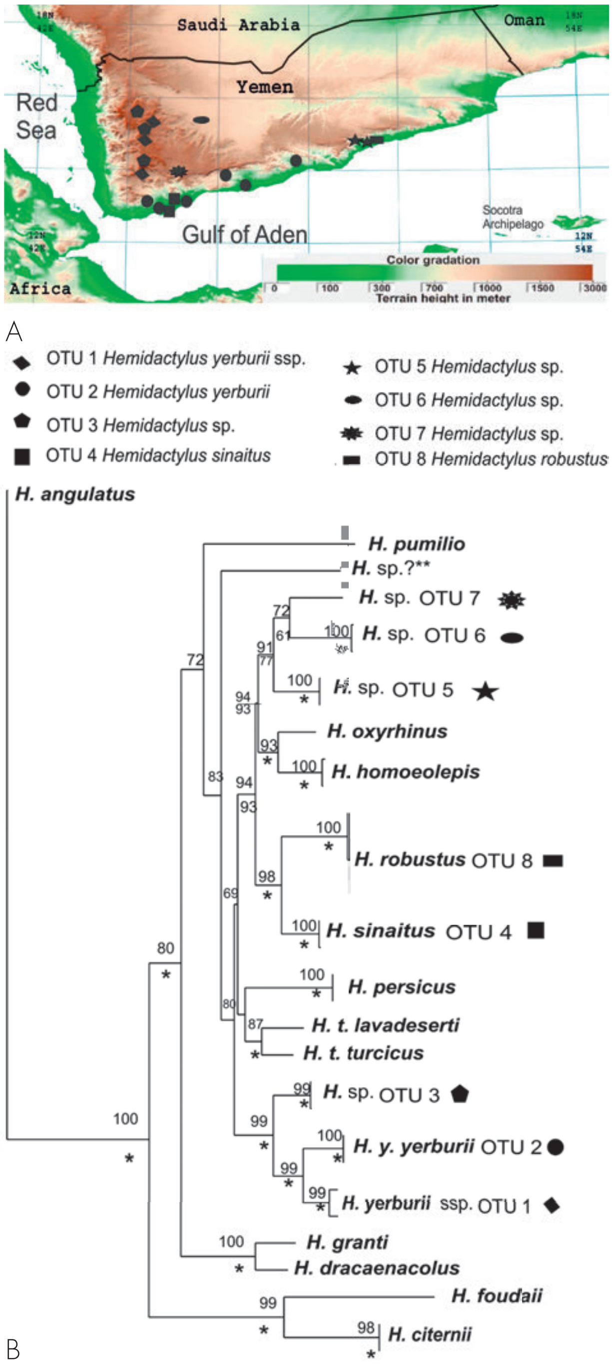


Fig. 1. (A) Distribution of mitochondrial lineages of *Hemidactylus* in the mainland of Yemen. ML tree for (B) a combination of the cytochrome b and 12S rRNA mtDNA sequences obtained with PHYML. Numbers by the nodes indicate: for ML bootstrap values (> 50%) are given above the nodes, and Bayesian probabilities are given below the nodes. An asterisk (*) indicates a posterior probability of ≥ 0.95. ** A sequence of *Hemidactylus* identified in Genbank as *H. yerburii* by Carranza & Arnold (2006).

SVL Length of the head and body: measures the distance from tip of snout to cloacal aperture.

LT Length of the tail: measures the distance from cloacal aperture to tip of the tail.

VS No. of ventral scales: counts the transverse row across the belly that includes the greatest number.

DS No. of dorsal scales: counts the mid-way scales between the fore and hind limbs.

TD Tubercle rows on dorsum: Body tubercles are the conspicuously enlarged scales forming relatively straight longitudinal rows on the dorsal and lateral surfaces of the body. They are counted at the mid-body.

UL Upper labials: counts number of scales for one side starting from the angle of the mouth to the middle of upper jaw except rostral.

LL Lower labials: counts number of scales for one side starting from the angle of the mouth to the middle of lower jaw except mental.

In G Internasal granules: counts the scales between supranasals.

NsN Nasals surrounding nostril: counts the scales surrounding nostril.

1st Sc Scansors under 1st toe: counts the subdigital lamellae in a single row of scales from the base of toe to the tip of the 1st toe.

4th Sc Scansors under 4th toe: counts the subdigital lamellae in a single row of scales from the base of toe to the tip of the 4th toe.

MP Male preanal pores: counts include the total number of the pre-anal pores which are confined to the area in front of the vent.

HL Head length: measures the distance from tip of snout to the retroarticular process of jaw.

HW Head width: measures the maximum width of head.

HH Head height: measures the maximum height of head, from occiput to underside of jaws.

OD Orbital diameter: measures the greatest diameter of orbit.

EED Eye to ear distance: measures the distance from anterior edge of ear opening to posterior corner of eye.

SED Snout to eye distance: measures the distance between anterior point of eye and tip of snout.

Meristic data were included in principal component analyses (PCA) using the analysis program SPSS for Windows, version 18. To assess significance of differences among taxa One-Way-ANOVA test and Independent-Samples T-test ($P < 0.05$) were performed. These results were confirmed by using the test of Mann-Whitney (U-test) $P < 0.05$ (Appendix 2,3).

Results

The examination of the morphological characters for the Yemeni *Hemidactylus* taxa showed significant differences among these groups as revealed by ANOVA analysis. All meristic characters in males and females showed significant differences among groups except the character of (LL) in males. For the morphometric characters, significant differences were detected in females except the characters of (OD & EED). However, no significant differences in morphometric characters were detected in males. Therefore, the statistical analysis of the morphometric characters were ignored.

The PCA using the meristic data extracted three principle components with an eigenvalue 1 in the analysis of females and three principle components in males, these factors demonstrated 62.49 % (females) and 74.23 % (males) of the total variance.

The difference between sexes was possibly related to one of the characters found in males. This character MP (male preanal pores) is considerably important to produce more reliable results to distinguish species (Vences *et al.*, 2004).

The first and second factors separated seven main groups by using scatterplots, which completely agreed with their placement within the phylogenetic tree. The separation was clear as no overlap was observed among the OTUs except the OTU 1 and OTU 2 in both sexes. A limited overlap was detected between OTU 1 & OTU 5, OTU 1 & OTU 8 and OTU 2 & OTU 8 in females (fig. 2).

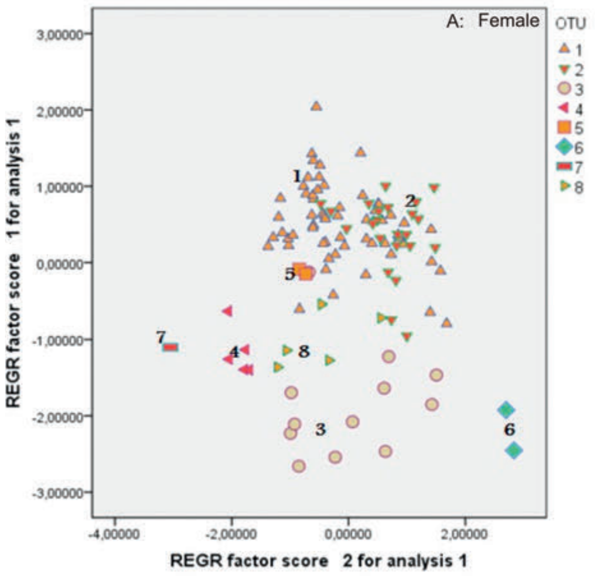
The analyses of T-test and Mann-Whitney test (U-test) were applied among the groups which had overlapped in PCA analysis to find significant characters among these clades. These analysis revealed significant differences among groups.

Discussion and Conclusions

Hemidactylus is one of the species rich genera of its family. This genus is pantropical. However, the diversification in number of species in Yemen is obvious. The distinction among the species within *Hemidactylus* using superficial features is taxonomically difficult. This is due to the considerable variation in the range of external characters. This variation makes it hard to construct clear identification keys for them. Therefore, the *Hemidactylus* species have been distinguished by sorting them into OTUs according to their phylogenetic affinities, and then assigning additional specimens to these OTUs accordingly to geographic proximately and altitude. Since these OTUs could also be distinguished morphologically, we conclude that they represent different taxa.

Results revealed three *Hemidactylus* groups (group of *H. yerburii*, group of *H. robustus* and group of new *Hemidactylus* species) present in the mainland of Yemen in the phylogenetic trees of the mitochondrial genes. Several clades within these groups refer to undescribed species or subspecies. These undescribed taxa are represented in the clades of OTU 1 and OTU 3 from the *H. yerburii* group as well as the OTU 5, OTU 6 and OTU 7 from the group of new *Hemidactylus* species (fig. 1).

The group of *H. yerburii* contains the members of the nominal subspecies of *H. y. yerburii* (OTU 2) from the type locality and other localities from the



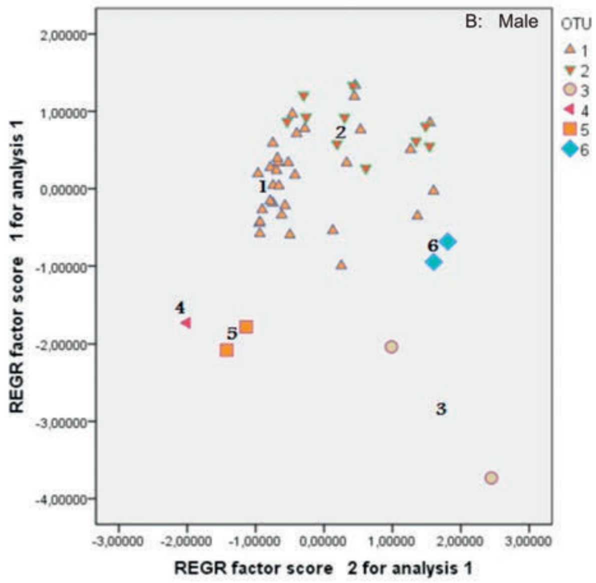


Fig. 2. (A. Female, B. Male) Scatter grams of PCA appear ordered along first and second principal components based on meristic data.

mainland. However, the others are undescribed units that are represented by the clades of OTU 1 and OTU 3. The description of OTU 1 fits to the description of the species *H. yerburii* with considerable variation, however, the members of OTU 3 clade have several distinct characters (see below).

The second group comprises the two known species of *H. robustus* (OTU 8) and *H. sinaitus* (OTU 4). The description of OTU 8 specimens fit to the diagnosis of the species *H. robustus*. Moreover, the sequences of these specimens are identical to each other and to specimens sequenced by CARRANZA & ARNOLD (2006); in addition, there is no genetic divergence between these populations in the mitochondrial genes nor the nuclear gene. *Hemidactylus robustus* can be distinguished from *H. sinaitus* by the high mean number of tubercle scales (15.60 vs. 14.20 in females), the high mean number of scansors under the first toe (6.20 vs. 5.00 in females) also the high mean number of scansors under the fourth toe (9.80 vs. 9.00 in females).

The OTU 4 specimens are recorded from Aden, Sheikh Othman in vicinity of Aden, Lahj and Shugra in the southern Yemen (ANDERSON 1895, 1901; ARNOLD 1986). The current samples were collected from Sheikh Othman and from the same locality which ANDERSON (1895) described.

The third group consists of three clades not mentioned previously in the mainland or Socotra archipelago. The members of these clades consist of the clade of OTU 5 from the coastal plain of Yemen, the clade of OTU 6 from the desert, and one specimen (OTU 7) from the high mountains. The members of these clades represent undescribed taxa of *Hemidactylus* (fig. 1).

Description of three new species and one new subspecies

1. *Hemidactylus yerburii montanus* ssp. nov. (OTU 1)

Holotype: Adult female NHM-BS N41836 from Al-Makhader, Ibb, (13° 58′ N – 44° 11′ E). Collected by S. Busais. 14. 03. 2009.

Paratypes: NHM-BS N41751 – N41756 from As-Sohool, Ibb; N41757 – N41758, N41770, N41776, N41778, N41781, N41783 – N41788, N41791 – N41794, N41797 – N41824, N41826 – N41832 from Ibb, NHM-BS N41837, ZFMK 91982 from Al-Makhader, Ibb; N41840, N41842, N41844, N41867, N41895 – N41896, N42617 – N42618 from Al-Odain, Ibb; N41771, N41775, N41780, N41795 from Yareem; N41833 – N41834 from Wadah, Amran; N41835, N41853 – N41855 from Sana'a. N41759, N41898.

Description of holotype: Snout-vent length: 49.1 mm. Tail length: 63.6 mm. Head length: 16.1 mm. Head width: 10.8 mm. Head height: 6.5 mm. Upper labials: 10. Lower labials: 8. Rows of dorsal tubercles: 16, dorsal scales across mid-body 85. Ventral scales across mid-abdomen 44. Lamellae under fourth toe: 10. Lamellae under first toe: 7. Nostril surrounded by three nasals (NsN), rostral and the first upper labial. Internasal granules separated by one smaller scale. Mental large, sub-triangular. Anterior postmental nearly 1½ time as long as wide, shorter than mental, ex-

Fig. 3. Holotype of *Hemidactylus yerburii montanus* ssp. nov. (OTU 1, scale = 3 cm).

panded nearly until the end of the second lower labials. Tail is more depressed than slender, tubercles of tail keeled, restricted, arranged in six rows.

The general color is light gray with dusky band before and behind the eye, with feeble dusky markings on the head, neck and shoulders; on dorsal side pattern of a series of indistinct dark spots is present. On the middle of the tail towards the tip there are faint indications of transverse dark bands. Ventral side is white, minutely spotted with livid on the sides of the belly.

Description of paratypes. *Hemidactylus yerburii montanus* ssp. nov. is a small to medium-sized gecko, with maximum recorded SVL of approximately 68 mm. Head sparsely covered with enlarged convex granules, the largest granules are between the eye and nostril. Nostril formed by the rostral, first upper labial and three nasals. 9–12 upper labials; 6–9 lower labials. Two pairs of post-mentals present, extending from the first lower labial shields into about the end of the second lower labials. Body depressed, covered with minute rounded granules with numerous large trihedral tubercles intermixed and arranged mostly in 14–16 longitudinal rows; 74–97 dorsal scales across mid body. Ventral scales cycloid, imbricate, and larger than dorsals; 36–48 ventral scales across mid-abdomen. Limbs are rather short and thick. Digital pads moderately expanded; 5–7 lamellae under first toe, 9–11 lamellae under fourth toe. Tail slender, almost smooth dorsally, with a few small distinct tubercles; transverse row of six distinct tubercles; subcaudals uniform.

Dorsal coloration in some specimens is gray or brownish gray, with dusky band before and behind the eye, sometimes with feeble dusky markings on the head, neck and shoulders; on dorsal side a pattern of a series of indistinct or distinct dark spots is present. On the middle of the tail towards the tip there are faint or distinct indications of transverse dark bands. Ventral side is white, sometimes minutely spotted on the sides of the belly.

Differential Diagnosis

Several studies indicate that the differences between populations of *H. yerburii* in the high altitude of Yemen are due to the variation within the species since this species has extreme geographical variation (Arnold, 1986), however, the results of phylogenetic trees revealed that OTU 1 is a separate sister clade of *H. y. yerburii* (OTU 2).

Following examination of the facial differences between the populations in the group of *H. yerburii*, results revealed that the population of OTU 1 (*H. yerburii montanus* ssp. nov.) can be distinguished from the population of OTU 2 (*H. y. yerburii*) by the low mean number of (DS) dorsal scales (87.19 vs. 91.70 in males and 85.40 vs. 91.70 in females), the low mean number of (4^{th} Sc) scansors under the first toe (6.26 vs. 6.70 in males and 6.25 vs. 6.83 in females) and the low mean number of (MP) the male preanal pores (10.19 vs. 12.50). Furthermore, the members of OTU 1 are relatively smaller than OTU 2.

The members of OTU 1 differ from the members of OTU 3 (*H. jumailiae* sp. nov.) by the high mean number of (VS) ventral scales (42.45 vs. 35.50 in females), the high mean number of (DS) dorsal scales (87.19 vs. 65.50 in males and 85.40 vs. 67.08 in females), the high mean number of (TD) tubercle dorsal scales (15.09 vs. 12.00 in males and 15.47 vs. 12.75 in females), the high mean number of (InG) internasal granules (1.00 vs. 0.50 in males and 1.00 vs. 0.75 in females), the low mean number of (1^{st} Sc) scansors under the first toe (6.25 vs. 7.00 in males), the low mean number of (4th Sc) scansors under the fourth toe (10.19 vs. 11.00 in males) and the high mean number of (MP) male preanal pores (10.19 vs. 7.50).

Since there is only one male specimen in the members of OTU 4 (*H. sinaitus*) the comparison between the members of OTU 1 and OTU 4 will be among the females.

OTU 1 differs from OTU 4 by the high mean number of (VS) ventral scales (42.45 vs. 35.00), the high mean number of (DS) dorsal scales (85.40 vs. 73.00), the high mean number of tubercle dorsal scales (15.47 vs. 14.20), the high mean number of (UL) upper labials (10.37 vs. 8.80 in females), the high mean number of (LL) lower labials (7.83 vs. 7.00), the high mean number of (1st Sc) scansors under the first toe (6.25 vs. 5.00) and the high mean number of (4th Sc) scansors under the fourth toe (10.10 vs. 9.00). In general, the snout-vent-length (SVL) in OTU 1 is higher than OTU 4.

The members of OTU 1 differ from the members of OTU 5 (*H. shihraensis* sp. nov.) by the low mean number of (VS) ventral scales (40.91 vs. 52.50 in males and 42.45 vs. 47.50 in females), the high mean number of (DS) dorsal scales (87.19 vs. 78.00 in males and 85.40 vs. 70.00 in females), the high mean number of (TD) tubercle dorsal scales (15.09 vs. 13.00 in males and 15.47 vs. 14.00 in females) and the high mean number of (MP) male preanal pores (10.19 vs. 6.00).

The members of OTU 1 differ from the members of OTU 6 (*H. saba* sp. nov.) by the high mean number of (VS) ventral scales (40.91 vs. 31.00 in males and 42.45 vs. 30.00 in females), the high mean number of (DS) dorsal scales (87.19 vs. 76.50 in males), the high mean number of (TD) tubercle dorsal scales (15.09 vs. 14.00 in males and 15.47 vs. 14.00 in females), the high mean number of (UL) upper labials (10.31 vs. 8.50 in males and 10.37 vs. 9.00 in females), the low mean number of (1st Sc) scansors under the first toe (6.25 vs. 8.00 in males as well as in females), the low mean number of (4th Sc) scansors under the fourth toe (10.19 vs. 11.00 in males and 10.10 vs. 11.00 in females) and the high mean number of (MP) male preanal pores (10.19 vs. 6.00).

Though there is only one female specimen of the OTU 7, but considerable differences are recognized between OTU 1 and OTU 7 in the high numbers of (DS) dorsal scales (85.40 vs. 63.00), the high numbers of (UL) upper labials (10.37 vs. 8), the high number of (1st Sc) scansors under the first toe (6.25 vs. 5.00) and the high number of (4th Sc) scansors under the fourth toe (10.10 vs. 8.00). The members of OTU 1 differ from the members of OTU 8 (*H. robustus*) in females by the high mean number of (VS) ventral scales (42.45 vs. 37.80), the high mean number of (DS) dorsal scales (85.40 vs. 70.80) and the high mean number of (UL) upper labials (10.37 vs. 8.60).

The new subspecies (*H. yerburii montanus* ssp. nov.) differs from *H. lemurinus* by the distinct character of dorsal tubercle. There are no dorsal tubercles in *H. lemurinus*. Furthermore, the number of male preanal pores is less in *H. lemurinus*.

Etymology. The name of *H. yerburii montanus* ssp. nov. refers to a new subspecies derived from the topographic area (mountains) which seems to be the habitat of the new taxon.

2. *Hemidactylus jumailiae* sp. nov. (OTU 3)

Holotype. Adult male NHM-BS N41891 from, Ibb, (14° 05′ N – 44° 13′ E), Collected by E. Aqlan, 20.11.2007

Paratypes. NHM-BS N41889, N41890, N41893 – N41897 from Ibb; ZFMK 91983, NHM-BS N41900 – N41901 from Sana'a; N41898 – N41899 from Thamar.

Description of holotype. Snout-vent length: 45.11 mm. Tail length: 51.2 mm. Head length: 15.6 mm. Head width: 11.1 mm. Head height: 5.4 mm. Upper labials: 10. Lower labials: 8. Dorsal tubercles are smooth, rows of dorsal tubercles: 12, dorsal scales across mid-body 65. Ventral scales across mid-abdomen 34. Lamellae under fourth toe: 11. Lamellae under first toe: 7. Nostril surrounded by three nasals, rostral and the first upper labial. Without internasal granules. Six preanal pores. Mental large, sub-triangular. Anterior postmental nearly as wide as long, shorter than mental, expanded nearly to the end of second lower labials. Tail is depressed, tubercles on tail rather flat, smooth, rather restricted, arranged in six rows. Dorsal coloration in holotype is light brownish gray, with dusky markings on the head, neck and shoulders; on dorsal side pattern of a series of distinct dark spots is present. On the middle of the tail towards the tip there are distinct dark bands. Ventral side is white.

Description of paratypes. *Hemidactylus jumailiae* sp. nov. (based on twelve Yemeni specimens collected from the high mountains and mountain basins) is a small to medium-sized gecko, with maximum recorded SVL of approximately 47 mm. Head moderately high. Nostril formed by the rostral, boarded by first upper labial and three nasals. 8 – 12 upper labials; 7 – 9 lower labials. Two pairs of post-mentals present, extending from the first lower labial shields into half of the second lower labials. Body depressed, covered with minute rounded granules with numerous small cycloid tubercles intermixed and arranged mostly in 10 – 14 longitudinal rows; 62 – 80 dorsal scales across mid body. Ventral scales rhomboid, imbricate, and lar-

Fig 4. Holotype of *Hemidactylus jumailiae* sp. nov. (OTU 3, scale = 3 cm).

ger than dorsals; 31–42 ventral scales across mid-abdomen. Limbs are rather short and thick. Digital pads moderately expanded; 6–7 lamellae under first toe, 9–12 lamellae under fourth toe. Males with 6 preanal pores. Tail is transverse, almost smooth dorsally, with a few small distinct tubercles; transverse row of eight distinct tubercles; subcaudals uniform.

General dorsal color of most specimens is pale brown to light brownish gray, pattern usually made of a series of distinct brown spots arranged transversely along mid-dorsum. Pair of brown lines on each side of the head extending from the nasals until occipital side. Tail with several dark or light brown bands, occasionally with indistinct brown spots.

Differential Diagnosis

The members of OTU 3 (*H. jumailiae* sp. nov.) can be distinguished from *H. y. yerburii* by the low mean number of ventral scales (35.50 vs. 41.35 in females), the low mean number of dorsal scales (65.50 vs. 91.70 in males and 67.08 vs. 91.30 in females), the low mean number of tubercle dorsal scales (12.00 vs. 15.40 in males and 12.75 vs. 15.30 in females), the low mean number of scansors under the first toe (6.33 vs. 6.83 in females) and the low mean number of the male preanal pores (7.50 vs. 12.50). They differ from the members of the subspecies *H. y. montanus* ssp. nov. by the low mean number of ventral scales (35.50 vs. 42.45 in females), the low mean number of dorsal scales (65.50 vs. 87.91 in males and 67. 08 vs. 85.40 in females), the low mean number of tubercle dorsal scales (12.00 vs. 15.09 in males and 12.75 vs. 15.47 in females), the low mean number of internasal granules (0.50 vs. 1.00 in males and 0.75 vs. 1.00 in females), the high mean number of scansors under the first toe (7.00 vs.6.25 in males), the high mean number of scansors under the fourth toe (11.00 vs. 10.19 in males) and the low mean number of male preanal pores (7.50 vs. 10.19).

The members of OTU 3 differ from the OTU 4 by the low mean number of tubercle dorsal scales (12.75 vs. 14.20), the high mean number of upper labials (10.00 vs. 8.80 in females), the high mean number of lower labials (8.08 vs. 7.00), the low mean number of internasal granules (0.75 vs. 1.00 in females), the high mean number of scansors under the first toe (6.33 vs. 5.00) and the high mean number of scansors under the fourth toe (10.17 vs. 9.00). In general, snout-vent-length in OTU 1 is higher than in OTU 4.

The members of OTU 3 differ from OTU 5 (*H. shihraensis* sp. nov.) by the low mean number of ventral scales (38.00 vs. 52.50 in males and 35.50 vs. 47.50 in females), the low mean number of dorsal scales (65.50 vs. 78.00 in males), the low mean number of tubercle dorsal scales (12.00 vs. 13.00 in males and 12.75 vs. 14.00 in females), the low mean number of internasal granules (0.50 vs. 1.00 in males and 0.75 vs. 1.00 in females) and the high mean number of male preanal pores (7.50 vs. 6.00).

The members of OTU 3 differ from the members of OTU 6 (*H. saba* sp. nov.) by the high mean number of ventral scales (38.00 vs. 31.00 in males and 35.50 vs. 30.00 in females), the low mean number of dorsal scales (65.50 vs. 76.50 in males and 67.08 vs. 80.00 in females), the low mean number of tubercle dorsal scales (12.00 vs. 14.00 in males and 12.75 vs. 14.00 in females), the low mean number of internasal granules (0.50 vs. 1.00 in males and 0.75 vs. 1.00 in females), the low mean number of scansors under the first toe (7.00 vs. 8.00 in males and 6.33 vs. 8.00 in females) and the high mean number of male preanal pores (7.50 vs. 6.00).

There is only one specimen of the OTU 7, but considerable differences are recognized between this probably new species and OTU 7 by the high number of upper labials (10.00 vs. 8), the high number of scansors under the first toe (6.33 vs. 5.00) and the high number of scansors under the fourth toe (10.17 vs. 8.00). The members of *H. jumailiae* sp. nov. differ from the members of OTU 8 (*H. robustus*) in females by the low mean number of tubercle scales (12.75 vs. 15.60) and the high mean number of upper labials (10.00 vs. 8.60). The new species *H. jumailiae* sp. nov. also differs from *H. lemurinus* recorded in the mainland by the distinct character of dorsal tubercles. There are no dorsal tubercles in *H. lemurinus*, furthermore, the male preanal pores are less in *H. lemurinus* than in this new species, and the number of scansors under the fourth toe is lower in the new species.

Etymology. The specific name of *H. jumailiae* sp. nov. refers to Prof. Dr. Masaa Al-Jumaily, Professor of Animal Ecology, Sana'a University, in acknowledgment to her efforts and contributions to the fauna of Yemen.

3. *Hemidactylus shihraensis* sp. nov. (OTU 5)

Holotype. NHM-BS N41911 from Ghail Bawzeer, Hadhramout, (14° 47′ N – 49° 22′ E). Collected by A. Nasher, 15.08.2008.

Paratypes. NHM-BS N41910 from Ghail Bawzeer; N41908, ZFMK 91984 from Al-Shihr.

Description of holotype. Snout-vent length: 48.2 mm. Head length: 15.6 mm. Head width: 10 mm. Head height: 5.7 mm. Upper labials: 10. Lower labials: 8. Rows of dorsal tubercles: 14, strongly keeled; dorsal scales across mid-body 74. Ventral scales across mid-abdomen 54. Lamellae under fourth toe: 10. Lamellae under first toe: 6. Male pores: 6. Nostril surrounded by three nasals, rostral and the first upper labial. Internasal granules separated by one smaller scale. Mental large, sub-triangular. Anterior postmental nearly as wide as long, shorter than mental, expanded to the 2nd lower labials.

Description of paratypes. In general, they are small to medium-sized geckos, with maximum recorded SVL of 48.2 mm. Head moderately high. Nostril bordered by rostral, three nasals and mostly the first upper labials not in contact with upper nasals. 9–10 upper labials; 7–8 lower labials. Two pairs of postmentals present, extending from the first lower labial shields into about the half of the second lower labials. Dorsal scales granular and small, 69–74 dorsal scales; dorsal tubercles large, keeled, arranged in 14 longitudinal rows across mid body. 46–54 ventral scales across mid-abdomen. Limbs are rather short and thick. Digital pads moderately expanded; six lamellae under first toe, ten lamellae under fourth toe. Males with six preanal pores. Tail slender, almost smooth dorsally, with a few small distinct tubercles; transverse row of six tubercles; subcaudals uniform.

The general color of the specimens is pinkish brown to light yellowish brown, with series of regular indistinct brown cross-bars extending somewhat on the dorsum to the end of the tail.

Etymology. The specific name of *H. shihraensis* sp. nov. refers to the occurrence of the new species in Al-Shihr city, Hadhramout Governorate, Republic of Yemen.

Differential Diagnosis of the new species in this group

The new species *H. shihraensis* sp. nov. can be distinguished from the members of OTU 6 (*H. saba* sp. nov.) by the higher mean number of ventral scales (52.50 vs. 31.00 in males and 47.50 vs. 30.00 in females), the higher mean number of upper labials (9.50 vs. 8.50 in males), the lower mean number of scansors under the first toe (6.00 vs. 8.00 in males as well as in females) also the lower mean number of scansors under the fourth toe (10.00 vs. 11.00 in males as well as in females).

Both populations of OTU 5 (*H. shihraensis* sp. nov.) and OTU 6 (*H. saba* sp. nov.) have larger numbers of scansors under the first and fourth toe than the specimen of OTU 7. The single specimen of OTU7 has only five scansors under the first toe and eight scansors under the fourth toe. Furthermore, the number of ventral scales in OTU 7 is lower than the number in OTU 5 but larger than in OTU 6. Moreover, the number of dorsal scales is lower than in both populations of OTU 5 and OTU 6.

The differences among the new species of *H. shihraensis* sp. nov. and the members of OTU 1 (*H. y. montanus* ssp. nov.) and OTU 3 (*H. jumailiae* sp. nov.) were described above.

The members of OTU 5 differ from the OTU 2 (*H. y. yerburii*) by the high mean number of ventral scales (52.50 vs. 41.00 in males and 47.50 vs. 41.35 in females), the low mean number of dorsal scales (78.00 vs. 91.70 in males and 70.00 vs. 91.30 in females), the low mean number of tubercle dorsal scales (13.00 vs. 15.40 in males and 14.00 vs. 15.30 in females) and the low mean number of male preanal pores (6.00 vs.

Fig 5. Holotype of *Hemidactylus shihraensis* sp. nov. (OTU 5, scale = 3 cm).

12.50) (table 10). The members of OTU 5 differ from the OTU 4 (*H. sinaitus*) by the high mean number of ventral scales (47.50 vs. 35.00 in females), the high mean number of scansors under the first toe (6.00 vs. 5.00 in females) and the high mean number of scansors under the fourth toe (10.00 vs. 9.00 in females). Though there is only one specimen of the OTU 7, but considerable differences are recognized between OTU 5 and OTU 7 in the high numbers of upper labials (9.50 vs. 8) and the high number of scansors under the fourth toe (10.00 vs. 8.00). The members of OTU 5 differ from the members of OTU 8 (*H. robustus*) in females by the low mean number of tubercle scales (12.75 vs. 15.60) and the high mean number of upper labials (10.00 vs. 8.60). The new species *H. shihraensis* sp. nov. differs from *H. lemurinus* by the distinct character of dorsal tubercles. There are no dorsal tubercles in *H. lemurinus*, furthermore, the number of scansors under the fourth toe is lower in the new species than in *H. lemurinus*.

The members of OTU 6 (*H. saba* sp. nov.) differ from the OTU 4 (*H. sinaitus*) by the low mean number of ventral scales (30.00 vs. 35.00 in females), the high mean number of dorsal scales (80.00 vs. 73.00 in females), the high mean number of scansors under the first toe (8.00 vs. 5.00 in females) and the high mean number of scansors under the fourth toe (11.00 vs. 9.00 in females). The members of OTU 6 differ from the OTU 2 (*H. y. yerburii*) by the low mean number of ventral scales (31.00 vs. 41.00 in males and 30.00 vs. 41.35 in females), the low mean number of dorsal scales (76.50 vs. 91.70 in males and 80.00 vs. 91.30 in females), the low mean number of tubercle dorsal scales (14.00 vs. 15.40 in males and 14.00 vs. 15.30 in females), the high mean number of scansors under the first toe (8.00 vs. 6.70 in males and 8.00 vs. 6.83 in females) and the low mean number of male preanal pores (6.00 vs. 12.50). There is only one specimen of OTU 7, but considerable differences are recognized between OTU 6 and OTU 7 in the low number of ventral scales (30.00 vs. 41.00), the high numbers of dorsal scales (80.00 vs. 68.00), the high number of scansors under the first toe (8.00 vs. 5.00) and the high number of scansors under the fourth toe (11.00 vs. 8.00).

The members of OTU 6 differ from the members of OTU 8 (*H. robustus*) in females by the low mean number of ventral scales (30.00 vs. 37.80), the low mean number of tubercle scales (14.00 vs. 15.60) and the high number of scansors under the first toe (8.00 vs. 6.20) and the high number of scansors under the fourth toe (11.00 vs. 9.80). The difference of the single specimen of OTU 7 and the other species was described above.

The new species *H. saba* sp. nov. differs from *H. lemurinus* by the distinct character of dorsal tubercles. There are no dorsal tubercles in *H. lemurinus*, furthermore, the number of scansors under the first toe is higher in the new species than in *H. lemurinus*.

Fig 6. Holotype of *Hemidactylus saba* sp. nov. (OTU 6) (scale = 3 cm).

4. *Hemidactylus saba* sp. nov. (OTU 6)

Holotype. Adult male NHM-BS N41912 from Al-Abr, Mareb, (14° 54′ N – 45° 30′ E). Collected by M. Al-Mansoob, 09.02.2008.

Paratypes. NHM-BS N41913 from Al-Abr - N41914 from Al-Mojamma, ZFMK 91985 from Wadi Al-Jufair.

Description of holotype. Snout-vent length: 56.1 mm. Head length: 16.2 mm. Head width: 11.4 mm. Head height: 6.6 mm. Upper labials: 9. Lower labials: 8. Rows of dorsal tubercles: 14, strongly keeled, dorsal scales across mid-body 77. Ventral scales across mid-abdomen 30. Lamellae under fourth toe: 11. Lamellae under first toe: 6. Nostril surrounded by three nasals, rostral and the first upper labial. Internasal granules separated by one smaller scale. Mental large, sub-triangular. Anterior postmental nearly as wide as long, shorter than mental, expanded into the half of second lower labials. Tail is slender, tubercles on tail rather flat, weakly keeled, restricted, arranged in eight rows.

Description of paratypes. *H. saba* is a small to medium-sized gecko, with maximum recorded SVL of approximately 59 mm. Head moderately high. Nostril bordered by rostral, three nasals and mostly the first upper labials in contact with upper nasals. 8 – 9 upper labials; 7 – 8 lower labials. Two pairs of post-mentals present, extending from the first lower labial shields into about the half of the second lower labials. Dorsal scales are granular and small, 76 – 82 dorsal scales; dorsal tubercles large, weakly keeled, arranged in 14 longitudinal rows across mid body. 2 – 32 ventral scales across mid-abdomen. Limbs are rather short and thick. Digital pads moderately expanded; eight lamellae under first toe, 11 lamellae under fourth toe. Males with six preanal pores. Tail slender, almost smooth dorsally, with a few small distinct tubercles; transverse row of eight tubercles; subcaudals uniform.

Basic dorsal color is brownish gray with regular dark bands, sometimes with irregular indistinct dark mottling, extending somewhat to the beginning of the tail. Tail is light brown with indistinct dark bands. The specimens were found during the day on old buildings.

Etymology. The specific name of *H. saba* sp. nov. refers to the area of the Sheba civilization where the new species is located in Mareb Governorate.

Unfortunately, there is only one specimen of OTU 7 collected throughout this study from Radman, but the phylogenetic mitochondrial and nuclear trees and the genetic divergence among the populations in this group confirm the differences among the members of this group (BUSAIS & JOGER, 2011).

Conclusions

This study highlights the extraordinary diversity of *Hemidactylus* in the mainland of Yemen and findings confirm that cryptic species are present in this genus in Yemen. The present study indicates that there are at least nine taxa of *Hemidactylus* recorded in the mainland of Yemen: *Hemidactylus flaviviridis, H. jumailiae* sp. nov., *H. lemurinus, H. robustus, H. saba* sp. nov., *H. sinaitus, H. shihraensis* sp. nov. and two subspecies of *H. yerburii: H. y. yerburii* and *H. yerburii montanus* ssp. nov. The occurrence of *H. sinaitus*

Fig 7. Sole specimen of OTU 7 (scale = 3 cm).

in Aden and Lahj area is due to accidental introduction; this also, may be the case of *H. robustus*. The geckos of *H. jumailiae* sp. nov., *H. saba* sp. nov., *H. shihraensis* sp. nov. may represent endemic species to Yemen. A tenth species (OTU 7) may be distinguishable, but needs further collecting.

Previous records of the Turkish house gecko *H. turcicus* in the mainland of Yemen are inaccurate. This mistake could not be avoided because of the considerable variation in the range of external characters among species as the previous studies on these geckos depended only on morphological characters. Populations that belong to the high altitude could be referring to the new species *Hemidactylus jumailiae* sp. nov. or the subspecies *H. yerburii montanus* ssp. nov., whereas the populations that exist in the lowlands might be referring to the species *H. robustus* or *H. y. yerburii*.

Additional field work is needed in the area of east and north Yemen near the boundary of Oman and Saudi Arabia.

In general, the study of herpetological species in Yemen is far from complete, and more additional field work and molecular studies are necessary to arrive at a more accurate picture of the true status of species in Yemen.

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For all statistical tests, relative measures were taken for morphometric characters (HL, HW, HH, OD, EED and SED) by dividing these characters by SVL.

Appendices

Appendix 1. List of samples deposited in the Natural History Museum, Braunschweig, Germany.

OTU	Species	locality	No. of specimens	Collection No.
1	*H. yerburii montanus* ssp. nov.	Ibb	79	N41751 – 758, 760- 770, 773, 776, 778, 781, 783 – 788, 791 – 794, 797 – 824, 826 – 832, 837, 840, 842, 844, 867, 895 – 6, N42617-8
		Sanaa	4	N41835, N41853 – 5
		Thamar	2	N41759,898
		Wadah	2	N41833 – 4
		Yareem	4	N41771, 775, 780, 795
2	*H. y. yerburii*	Tour Al-Baha	13	N41856-59, 861 – 866, 868 – 870, 888
		Aden	1	N41887
		Ariab	2	N41874 – 5
		Lowder	11	N41876 – 886
		Radfan	2	N41871 – 2
		Shihr	1	N41873
3	*H. jumailiae* sp. nov.	Ibb	8	N41889 – 890, 893 – 897
		Sanaa	2	N41900 – 1
		Thamar	2	N41898 – 9
4	*H. sinaitus*	Lahj	2	N41902 – 3
		Sh. Othman	3	N41905 – 7
5	*H. shihraensis* sp. nov.	Shihr	2	N41908 – 9
		Ghail Ba-Wazeer	2	N41910 – 11
6	*H. saba* sp. nov.	Marib	4	N41912 – 14
7	*H.* sp.	Radman	1	N41916
8	*H. robustus*	Shihr	5	N41917 – 20, 42044

Appendix 2: The results of T-test and Mann-Whitney test (U-test) comparisons among the groups of *Hemidactylus yerburii* from the mainland of Yemen by meristic and morphometric characters. One asterisk marks significance values below 0.05, two asterisks mark significance values below 0.01 and three asterisks mark significance values below 0.001 and (n.s) marks insignificant values which were more than 0.05.

	T-test						U-test					
	OTU 1 vs OTU 2		OTU 1 vs OTU 3		OTU 2 vs OTU 3		OTU 1 vs OTU 2		OTU 1 vs OTU 3		OTU 2 vs OTU 3	
Sex	F	M	F	M	F	M	F	M	F	M	F	M
VS	n.s.	n.s.	***	n.s.	***	n.s.	n.s.	n.s.	***	n.s.	***	n.s.
DS	***	*	***	***	***	***	**	*	***	**	***	*
TD	n.s.	n.s.	***	***	***	**	n.s.	n.s.	***	**	***	*
UL	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
LL	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
In G	*	n.s.	***	***	n.s.	n.s.	*	n.s.	***	*	n.s.	n.s.
1st Sc	***	**	n.s.	*	**	n.s.	***	*	n.s.	*	*	n.s.
4th Sc	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
MP		***		*		**		***		n.s.		*
SVL	**	*	n.s.	n.s.	**	*	**	*	n.s.	n.s.	**	*
Rel. HL	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Rel. HW	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Rel. HH	n.s.	n.s.	*	**	*	**	n.s.	n.s.	*	*	*	*
Rel. OD	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Rel. EED	n.s.	*	*	n.s.	*	n.s.	n.s.	*	**	n.s.	**	n.s.
Rel. SED	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.

Appendix 3: The results of T-test and Mann-Whitney test (U-test) comparisons among the remaining groups of Yemeni *Hemidactylus* clades (OTU 4 vs OTU 8) and (OTU 5 vs OTU 6), by meristic characters in addition to one morphometric character (SVL) for both sexes. One asterisk marks significance values below 0.05, two asterisks mark significance values below 0.01 and three asterisks mark significance values below 0.001 and (n.s) marks insignificant values which were more than 0.05.

	T-test		**U-test**	
	OTU 5 vs OTU 6	OTU 4 vs OTU8	OTU 5 vs OTU 6	OTU 4 vs OTU 8
VS	***	n.s.	*	n.s.
DS	n.s.	n.s.	n.s.	n.s.
TD	n.s.	**	n.s.	*
UL	n.s.	n.s.	n.s.	n.s.
LL	n.s.	n.s.	n.s.	n.s.
In G	n.s.	n.s.	n.s.	n.s.
1st Sc		***	*	**
4th Sc		*	*	*
MP	n.s.		n.s.	
SVL	n.s.	n.s.	n.s.	n.s.