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A new, sibling, tree frog from Jerusalem (Amphibia: Anura: Hylidae)*

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Abstract

A new, sibling, species of tree frog of the *Hyla arborea* group is described from Jerusalem and the adjacent Judean hills. *Hyla heinzsteinitzi* sp. n. differs from the sympatric common *H. savignyi* of the Middle East in head shape, as the head is relatively wider and the snout more truncate; in call structure, as in each segment of its advertisement call the energy peaks abruptly near the segment's onset; and in colouration, as its dark lateral band is highly disrupted. In at least one of the *H. heinzsteinitzi* populations the frogs' green-phase colour is turquoise rather than green. The distinction of the two species is demonstrable by Principal Coordinate Analysis. *Hyla heinzsteinitzi* seems to be endemic to a small area within the range of distribution of *H. savignyi*; here the two are sympatric and at least sometimes apparently syntopic. The ecological relations of the two are unknown. The new species is probably endangered.

Keywords: *Amphibia*, *Anura*, *Hylidae*, *Hyla heinzsteinitzi* sp. n., *H. savignyi*, *Israel*, *sympatry*, *advertisement call*

Introduction

The discovery of a new frog in the herpetologically well-studied Israel (Werner 1988), within a city, Jerusalem, requires explanation of the circumstances. In spring 1996 the first author heard of a bluish tree frog seen in the seasonal Mamilla reservoir in central Jerusalem. He collected there 20 tadpoles and raised them. The adolescents resembled the local *Hyla savignyi* Audouin but differed from it in that the dark lateral band was disrupted (Figure 1) and in the green phase the body colour was turquoise. From these froglets a captive colony was developed. Investigation (Grach, Plessner and Werner, unpublished) verified that this blue phenotype was no exotic introduction (Banks 1985) and no artifact of captive rearing (Love 1994). Subsequently, bioacoustics revealed that the "suspect" population was not new to the area.

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Figure 1. Lateral colour pattern of *Hyla* species, daytime colouration, green phase: Top, *Hyla savignyi*, adult male from the Dor beach, Israel (IG 1425 2234). Note that the dark lateral stripe has a fairly smooth upper border. Bottom, *H. heinzsteinitzi* sp. n., 1-year-old female of the laboratory colony, metamorphosed in the beginning of May 2000 and photographed 16 January 2001. Note that the dark lateral stripe is posteriorly broken into islands and rosettes. The difference in the lateral stripe pattern is not related to sex. Scale: cm and mm.

The structure of advertisement calls from the captive colony differed from that of *Hyla savignyi* in northern Israel (Western Galilee - Schneider and Nevo (1972); Mt. Carmel near Haifa - Brzoska et al. (1982); Bet Oren, Mt. Carmel - Schneider et al. (1984), Turkey (Weber 1976; Kaya and Megela Simmons 1999), or Armenia (Egiasarian and Schneider 1990) but equalled that reported by Shy (1978, 1980, 1985) from two locations in the Judean Hills. Shy's (1978) preserved voucher specimens were found to belong to the suspected new taxon, confirming it as a natural faunal element. A preliminary report (Grach 1998) elicited no informative feedback. A literature search revealed no earlier description of this population. Thereupon the new species is described here; in lieu of comparing it with the non-existent type of *H. savignyi* (see below), it is compared with conventional *H. savignyi* specimens. These were taken mostly from the geographical vicinity of the type material, to exclude confounding from geographical variation.

Material and methods

Abbreviations, terminology and conventions

HUJ-R, Herpetology Collection, the Hebrew University of Jerusalem; MHNL, Muséum d'Histoire Naturelle, Lyon; MTKD, Museum für Tierkunde, Dresden; TAU, Tel Aviv

University; IG, Old Israel Topographical Grid (Palestine 1923 Israel CS), longitude and latitude; (L), left side; (R), right side; L/R, data for left and right sides; R:L, ratio of measure on the right side to that on the left; PERCRA, percents of rostrum–anus length (Werner 1971); RA, rostrum–anus length (Werner 1971).

Morphological abbreviations are given under Morphology. Head shape terminology follows Duellman (1970). Webbing formula follows Myers and Duellman (1982, p. 6 footnote).

Bioacoustic terminology is not standardised (Duellman 1970). Following Shy (1985) the complete “song” of the tree frog is termed here “call”, and each of its sequential, near-repetitive, units, a “segment” (=“note” of Duellman (1970); “call” of Schneider et al. (1984); “chirp” of Balletto et al. (1985); “pulse group” of Egiasarian and Schneider (1990)).

Material examined

The material of the new taxon used for measurements ($n=13$) is listed within its description. Additionally, the colouration was studied in 60 live young adults (siblings) of the laboratory colony. The statistical control material of *Hyla savignyi* ($n=9$) comprised HUI-R 9398–9401, 9403–9404 Water reservoir at Bet Zayit near Moza, Judean Hills, 15 March 1959, H. Steinitz; HUI-R 15137 Nahal Samakh, Golan, 21 July 1974, M. Tintpulver; HUI-R 15318 Jericho, January 1979, Y. L. Werner et al.; HUI-R 15681 ‘Ein Fara, Wadi El Qilt, Judean Desert, 1976–77, E. Shy. Also examined were MHNL 42003700 ($n=3$) from “Lac de Houleh, Syrie, Mission Lortet, 1880”, and colour diapositives of six adults from assorted Israeli localities. The following material was inspected for comparison: *H. arborea arborea* from Bulgaria ($n=18$, MTKD 16591–596, 17389–397, 17399–401); *H. arborea schelkownikowi* from Armenia ($n=5$, MTKD-D 12059, 12062, 12066, 12070, 12073) and *H. savignyi* from Cyprus ($n=25$, HUI-R 20207–213; MTKD 18591–18603, 18605–606, 15608–610), Lebanon ($n=3$, HUI-R 15776–778), and Turkey ($n=4$, MHNL 42003701 [$n=2$]; MTKD 25225, 33909). For determining geographical distribution(s) in Israel, the whole material of *Hyla* from Israel in HUI and TAU ($n=183$) was examined.

Osteology

After experimentation with protocols of clearing and staining formalin-fixed, ethanol-stored, museum specimens, the following sequence was used: skinning; dehydration successively in ethanol 70, 96, 100 and 100% for 1–2 h each (fluid volume 30 times the body volume, in these and later solutions); rinsing in 0.5% KOH for 1 h, twice; in fresh 0.5% KOH adding H_2O_2 up to 3% gradually to avoid bubbles, and waiting to achieve depigmentation; enzyme solution (1 g trypsin in 30 ml saturated borax solution and 70 ml water) until the preparation becomes transparent (three weeks did not suffice); 5% KOH for 16 days (including twice changing the solution). When the bones are clearly visible, 0.5% KOH with alizarine-red, for 24 h, with agitation; rising series of glycerol 1:3, 1:1, 3:1, pure, at least 24 h in each; storage in glycerol with a thymol crystal.

Because of the scarcity of type specimens, clearing and staining was only applied to three control specimens of “normal” *Hyla savignyi* (HUI-R 9627, 20694, 20695), whereas the single adult type specimen of the new species was radiographed.

Morphology

The following 25 mensural characters (Figure 2), were taken with calipers to nearest 0.1 mm (for the smaller sizes under a dissecting microscope); bilateral characters were examined on both sides: Rostrum–anus length (RA – Werner 1971); head length, to angle of jaw (HLj); head length, to posterior border of tympanum (HLt) (HLj and HLt were measured parallel to the long axis of the body using the modified calipers of Goren and Werner (1993)); head width (HW); inter-nostril distance (IND); inter-orbital space where the eyes bulge mediad (IOM), between the anterior corners of the eyes (IOA), and between the posterior corners (IOP); horizontal eye diameter (ED); horizontal tympanum diameter (TD); distance nostril–lip (NL); distance eye–snout (ES, measured parallel to the long axis of the body, as above); distance eye–nostril (EN); distance eye–tympanum (ET); distance tympanum–lip (TL); forearm length (FA); femur length (FM); tibia length (TB); tarsus length (TR); fourth toe length (T4); first toe length (T1); callus internus (metatarsal tubercle) length (C); extent of webbing between the third and fourth toes (W); width of digital disk of third finger (DD3); width of digital disk of fourth toe (DD4).

All values were transformed to PERCRA. Additionally the following five proportions were calculated: HW:HLj; TD:ED; ES:EN (L/R); T1/T4; W:T4 (L/R). Finally, as a further test of asymmetry, the ratio R:L was calculated for the ratio ES:EN (ES:EN, R:L), for tibia length (TB, R:L), and for the ratio W:T4 (W:T4, R:L).

Colours were defined according to Kornerup and Wanscher (1978). The dark lateral band was assessed in terms of five arbitrary qualitative categories, from 0 (no breaks) to 4 (wholly composed of dots), with intermediate categories as needed. Each body side was evaluated separately, and the two sides were averaged for the individual's score.

Bioacoustics

Advertisement calls were recorded by Shy (1978, 1980, 1985) from 10 males from near Moza, Judean Hills, and Wadi El Qilt, Judean Desert, as detailed below for the type material. The method involved recording from single males in a wood-and-fly-screen cage inside an anechoic chamber. The frog was stimulated to call by playing to it a recorded conspecific call from a UHER T22 tape-recorder. Calls were recorded by an AKG-D9 DHC dynamic microphone and a Nagra III tape-recorder (at 19 cm/s), then graphed by a Kay Vibralyzer 7030A and analysed statistically from manual measurements.

Calls from the newly discovered Mamilla-reservoir population, presented here, were recorded by Grach in February–March 1998 using a Sony-5000-EV cassette recorder (at 4.75 cm/s). Males in a plastic-mesh cage were stimulated to call by the observer's vocal imitation of a tree frog call. A sample that was digitised by the Bat Sound Pro 3.31 program, at 8 bit, Mono, and 11025 samples per second, is accessible as supplementary material to this article and will also be deposited on Amphibiaweb and in the British Library Sound Archive.

Recently calls from both sources were analysed with the CSL (Computerized Speech Lab, Model 4300B) program for computerised sound analysis of the Kay Elemetrics Corporation, in the Laboratory of Musicology, the Hebrew University of Jerusalem. Single segments of these are depicted here.

Figure 2. Pictorial definitions of the measurements taken.

Statistics

Multivariate statistics. Principal Coordinate Analysis (PCO) based on Standardised Euclidian, using the multivariate statistical package of Kovach Computing Services (MVSP). All measurements were normalised for RA size.

Bivariate statistics. Measurements were compared between samples in terms of PERCRA or sometimes a ratio between two characters. The significance of the differences between the samples was tested by two-tailed *t*-test for equal variances, based on Levene's test for equality of variances. Within each tentative taxon, first the bilateral characters were tested for directional asymmetry (Werner et al. 1991) and if the presence of such was indicated, left- and right-side characters were treated separately. Otherwise the average of left and right sides served for further computations. Next, characters were tested for sexual dimorphism; in its nearly complete absence (see below), the sexes were pooled for the inter-taxon comparisons.

Synonymy

Listed are only the main references necessary to document and illustrate the history of names applied to the relevant population, either expressly or by clear implication. As will be explained below, the description of *Hyla savignyi* (Audouin "1809" [1827], 1829) did not concern the new species.

Description of the new species***Hyla heinzsteinitzi* sp. n.**

(Figures 1 and 3)

Hyla arborea (Linnaeus, 1758) (part): Tristram 1885, pp.160–161; Lulav 1978, p.431; Fishelson 1979, p.327.

Hyla arborea var. *savignyi* Audouin, "1809" [1827], p.183; 1829, pp.137–138 (part): Boulenger 1882, p.380; 1898, pp.250–251; Anderson 1898, pp.357–358.

Hyla arborea savignyi Audouin, 1827 (part): Flower 1933, pp.843–844; Bodenheimer 1937, p.73; Aharoni p.1940, p.56; Mendelssohn and Steinitz 1944, p.294–295.

Hyla arborea savignyi Audouin, 1827: Shy 1980, 1985.

Hyla savignyi (part): Bodenheimer 1935, p.199; Schneider and Nevo 1972; Werner 1988, p.359, 1995, pp.12–15; Bouskila and Amitai 2001, pp.32–34; Disi et al. 2001, pp.97–98.

Type series

Holotype. HUI-R 20193, female, Mamilla reservoir, IG 1710 1317, Jerusalem, Israel, spring 1996, C. Grach (collected as tadpole, raised in captivity, died accidentally when two years old).

Paratypes (*n*=12). HUI-R 15186, 15188–15190, 15192, 15194 males, Wadi near Moza, Judaeen Hills at IG 1658 1353, April 1977, E. Shy; HUI-R 15193 male, Ein Fara, Wadi El Qilt, Judaeen Desert, IG 1789 1378, approx. 300 m a. s. l., October 1976, E. Shy; HUI-R 15187 male, 15185, 15191 females, either of the previous two locations; HUI-R 20198 female, 20199 male, captive bred spring 2000, from parents collected as tadpoles from the

Figure 3. Lateral views of heads showing snout shape (from photographs, reproduced at equal image size): (A) *Hyla heinzsteinitzi* sp. n. male HUI-R 15192. (B) *H. heinzsteinitzi* female HUI-R 15191. (C) Sympatric *Hyla savignyi* male HUI-R 9400. (D) Allopatric *H. savignyi* female, HUI-R 15318. (Specimen details in the text.)

Mamilla reservoir (IG 1710 1317, Jerusalem, Spring 1996, C. Grach) and raised in captivity.

Differential diagnosis

A tree frog of the *Hyla arborea* group differing from all others in the structure of the call, in which the energy amplitude has a short rise time and a much longer decay time. Morphologically its snout has a truncate, rather than round, profile; the dark lateral stripe, visible in daytime along the flank, lacks the inguinal branch of *H. arborea* and is strongly fragmented. The white stripe along the lips is greatly reduced, anteriorly absent. Apparently endemic to the Judaeen Hills, *H. heinzsteinitzi* differs from sympatric *H. savignyi* (values in parentheses) especially in the shorter eye–snout distance, <8 PERCRA (>9 PERCRA) with greater nostril–lip distance, approx. 7 PERCRA (approx. 6 PERCRA); wider inter-orbital space, at minimum >25 PERCRA (<23 PERCRA); and somewhat coarser feet, with longer callus internus, >4 PERCRA (<4 PERCRA) and larger digital discs, that of the third finger approx. 4 PERCRA (approx. 3 PERCRA).

Description of the holotype

Adult female. The radiograph showed the following skeletal characters which are typical of the Hyliidae (Nieden 1923) and were identical in three cleared and stained control specimens, Israeli *H. savignyi*: vertebrae procoelous, no free ribs, sacral transverse process

broad, urostyle connected with two joints, all fingers and toes with the terminal phalanx claw-like.

External morphology. Head distinctly wider than long, snout acutely rounded in dorsal view, moderately truncate in profile; top of head flat (between nostrils and between eyes); nostril vertically elliptical, facing laterad; eye much larger than tympanum, protruding, pupil horizontal, supratympanic fold distinct, starting at the eye, extending caudad to behind axilla; upper jaw toothed, palate toothed; body and limbs without skin folds; skin of dorsum smooth, of venter glandular (granular), of throat intermediate; heels of adpressed hindlimbs meet or overlap by up to half the diameter of the eye; all fingers and toes with terminal digital pads; only the feet webbed, with thin webs between toes 2–5, webbing formula **II** 3-2 **III** 3-1 **IV** 1-2 **V**.

Measurements. In mm (PERCRA) and where relevant left/right: ra 44 mm; HLj 10/9.7 (22.7/22.05); HLt 10.8/10.1 (24.5/22.05); HW 13.7 (31.1); IND 2.9 (6.6); IOM 10.5 (23.9); IOA 7.9 (17.9), IOP 11.5 (23.1); ED 4.6/4.5 (10.4/10.2); TD 2.7/2.5 (6.1/5.7); NL 3.4/3.4 (7.7/7.7); ES 3.6/3.4 (8.2/7.7); EN 3.8/3.5 (8.6/8.0); ET 1.3/1.4 (3.0/3.2); TL 1.7/1.5 (3.9/3.4); FA 9.7/10.5 (22.05/23.9); FM 20.1/20.8 (45.7/47.3); TB 19.5/19.5 (44.3/44.3); TR 10.8/10.4 (24.5/23.6); T4 16.8/16.6 (38.2/37.7); T1 4.4/4.4 (10/10); C 1.9/1.7 (4.3/3.9); W 9.5/9.1 (21.7/20.7); DD3 1.6/1.8 (3.6/4.1); DD4 1.7/1.4 (3.9/3.2).

Proportions. HW:HLj=1.37/1.41; ES:EN=0.95/0.97; TD:ED=0.59/0.55; T1:T4=0.26/0.26; W:T4=0.57/0.55.

Colouration in preservative. Generally grey. Upper lips only indistinctly and posteriorly with light stripe. Dark, somewhat brownish, lateral stripe, its upper and lower margins emphasized, extending from behind eye (above tympanum) to just behind axilla, more posteriorly represented by indistinct, interrupted, fragments of irregular shape; flanks and posterior half of dorsum with small roundish dark spots in lighter halos; small dark dots pepper the tibiae. Ventral side “off-white”.

Variation and comparisons

The qualitative morphological description holds true for the type series. In the control *H. savignyi* specimens the snout is less truncate, more rounded (Figure 3).

Principal Coordinates Analysis (Figure 4), based on 14 mensural characters marked in Table I, displayed two fairly distinct clusters when the individuals were identified by snout shape.

The mensural characters and their variation are compared in Table I with those of the control sample of sympatric *H. savignyi*. Both samples showed little asymmetry: in *H. heinzsteinitzi* the tympanum–lip distance was greater on the R ($P=0.05$), and the toe webbing greater on the L ($P=0.03$); in the control *H. savignyi* sample the ratio eye–snout: eye–nostril was greater on the R ($P=0.02$). These characters are treated in Table I separately for the R and L sides. Sexual dimorphism was significant only in the control *H. savignyi* sample: the distances nostril–lip and eye–snout were greater in the males ($P=0.02$, $P=0.01$ respectively). For practical purposes we show in Table I the variation of all characters within and between the two taxa, after pooling the sexes. In Israel there seems to be no sexual size difference in *H. savignyi*: the largest of 44 males measured 49.0 mm and

Figure 4. Principal Coordinates Analysis (see text). Triangles, specimens with truncate snout profile, later assigned to *Hyla heinzsteinitzi* sp. n.; circles, specimens with round snout profile, later assigned to *Hyla savignyi*, from the area of sympatry.

the largest of 31 females 48.6 mm (Berger, Seligmann and Werner, unpublished). However, this seems to vary geographically: in Arabia, among 129 specimens, the largest male measured 42.0 mm and the largest female 47.5 (Balletto et al. 1985).

The colouration in most preserved specimens is rather faded. Yet in the *H. savignyi* sample the upper lips are consistently and conspicuously marked by a light or white stripe all around; in *H. heinzsteinitzi* this stripe is indistinct and limited to the posterior part of the lip.

Live frogs change colour through the diel cycle. In daytime the dark lateral stripe is distinct; at night it pales and may disappear. Additionally daytime colouration can change between green and various shades of brown and grey, with or without spots. The night colouration seems to vary with temperature, towards green when cold and brown when warmer. The ontogenetic development of these capacities for colour change seems to be completed only four months after metamorphosis (in captivity; in nature presumably at least six months). The following comments are based on the green phase of daytime colouration of frogs at least eight months old (see Material for description of samples).

In the *H. heinzsteinitzi* sample originating from the Mamilla reservoir the general body colour resembled turquoise A-5 or A-6 on p. 25 (Kornerup and Wanscher 1978) and this accorded with the notes taken four years earlier of the parent generation. In contrast, the control animals and photographs of *Hyla savignyi* approximated B-7, B-8, C-7 or C-8 on p. 29, apple-green. The hidden parts of the legs, especially thighs, were orange in *H. heinzsteinitzi* and brown in *H. savignyi*.

Table I. Mensural characters of *Hyla heinzsteinitzi* sp. n. (N=13) and sympatric *Hyla savignyi* (N=9). In the list of characters, PCO marks those used in the principal coordinate analysis. All values in PERCRA except as noted. P, significance of the difference between the taxa; ***, $P \leq 0.001$; **, $P \leq 0.01$; *, $P \leq 0.05$; (*), $P = 0.07$.

	<i>Hyla heinzsteinitzi</i> sp. n.			<i>Hyla savignyi</i>			P
	Mean	SD	Range	Mean	SD	Range	
Rostrum–anus, maximum, mm			45.7			46.4	
Head length, incl. Jaw (PCO)	25.09	2.10	21.6–28.6	25.88	1.39	23.4–28.5	n.s.
Head length, incl. tympanum	24.47	1.69	21.8–29.0	24.68	1.67	22.6–28.4	n.s.
Head width (PCO)	31.83	3.92	19.8–36.4	30.39	1.14	28.8–32.4	n.s.
Head width: head length	1.28	0.17	0.8–1.5	1.18	0.43	1.0–1.3	n.s.
Inter-nostril space	7.07	0.90	6.0–8.8	6.55	1.34	5.3–9.3	n.s.
Inter-orbital space, anterior (PCO)	18.89	1.52	16.9–23.2	16.82	1.63	13.8–19.3	**
Inter-orbital space, minimal (PCO)	25.51	1.50	23.8–29.1	22.28	0.99	21.0–23.9	***
Inter-orbital space, posterior (PCO)	27.70	1.71	25.6–32.1	25.62	1.40	23.9–27.8	**
Nostril to lip (PCO)	7.05	0.79	5.2–8.1	6.01	0.53	5.4–6.9	**
Eye to snout (PCO)	7.67	1.28	5.1–9.9	9.54	1.00	8.1–10.7	***
Eye to nostril	7.99	0.96	6.9–10.4	7.93	0.52	7.2–8.6	n.s.
Eye diameter	10.39	0.75	8.8–11.3	10.00	0.70	9.1–11.0	n.s.
Eye to tympanum (PCO)	3.66	0.57	2.8–5.1	2.77	0.36	2.3–3.4	***
Tympanum diameter	5.59	0.49	4.8–6.5	5.89	0.53	5.2–6.5	n.s.
Tympanum:eye (diameters) (PCO)	0.54	0.05	0.5–0.6	0.59	0.03	0.6–0.7	*
Eye–snout:eye–nostril, R (PCO)	1.00	0.21	0.7–1.3	1.29	0.11	1.2–1.5	***
Eye–snout:eye–nostril, L (PCO)	0.93	0.15	0.7–1.3	1.12	0.14	0.9–1.4	**
Tympanum to lip, R	3.77	0.77	2.4–5.3	3.39	0.58	2.3–4.6	n.s.
Tympanum to lip, L	3.21	0.70	2.2–5.0	3.37	0.73	2.2–4.3	n.s.
Forearm length	22.66	1.43	19.9–24.5	22.36	0.88	21.5–23.3	n.s.
Femur length	46.57	3.25	41.8–53.1	48.05	5.42	41.4–57.9	n.s.
Tibia length	48.32	3.89	42.8–58.1	48.25	3.09	43.7–53.9	n.s.
Tarsus length	25.76	1.97	22.7–30.5	25.91	1.42	23.6–28.4	n.s.
Callus internus length (PCO)	4.33	0.34	3.3–4.8	3.77	0.33	3.2–4.1	***
Toe 4 length	38.33	4.23	28.4–47.5	38.95	2.78	34.5–42.7	n.s.
Toe 1 length	10.81	2.34	9.3–18.4	10.13	1.13	8.2–11.6	n.s.
Digital disc, finger 3 (PCO)	3.86	0.38	3.3–4.5	3.07	0.31	2.7–3.7	***
Digital disc, toe 4 (PCO)	3.12	0.45	2.6–3.9	2.65	0.49	1.9–3.3	*
Webbing depth (btw. toes 3&4)	21.56	1.47	18.9–24.2	21.85	1.77	19.4–24.4	n.s.
Webbing: toe 4, R	0.53	0.03	0.5–0.6	0.56	0.03	0.5–0.6	n.s.
Webbing: toe 4, L	0.58	0.07	0.5–0.8	0.56	0.03	0.5–0.6	n.s.
Toe 1: toe 4 (lengths)	0.28	0.05	0.2–0.4	0.26	0.02	0.2–0.3	n.s.
Eye–snout: eye–nostril, R:L	1.08	0.18	0.8–1.4	1.17	0.22	0.9–1.5	n.s.
Tibia length, R:L (PCO)	1.19	0.19	0.9–1.4	1.03	0.20	0.8–1.5	(*)
Webbing: toe 4, R:L	0.96	0.07	0.8–1.1	0.98	0.03	0.9–1.0	n.s.

The dark lateral band score of the *H. heinzsteinitzi* sample (see Material) ranged over 3–4 (completely represented by dots), with the median at 4. Thus it was generally fragmented. Often it resembled a broad belt of irregular spots, sometimes cloud-like, sometimes rosette-like. For the *H. savignyi* control sample the score ranged over 0–2, with the median at 1.75, nearly complete (Figure 1). In Arabia, according to the text of Balletto et al. (1985), the dark lateral band is complete to the groin but according to their photographs its ventral border tends to be “washed out” behind the axilla, and at least in one individual the band is a little fragmented in the groin.

In Israel our individuals of both samples scored symmetrically for the dark lateral band, except one in which the sides differed by one half-unit. Interestingly, in the sample from Cyprus, 11/25 specimens were asymmetrical in this respect. In a larger sample of 75 *H.*

savignyi from Israel the lateral band was variable, in nine it had a partial inguinal branch bilaterally (in one or two fairly complete) but in eight this branch was unilateral. The occurrence of the inguinal branch was not correlated with morphometry and could not be defined geographically (Berger, Seligmann and Werner, unpublished).

There is also a difference in the spotted phase. While in local *Hyla savignyi*, as in *H. arborea*, the background of grey, brownish, or yellowish may be spotted with darker or lighter blotches (Boulenger 1897–98; Nielsen 1980; Engelmann et al. 1993; Özeti and Yılmaz 1994; YLW pers. obs.), in *H. heinzsteinitzi* there exists an additional colouration, not known to us from local *H. savignyi*: brown (rust-brown, golden-brown) background, with green blotches.

Bioacoustics

The advertisement call of *Hyla heinzsteinitzi* resembles the published calls of *H. savignyi* and *H. arborea* in that it comprises a sequence of similar, evenly spaced, segments. Shy (1985) found from 10 males that at 22–28°C call duration averaged 4.02 s (range 1.7–6.7), segment duration averaged 100.1 ms (92–125), and segment repetition rate averaged 3.67 segments/s (2.9–4.2).

However, segment structure conspicuously and consistently differs among the three species (Figure 5). In *H. heinzsteinitzi* (in both projects) each segment had its energy peak near its temporal beginning, whereas in *H. savignyi* the segment's rise and fall times are similar, energy being high throughout its middle, and in *H. arborea* segment energy gradually rises to peak near the segment's end (Figure 5). The latter applies also to *H. sarda* (Schneider 1977) while the segment shape of *H. meridionalis* is intermediate between those of *H. arborea* and *H. savignyi* (Schneider 1977).

Field notes

The type locality is interesting historically and ecologically. The Mamilla reservoir is a $97 \times 65 \times 6$ m (deepest point) cistern excavated in limestone and faced with limestone masonry (Figure 6). Allegedly dating back to the Roman period, second to third century A.D. (Martens & Jelden 1992), it is documented (Arabic: Mamala) from the year 614 A.D. (Tsafrir and Safrai 1999, pp. 255, 236, 340). Dry in summer, it is annually filled by winter rains to varying extent, modulated by its sloping bottom. In recent decades its newly elevated rim prevents its filling by direct rain runoff; water enters from the soaked earth through crevices in the walls (Ortal 1997). Its history and ecology are briefly reviewed in Martens and Jelden (1992).

Translated excerpts from the collector's notes (Shy 1978): "Ein Fara in the Judean desert is a spring-fed pool (Figure 7). The ample vegetation is dominated by *Typha australis*. In October 1976, on several occasions, tree frogs were sitting adpressed on the *Typha* stalks, vertically, head up, during 0900–1100 h and again around 1600 h. Their green colour with the dark flank merged well with the cattail. In earlier morning hours and in mid-day hours I saw none but due to their camouflage it is not sure that they were absent".

"The Wadi at Moza: in April 1977 water depth exceeded 1 m and the vegetation, ample and tangled, was dominated by *Rubus sanctus*. Tree frogs sat on this spiny bush. During 0900–1200 h, visual detection being difficult, I stimulated males to call by playing tree frog calls recorded in nature (Jerusalem), in 1970, at 19°C. Two males answered and one was

Figure 5. Oscillograms of representative segments from advertisement calls of assorted *Hyla* populations, in approximate geographical order from west to east and to south, all at the same time scale. Sources are indicated in parentheses. (A–E) *Hyla arborea*. (A) *Hyla a. arborea*, near Tübingen, Germany (Schneider 1967). (B, C) *Hyla a. kretensis*, near Chania, Crete (Schneider 1974): (B) at 8°C; (C) at 22°C. (D) *Hyla arborea*, Western Anatolia (Schneider, 2000) at approx. 19°C (according to Figure 5). (E) *Hyla a. schelkownikowi*, Dilijan, Armenia (Egiasarian and Schneider 1990), approx. 12–13°C. (F–H) *Hyla savignyi*. (F) Anamur, Turkey (Kaya and Simmons 1999) at 12°C. (G) Armenia (Egiasarian and Schneider 1990) at 16–17°C. (H) Sa'ar, Israel (Schneider and Nevo 1972) at 23°C. (I–K) *Hyla heinzsteinitzi* sp. n. (I) 'Ein Fara, Judean Desert, Israel (Shy's recording) at 23°C. (J) Moza bridge, Judean Hills, Israel (Shy's recording) at 22–23°C. (K) Jerusalem, Israel (Grach's recording) at 17°C.

caught, its colour green. The same day around 1700 h, no males answered the played calls. But about 30 min after sunset a few calls were heard and gradually a large chorus assembled. To catch a male I would enter the water, deliver the stimulus call, approach the source of the answer in darkness, dazzle the male with torchlight, and catch it calling. All seven males caught were sitting on bush leaves close to the water, facing it. During call emission they erected the forelimbs, contracted the body, and inflated the vocal sac; pausing, they contracted the vocal sac and inflated the lungs”.

Distribution and conservation

So far *H. heinzsteinitzi* is documented only from the three Judean Hills localities from which the type series originated, within a west–east stretch of 13 km and a north–south

Figure 6. The type locality of *Hyla heinzsteinitzi* sp. n.: Mamilla reservoir, April 1951.

extent of 6 km (Figure 8). The Mamilla reservoir (IG 1710 1317) and the Wadi near Moza (IG 1658 1353) lie within the Mediterranean region (*sensu stricto*) with average annual precipitation of 500–700 mm, and average annual temperatures of 17–19°C. The third locality, Ein Fara (IG 1789 1378), is an oasis-like spring habitat on the fringe of the Judean Desert, with average annual precipitation fluctuating widely around 300 mm, and average annual temperatures around 19–21°C. In this area there is a steep transition between the mesic and desert zones, as travelling from Jerusalem east towards the Dead Sea, over an arial distance of 25 km, one passes through belts representing the Mediterranean, Irano-Turanian, Saharo-Arabian and Sudanian Regions (maps in Werner 1987, 1988).

Apparently *Hyla heinzsteinitzi* is sympatric with *H. savignyi* and in some places the two are apparently syntopic. *Hyla savignyi* ranges widely from Turkey, Transcaucasia and northwestern Iran over Syria and Lebanon to central Jordan and Israel and the southwestern Arabian Peninsula (Balletto et al. 1985; Baran and Atatür 1998; Kuzmin 1999; Tarkhnishvili and Gokhelaashvili 1999; Disi et al. 2001); it occurs marginally in northern Sinai (Adel Ibrahim, unpublished; Saleh 1997).

In Israel the distribution of amphibians was mapped by Mendelssohn and Steinitz (1944), Wahrman (1956) and Gerchman and U. Werner (1990). Because these authors could not have distinguished the two species of *Hyla*, a map of *H. savignyi* locality records is presented here besides that for *H. heinzsteinitzi*.

The tiny range of *H. heinzsteinitzi* and its possible constraint to isolated sites significantly endanger it. Unfortunately, this danger seems aggravated by the lack of interest of the national conservation authority.

Figure 7. Collection site of some of the paratypes of *Hyla heinzsteinitzi* sp. n.: 'Ein Fara, Wadi El Qilt, Judean Desert, 19 February 1977.

Etymology

The species is named for the late Heinz Steinitz, 26 April 1909–28 April 1971, Professor and Curator of Fishes at the Hebrew University of Jerusalem, in recognition of his contribution to the knowledge, and thus conservation, of the amphibians of Israel (Clark 1971).

Discussion

Validation of taxonomic status

The distinction of *Hyla heinzsteinitzi* rests most soundly on its advertisement call, which differs from all those reported from *H. savignyi* and *H. arborea* ssp. *sensu lato*. As shown

Figure 8. Map of locality records of *Hyla* spp. in Israel (from specimens in HUJ): solid triangles, *Hyla heinzsteinitzi* sp. n. (only in the enlarged inset); solid circles, *H. savignyi*; open squares, towns for orientation.

above, the time course of energy during each segment differs as much between *Hyla heinzsteinitzi* and the sympatric *H. savignyi* as between the latter and the parapatric *H. arborea*. These differences hold true despite temperature effects (Schneider 1974; Balletto et al. 1985) and regardless of call function, whether courting (mating) or territorial (Schneider 1967, Schneider and Nevo 1972). Remarkably, the call of *H. arborea* varies geographically so that in the west, far from *H. savignyi*, the segment is least different from the segment of the latter (Figure 5), raising the possibility of acoustic character displacement. Interestingly, the same three shapes of call segments (besides others) occur among sympatric congeners of Hylidae in Bolivia (Marquez et al. 1993). Other features of the calls, which are more susceptible to temperature effects and equipment qualifications, remain to be properly explored, although partly presented by Shy (1985).

The morphological distinction is decisive in several characters (Differential diagnosis; Table I) and visualised by Principal Coordinate Analysis (PCO). In the PCO we used PERCRA values of adult individuals. In some cases, the samples' allometry parameters, slope and intercept, compensate for each other, and this technique may cause a type II error (false acceptance of the null hypothesis), but it is unlikely to cause a type I error (false rejection of null hypothesis) (H. Seligmann, personal communication). However, the morphological distinction is complex in that *Hyla heinzsteinitzi* differs in snout profile from

sympatric *H. savignyi* but the difference from allopatric *H. savignyi* may be less clear (Figure 3). Character displacement is difficult to test here because, as remarked by Kuzmin (1999, p. 290), variability in the wide-ranging *H. savignyi* has not been sufficiently explored. An Israel-wide exploration of allozyme variation in *H. savignyi* (Nevo and Yang 1979) found the intra-population variation in Jerusalem apparently lower than expected, which may accord with character displacement. However, recent and ongoing research (Zaloglu 1972; Kaya 2001; Gvozdk 2003; Gvozdk and Moravec 2003) may soon enable a conclusion.

The disruption of the dark lateral stripe in *Hyla heinzsteinitzi* and its representation by a broader band of assorted irregular small spots differs from the smooth stripe (at least, its upper border) of sympatric *H. savignyi* just as much as the latter, through lack of inguinal loop of the lateral stripe, which differs from *H. arborea*. The colouration of the hidden thigh area, orange in *Hyla heinzsteinitzi* but brown in *H. savignyi*, is also distinctive.

The turquoise daytime colouration of the *H. heinzsteinitzi* individuals from the Mamilla reservoir was not noted in the earlier individuals from the other localities. It seems to be a local mutation rather than characterising the species. Occasional blue mutants (lacking the yellow pigment in the skin) occur in frog populations (Smith 1954, p. 141; Hofstra 1997; Hoffman and Blouin 2000), including *Hyla japonica* (Nishioka and Ueda 1985).

Colour is a difficult taxonomic character in the *Hyla arborea* group. Hylids physiologically change their colour between day and night, at night some species being paler but others darker (Duellman 1970, p. 33). The diel variation described here constrains the use of colour in identification. Additionally, the Middle Eastern and European tree frogs show physiological hue changes in daytime, over green, grey and brown, sometimes with dark or light spots, and occasionally blue (Werner 1890; Boulenger 1897–98; Schreiber 1912; Nielsen 1980; Engelmann et al. 1993; Özeti and Yilmaz 1994). This has been described by several authors as if it reflected individual genetic variation: “Two distinct color phases occur, the green and brown phases” (Saleh 1997); “Colour: camouflage colours, especially green, brown and grey [our translation]” (Bouskila and Amitai 2001, p. 32); “Dorsal colour is bright green, sometimes brownish...” (Disi et al. 2001, p. 97).

In summary, in order to avoid any confounding effects of geographical variation, the formal statistical comparison of *Hyla heinzsteinitzi* sp. n. with *H. savignyi* has been limited to a sympatric (and therefore small) sample of the latter. Hence the manifoldly distinct population of *H. heinzsteinitzi* clearly is a local sibling species and not an extreme variant of *H. savignyi*. Moreover, enough information from other *H. savignyi* populations is quoted, to show the generality of the distinction.

Validation of nomenclature

Because the original “*Hyla savignyi*” now comprises two taxa, the question arises which of the two had been described by Audouin (1827, 1829) in the Description de l’Égypte. (The date of the relevant first text volume of the first edition of this work is usually, but not always, considered 1827 [Bour, pers. comm.]. The book is marked 1809 [Gvozdk pers. comm.] and this has been accepted by Munier [1943] and Monglond [1957] but in 1809 Audouin was 12 years old [Bour pers. comm.].) As apparently no type specimen exists (Anderson 1898) Savigny’s drawing (dated as prepared during 1805–1812; reproduced in

Anderson (1898)) represents the holotype (Bour pers. comm.). This drawing shows an entire lateral band, lacking the inguinal branch characterizing *Hyla arborea*, depicting “conventional *Hyla savignyi*” rather than the new taxon. The probable type locality is compatible with this interpretation. Audouin (“1809” [1827], p. 183; 1829, pp. 137–138) detailed no type locality and this has misled many to assume that *H. savignyi* occurs in Egypt (e.g., Boulenger 1898; Kuzmin 1999; Tarkhnishvili and Gokhelašvili 1999) although it does not (Anderson 1898; Flower 1933) except for Rafah on the northeastern frontier of Sinai (Saleh 1997; A. Ibrahim, unpublished). Flower (1933) restricted the type locality, saying ‘Type-locality. - “Syria.” ... Audouin’s specimen was probably brought from Palestine or Syria’. Bodenheimer (1944) and Özeti and Yilmaz (1994) say “Terra typica: Palestine, ex errore Egypt” and Duellman (1977) and Kuzmin (1999) say “type territory - western Syria”. Napoleon’s military expedition to Egypt extended into “Syria” in 1799, reaching in northern Israel Acre (Godechot 1975) and Tiberias, and these places were visited by Savigny (Bour, in press). Napoleon advanced over the coastal plain, not over the Judean hills. Only his scouts presumably reached 13 km west of Jerusalem but not today’s known range of the new taxon (Gichon 1993; Schur 1999). Hence, if the frogs’ distributions have remained stable, Savigny had much better access to *Hyla savignyi* than to the new taxon, in accord with Savigny’s illustration (see above). The name *H. savignyi* indeed belongs to the widespread taxon conventionally known by it while the localized new taxon deserves the new name.

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