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Evidence for the specific validity and resurrection of *Heterixalus luteostriatus* (Andersson, 1910) (Anura: Hyperoliidae)****

ABSTRACT

In conjunction with ecological and conservation surveys two *Heterixalus* populations from central-E. (Manjakatompo, Ankaratra Massif) and N.W. Madagascar (Ampijoroa, Ankarafantsika), both formerly ascribed to *H. betsileo*, were analysed. The specimens from Ampijoroa have an almost light brownish back with two dorsolateral whitish-yellowish stripes from the tip of the snout to the groin, continuing on the distal part of tibiae. This colouration corresponds to that of *Megalixalus boettgeri* var. *luteostriata*, described by Andersson (1910). The calls of this form last 102-137 ms (sometimes with a second single sound), the frequency variable from 1.5 to 8.0 kHz, a dominant frequency of about 3.5 kHz and the call repetition rate (at about 24 °C) of 300 notes/min. The specimens of Manjakatompo are smaller and have a greenish colouration: dorsolateral and hindleg stripes are not so contrasted as in the Ampijoroa population. The call of these specimens has a duration of each single note variable from 170-228 ms, a frequency from 2 to 4 kHz, a dominant frequency of about 3 kHz and a call repetition rate (at about 15 °C) of about 20 notes/min. Since the Ampijoroa population differs significantly from that of Manjakatompo in biometry and acoustic emissions, the revalidation of *luteostriata* at a specific level is proposed: *Heterixalus luteostriatus*. According to the present knowledge this species is distributed throughout the western Madagascar, while *Heterixalus betsileo* s.str. occurs in the central-eastern areas.

INTRODUCTION

According to Glaw & Vences (1992), the genus *Heterixalus* Laurent, 1944 - endemic to Madagascar and closely related to the mainland African *Hyperolius* - is currently known with seven (or, possibly, eight) species: *H. albogutta-*

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tus, H. andrakata, H. betsileo, H. boettgeri, H. madagascariensis, H. tricolor, H. rutenbergi and the uncertain *H. "variabilis". H. betsileo* is the most widely distributed species, being found all around Madagascar; nonetheless, it is important to point out that such a wide distribution may reflect an interpopulational differentiation, or even the presence of closely related species yet unidentified.

The north-western and western *Heterixalus* populations formerly ascribed to *H. betsileo* show a contrasting back colouration, with two wide yellowish stripes on a blackish background continuing on the upper tibiae. This morph was recognized as sufficiently differentiated from the typical *H. betsileo* by Andersson (1910), who named it *Megalixalus boettgeri* var. *luteostriata* and designated as its *terra typica* Andranolava. Other localities in which this form occurs are quoted by Glaw & Vences (1992): Mahajanga, Kandani, Ampijoroa (Ankarafantsika) and Ambalobongo. Yet Glaw & Vences (1992, 1993) suggested that *luteostriata* could be a separate species, stressing however the lack of data about its vocal repertoire and morphology. Glaw & Vences (1993) designated as lectotype of this variety the adult female from the five syntypes (four subadults), and presently conserved in the collection of the Swedish Museum of Natural History (Stockholm) under the collective number NRM 30227.

During a series of field expeditions aimed to the conservation of the Malagasy herpetofauna (see Andreone, 1991, 1993, 1994) two of us (F.A. & D.V.) analysed one population of the *luteostriata* morph from Ampijoroa (Ankarafantsika) and had the possibility to compare it with the biological traits of another *Heterixalus betsileo* population from the Ankaratra area: this article provides data about its revalidation at a specific rank.

Materials and Methods

A map with the localities visited is provided in Fig. 1. The *luteostriata* population was studied at Ampijoroa, a dry deciduous forest located in the N.W. slope of Madagascar within the Strict Nature Reserve of Ankarafantsika, at about 50 Km from the town of Mahajanga. During February 1993 the *Heterixalus* population was observed breeding in a temporary pond, which was also the reproductive site of other anurans (e.g. *Tomopterna labrosa, Boophis tephraeomystax, Mantidactylus* cf. *wittei*). The advertisement calls of males were taken at night by means of a Sony TC-D3 recorder and were analysed with the program "Voxys". At present one of the most useful methods to identify sibling frog species in the field (when other methods are unappliable) is the analysis of their reproductive calls, as yet pointed out by Glaw & Vences (1991, 1992, 1993) also for the genus *Heterixalus*. They were successively compared with calls of a typical *H. betsileo* population from Manjakatompo, a

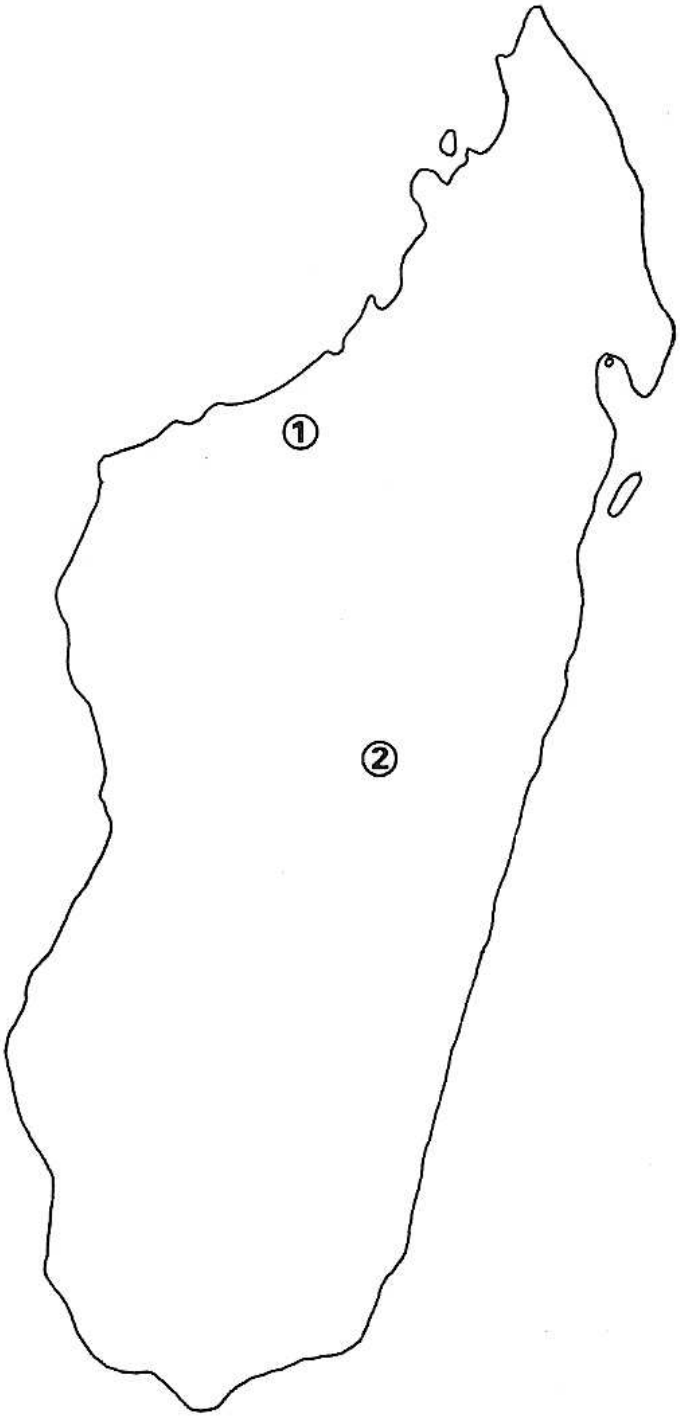

Fig. 1 - Map of Madagascar with the visited localities: (1) = Ampijoroa, Ankarafantsika, Mahajanga (Majunga) Province, study site of *Heterixalus luteostriatus*; (2) = Manjakatompo, Ankaratra Massif, Antananarivo (Tananarive) Province, study site of *H. betsileo*.

mountain forestry station next to Ambatolampy, and with data provided by Blommers-Schlösser & Blanc (1991) and by Glaw & Vences (1992).

Voucher specimens were also collected in these localities and are presently held in the herpetological collection of the Museo regionale di Scienze naturali, Turin (acronym = MRSN):

MRSN A399.1-9, Manjakatompo, Ankaratra Massif, Antananarivo (Tananarive) Province, leg. F. Andreone & D. Vallan 1-4.II.1993; MRSN A433.1-2, Manjakatompo, Ankaratra Massif, Antananarivo (Tananarive) Province, leg. R. Nincheri 28.XII.1992-03.I.1993; MRSN A393.1-7, Ampijoroa, Ankarafantsika, Mahajanga (Majunga) Province, leg. F. Andreone & D. Vallan 21.I.1993.

Morphometric measurements (to the nearest 0.1 mm) of the analysed specimens were taken (according to Glaw & Vences, 1993) of the following parameters:

(A) = snout-vent length (SVL).
(B) = eye diameter.
(C) = distance between eye and nostril.
(D) = distance between nostrils.
(E) = distance between nostril and tip of snout.
(F) = head width.
(G) = foot length (including tarsus).
(H) = hand length.

Biometric comparisons were made on the SVL of males (only male specimens were found at Ampijoroa) and on some ratio indices - using Student's *t* test - as follows:

(I) = eye diameter : SVL.
(J) = eye-nostril distance : eye diameter.
(K) = distance between nostrils : eye diameter.
(L) = nostril-tip of snout distance : eye diameter.
(M) = head width : SVL.
(N) = foot length : SVL.
(O) = hand length : SVL.

Results and Discussion

Descriptive morphometric data are reported in Tabs. I-III. The males from Ampijoroa have a mean SVL $\pm$ SD of 26.8 $\pm$ 1.3 mm (Tab. III), being therefore significantly larger than those from Manjakatompo, whose SVL is of 21.0 $\pm$ 1.5 mm. Significant differences were also found for some ratios (I, J, N, O).

Some specimens from Ampijoroa show an almost light brownish back with two dorsolateral whitish stripes from the tip of the snout, through the eyes, to the groin. Stripes are also present on the distal tibiae. When the frogs are motionless (e.g. during daytime hours) and keep the legs appressed to the body, the dorsolateral stripes continue with the leg stripes (see Fig. 2 and Glaw & Vences, 1992: Fig. 121, p. 96). Other specimens are more uniformly coloured, and the stripes are reduced to a series of small spots. The colour generally fades in preservative, the back colouration varying from beige to light brown. The belly (both in life and in preservative) is almost uniformly whitish. Specimens from Manjakatompo have a slender habitus and a greenish dorsal colouration (Fig. 3). Dorsolateral and hindleg stripes are also present, but not as contrasting as in Ampijoroa specimens. When preserved these

Tab. I - Biometric measurements of the analysed *Heterixalus betsileo* specimens from Manjakatompo, Antananarivo (Tananarive) Province, to the nearest 0.1 mm.

Number	a	b	c	d	e	f	g	h	i	j	k
	♂	♂	♂	♂	♂	♂	♀	♀	♀	♀	♀
A	19.9	22.8	22.6	19.7	21.4	19.7	23.6	24.2	19.0	21.7	20.5
B	2.9	3.6	3.2	2.6	2.9	2.8	3.8	3.3	2.7	2.8	3.2
C	1.8	2.5	2.2	2.1	1.7	1.8	2.3	2.9	1.9	1.7	2.0
D	2.3	2.3	2.6	2.2	1.9	2.2	2.5	2.3	2.0	2.0	2.1
E	2.3	2.3	1.9	1.4	1.9	1.9	1.9	1.9	1.6	1.8	1.9
F	7.1	7.8	7.4	6.7	9.0	6.8	7.4	7.8	6.5	7.3	7.1
G	15.3	17.1	15.2	14.5	17.9	16.3	17.9	17.0	14.6	16.8	15.1
H	6.0	7.5	7.3	5.6	6.6	6.9	6.8	6.2	5.8	6.0	5.7

Number: museum acronym and reference numbers (a-d = MRSN A399.1-4; e-f = MRSN A433.1-2; g-k = MRSN A399.5-9). A-H: biometric measurements (A = snout-vent length; B = eye diameter; C = distance between eye and nostril; D = distance between nostrils; E = distance between nostril and tip of snout; F = head width; G = foot length, including tarsus; H = hand length).

Tab. II - Biometric measurements of the analysed *Heterixalus luteostriatus* specimens from Ampijoroa, Mahajanga (Majunga) Province, taken to the nearest 0.1 mm.

Number	l	m	n	o	p	q	r
	♂	♂	♂	♂	♂	♂	♂
A	26.7	25.2	28.5	28.2	25.5	26.3	27.3
B	3.1	3.3	3.5	3.3	2.9	3.3	4.3
C	2.5	2.7	3.3	3.0	2.6	2.9	3.1
D	2.4	2.5	2.9	2.7	3.0	2.6	2.9
E	2.3	1.7	2.1	1.9	1.8	1.8	2.0
F	9.4	8.6	9.1	9.0	9.0	8.5	9.3
G	18.5	16.5	18.9	19.2	17.4	18.3	18.9
H	6.9	7.2	8.0	7.1	6.7	7.3	6.4

Number: museum acronym and reference numbers (l-r = MRSN A393.1-7). Other captions as in Tab. I.

specimens have a dorsal colouration ranging from greyish to greenish. In this population also, the belly is uniformly whitish.

The sonagrams and power spectra of Figs. 4-7 document also a remarkable call difference: the *H. betsileo* specimens at Manjakatompo show a duration of each single note variable from 170-228 ms, a frequency from 2 to 4 kHz, with a dominant frequency of about 3 kHz and a call repetition rate (at a temperature of about 15 °C) of about 20 notes/min. The apparent higher repetion rate of Fig. 6 (of about 175 notes/min) is due to the contemporary chorus of several

Tab. III - Comparisons (by means of Student's *t* test) of the SVL (A) and some biometric ratios (I-O) (mean ± standard deviation) of the analysed *Heterixalus betsileo* and *H. luteostriatus* populations (♂♂).

	Manjakatompo *H. betsileo* M ± SD	Ampijoroa *H. luteostriatus* M ± SD	*t*
A	21.017 ± 1.452	26.814 ± 1.265	7.698 **
I	0.142 ± 0.009	0.126 ± 0.015	2.306 *
J	0.673 ± 0.077	0.853 ± 0.076	4.223 **
K	0.755 ± 0.087	0.811 ± 0.111	0.992
L	0.650 ± 0.086	0.581 ± 0.088	1.421
M	0.355 ± 0.033	0.336 ± 0.015	1.428
N	0.765 ± 0.061	0.680 ± 0.016	3.569 **
O	0.316 ± 0.023	0.264 ± 0.018	4.508 **

The analysed ratios are as follows: I = eye diameter : SVL; J = distance between eye and nostril : eye diameter; K = distance between nostrils : eye diameter; L = distance between nostril and tip of snout : eye diameter; M = head width : SVL; N = foot length : SVL; O = hand length : SVL; *t* = *t* value of the Student's *t* test; values with an asterisk are significantly different for $P \leq 0.05$, those with two asterisks are significantly different for $P \leq 0.01$.

Fig. 2 - Live male specimen (MRSN A393.1) of the revalidated species *Heterixalus luteostriatus* from Ampijoroa, Ankarafantsika, Mahajanga (Majunga) Province, N.W. Madagascar. SVL (snout-vent length) = 26.7 mm.

Fig. 3 - Live male specimen (MRSN A399.1) of *Heterixalus betsileo* from Manjakatompo, Ankaratra Massif, Antananarivo (Tananarive) Province, central eastern Madagascar. SVL = 19.9 mm.

specimens. Each single note is quite unharmonious and not easily distinguishable as separate single sounds. Glaw & Vences (1992) report characteristics for some other *H. betsileo* populations: at Antananarivo the duration of the single note was of about 500 ms, with a frequency between 2 and 4 kHz, a dominant frequency of about 3 kHz and a call repetition rate of 30 notes/min; at Andasibe (Périnet) the duration was of 155-210 ms, with a frequency of 3.5 kHz and a call repetition rate of 32 notes/min (temperature of about 18 °C). According to Blommers-Schlösser & Blanc (1991), the duration of the call of a population recorded at Antananarivo was of 130-165 ms, with a frequency of 3 kHz and a call repetition rate of 44 notes/min (t of about 20 °C).

The calls of the specimens recorded at Ampijoroa (temperature of about 24 °C) have a note duration of 102-137 ms (sometimes with a second single sound discernable), the frequency variable from 1.5 to 8.0 kHz, a dominant frequency of about 3.5 kHz and the call repetition rate of 300 notes/min. The call emission of the analysed populations differs enough to further support the specific validity of the taxon *luteostriata*, stressing however the allopatric distribution of many species of the genus *Heterixalus*. This variety is therefore resurrected and revalidated at a specific rank as follows:

Diagnosis - *Heterixalus luteostriatus* (Andersson, 1910) bona species: this species is differentiated from the most similar species, *H. betsileo*, by a higher note repetition rate and by the presence of distinct light dorsolateral and distal tibial stripes.

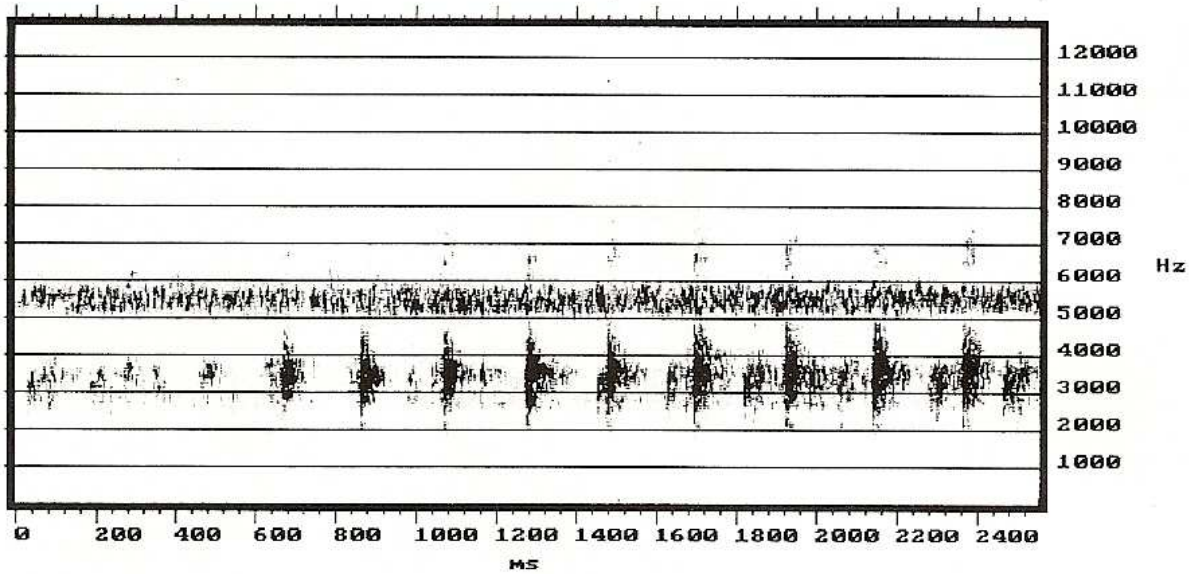

Fig. 4 – Sonagram (band width of 300 Hz) of *Heterixalus luteostriatus* from Ampijoroa (recording air temperature of about 24 °C). The vocalizations are emitted by only one specimen.

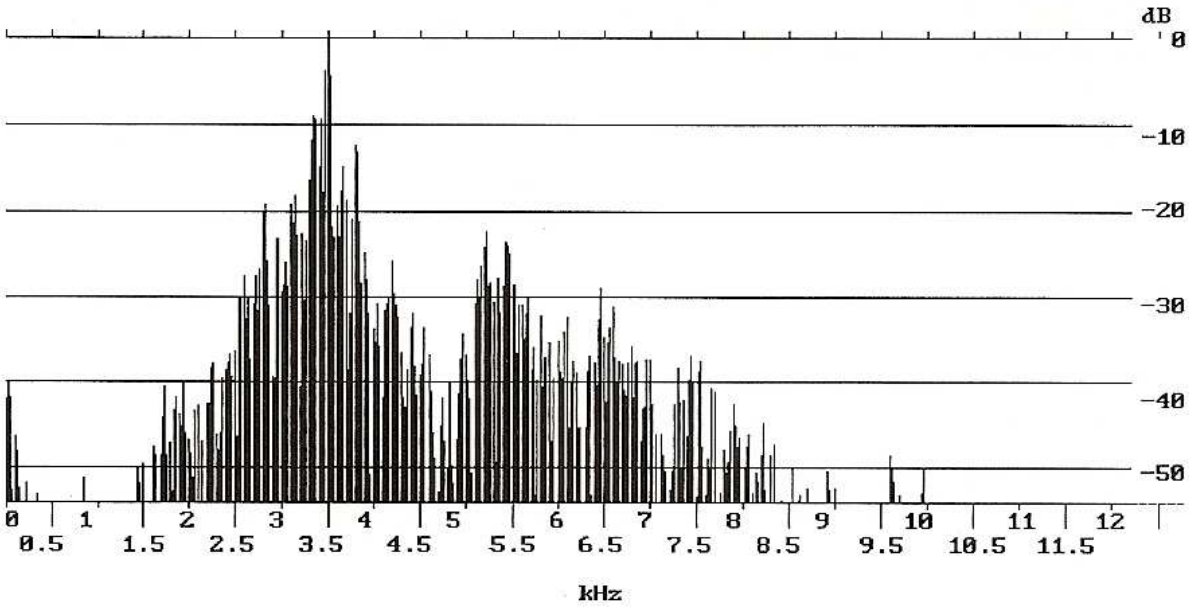

Fig. 5 – Power spectrum (temporal window = 40 ms; analysed ms = 1300) of the advertisement call of *H. luteostriatus* from Ampijoroa.

Although it is suggested that only the populations of central-eastern Madagascar belong to *Heterixalus betsileo* s.str., further studies are necessary to understand the variability among *H. betsileo* populations, and to analyse possible situations of sympatry or syntopy.

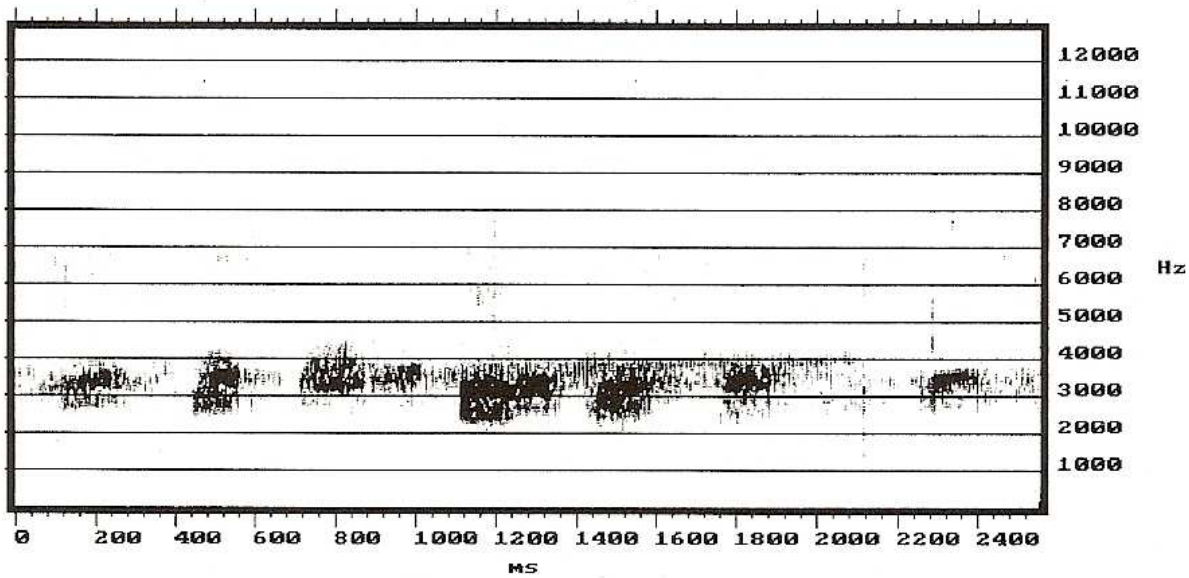

Fig. 6 - Sonagram (band width of 300 Hz) of the advertisement call of several *Heterixalus betsileo* specimens (a chorus) from Manjakatompo (recording air temperature of about 15 °C). Each note correponds to the advertisement call of one frog.

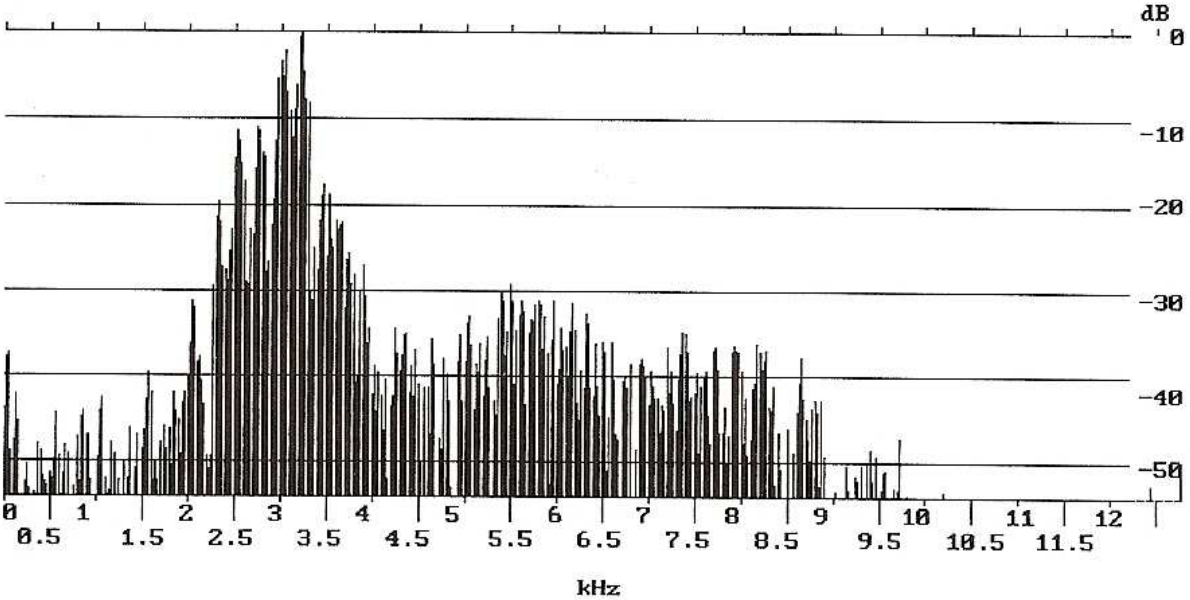

Fig. 7 - Power spectrum (temporal window = 40 ms; analysed ms = 1160) of the advertisement call of *H. betsileo* from Manjakatompo.

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RIASSUNTO

Nel corso di indagini ecologiche sugli anfibi malgasci è stata effettuatata un'analisi morfologica e bioacustica di due popolazioni del genere *Heterixalus* provenienti dalle aree centro-orientali (Manjakatompo, massiccio dell'Ankaratra) e nord-occidentali (Ampijoroa, Ankarafantsika) del Madagascar, precedentemente ascritte alla specie *H. betsileo*. Gli esemplari di Ampijoroa hanno una colorazione dorsale brunastra chiara, con due linee biancastre dalla punta del muso fino all'inguine, mentre strie analoghe sono presenti sulla parte distale delle tibie. Tali aspetti cromatici concordano a quelli di *Megalixalus boettgeri* var. *luteostriata*, descritta da Andersson nel 1910. Le vocalizzazioni di questi esemplari hanno una durata (a circa 24 °C) di 102-137 ms (talora con un evidente secondo "single sound"), una frequenza fra 1.5 e 8.0 kHz, una dominante a circa 3.5 kHz ed un tasso di ripetizione di 300 note/min. Gli esemplari di Manjakatompo sono più piccoli e presentano una colorazione del dorso verdastra. Benché strie dorso-laterali e sulle zampe posteriori siano presenti in questa popolazione, non così contrastate come negli esemplari di Ampijoroa. Il richiamo dei maschi di Manjakatompo ha una durata (riferibile alla singola nota) variabile da 170 a 228 ms, una frequenza da 2 a 4 kHz, una dominante di circa 3 kHz ed un tasso di ripetizione (a circa 15 °C) di circa 20 note/min. Poiché la popolazione di Ampijoroa differisce da quella di Manjakatompo sia per la biometria, sia per le emissioni acustiche, viene rivalidata la varietà *luteostriata* ad un rango specifico: *Heterixalus luteostriatus*. In accordo con i dati corologici attualmente disponibili, questa specie è distribuita nella parte occidentale del Madagascar, mentre *Heterixalus betsileo* s.str. è presente nelle aree centro-orientali.

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