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A NEW SPECIES OF LEPTODACTYLID FROG FROM THE ATLANTIC FORESTS OF SOUTHEASTERN BRAZIL WITH NOTES ON THE STATUS AND ON THE SPECIATION OF THE *HYLODES* SPECIES GROUPS.

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ABSTRACT

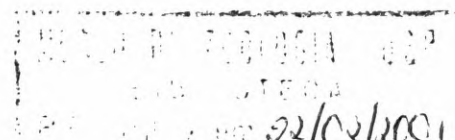
A new species of the leptodactylid frog genus Hylodes is described from Praia do Guaraú (24°23' S and 47°01' W), in the coastal Atlantic Forest of the State of São Paulo, southeastern Brazil. The new species is a member of the Hylodes nasus group and is characterized by its small size, by a tubercular dorsal skin and by a conspicuous red coloration around the vent in males. Descriptions of the advertisement call, tadpole morphology and data on natural history are provided. The new species is thought to be related to the parapatric Hylodes asper. The systematic status of Hylodes species groups and the allopatric speciation mechanisms probably involved in the differentiation of the Atlantic Forest stream-adapted frogs are discussed.

Keywords: Anura, Leptodactylidae, new species, *Hylodes*, speciation, Atlantic Forest, Brazil.

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INTRODUCTION

Leptodactylid frogs of the genus *Hylodes*, Fitzinger 1826, are restricted to southern and southeastern Brazil (Haddad *et al.*, 1996; Frost, 1996). They are diurnal, rheophilic and frequently found along mountain streams on the rocks or in the adjacent litter, mainly associated with the Atlantic Forest (Mertens, 1927; Gouvêa, 1979; Heyer, 1982; Sazima & Bokermann, 1982; Heyer & Cocroft, 1986; Heyer *et al.*, 1990; Haddad & Pombal, 1995; Haddad *et al.*, 1996). Despite its peculiar ecology the genus has not been the object of recent systematic revisions and their phylogenetic relationships remains unknown. Several new species have been described in the last years and some still remain undescribed on museum shelves (Heyer, 1982; Heyer & Cocroft, 1986; Haddad & Pombal, 1995, Haddad *et al.*, 1996).

Heyer (1982), was the first author attempting to summarize the chaotic taxonomy of the genus. Based on similarity of external attributes he recognized four groups: *pulcher*, *mertensi*, *lateristrigatus* and *nasus*. The presently 17 recognized species of *Hylodes* are still allocated following the Heyerian scheme, a convenient rather than phylogenetic one, as he admitted.

The *pulcher* group was created to place the very distinctive *Hylodes pulcher*, later shown to be a junior synonym of *Elosia glabra* (Izecksohn & Gouvêa, 1983; Heyer & Cocroft, 1986). The group was subsequently referred to as the *glaber* group (Haddad & Pombal, 1995; Haddad *et al.*, 1996). *Hylodes glaber* is still the only species recognized in this group; it is a moderate sized, slender, ranoid-like species, characterized by its bright colors in life; most individuals have bright blue and/or yellow dorsal spotting. There is also only one species (*H. mertensi*) in the *mertensi* group: it is a large and robust frog with leathery dorsal skin. The *lateristrigatus* group is the most diverse (11 species), assembling small to moderate sized, slender and ranoid-like species with a smooth dorsal skin; its species are characterized by the presence of conspicuous dorsolateral light stripes and a smooth dorsal skin. Species included are: *H. babax*, *H. charadranaetes*, *H. heyeri*, *H. lateristrigatus*, *H. magalhaesi*, *H. ornatus*, *H. otavioi*, *H. phyllodes*, *H. regius*, *H. sazimae*, and *H. vanzolinii*. The *nasus* group contains four species: *H. asper*, *H. meridionalis*, *H. nasus*, and *H. perplicatus* (Frost, 1996). They are robust frogs varying from moderate to large sized, with granular dorsal surfaces and lacking dorsolateral light stripes.

Several years ago, collecting in a forest stream near the coast of the south of the state of São Paulo, we obtained a small species of *Hylodes*. This species was the subject of an intensive study of reproductive biology and behavior that will be published elsewhere (Narvaes, 1997). Although at first glance it was associated with *Hylodes asper*, it differed strikingly from it by a smaller

body size. The examination of specimens of *Hylodes* at the collections of the Museu de Zoologia, Universidade de São Paulo, supplemented by specimens housed in other collections (Museu de História Natural/Instituto de Biologia/UNICAMP, ZUEC and Museu Nacional do Rio de Janeiro, MNRJ) show that it is a yet undescribed species. Its description leads us to comment upon putative close relatives and on the distribution and speciation mechanisms of other Atlantic Forest stream-adapted frogs.

MATERIALS AND METHODS

The abbreviations of the institutions are: MZUSP (Museu de Zoologia, Universidade de São Paulo); MNRJ (Museu Nacional, Rio de Janeiro); and, ZUEC (Museu de História Natural, Universidade de Campinas UNICAMP). Abbreviations used are SVL (snout-vent length); HL (head length), HW (head width), IND (inter-nostril distance); ED (eye diameter), END (eye-nostril distance), TD (tympanum diameter); ESD (eye-snout distance); IOS (interorbital space); HAL (hand length); THL (thigh length), TBL (tibia length), TAL (tarsus length), FL (foot length).

Vocalizations were recorded with a Sony Digital Walkman Audio Tape (TCD-07) and a Sony microphone (ECM-959). The tapes were analyzed on a Power Macintosh computer (8500/120) using the Canary 1.2.1 program.

***Hylodes dactylocinus* sp. nov.**

Holotype: MZUSP 89904, adult male, collected at Guaraú (24°23' S, 47°01' W; approximately 50 m above sea level), Estação Ecológica Juréia-Itatins (Núcleo Arpoador), Peruíbe, São Paulo, Brazil in March 21, 1998 by Patrícia Narvaes and Dante Pavan.

Paratypes: MZUSP 89912-37, seven adult males, twelve adult females and seven sub-adults, collected in the same place as the holotype by Patrícia Narvaes, in December 1995; MZUSP 89909-11, two adult males and one adult female, collected at Morro da Boa Vista, Vale do Rio Taquaruçu, Serra dos Itatins, Estação Ecológica Juréia-Itatins (Núcleo Despraiado), Pedro de Toledo, São Paulo, Brazil in January 1994 by Dante Pavan and Patrícia Narvaes; MZUSP 89905-08, four adult females collected by Dante Pavan and Patrícia Narvaes, at Clube Serra Mar, Cachoeira Flora, Córrego Vermelho, Km 352.5 of Padre Manuel da Nóbrega road, Itariri, São Paulo, Brazil on March 21, 1998; MZUSP 89901-03, one adult male and two adult females collected at Estação Ecológica Juréia-Itatins (Núcleo Arpoador), Peruíbe, São Paulo, Brazil on July 10, 1997, by Gustavo de Matos Acaccio.

Diagnosis: A small species of *Hylodes* (24-31mm SVL) lacking continuous dorsolateral light stripes, and characterized by a tuberculate dorsal skin (Fig. 1). Snout subovoid in dorsal view and rounded-acute in lateral view, hands and feet large compared to body size. Extensive fringing on fingers. Dorsal surface of fingers and toes, and the anteroventral face of thighs with bright white spots in males. Dorsal ground color olive gray mottled with irregular dark spots and gold reflexes. A conspicuous red area around vent in males.

Comparison with other species: Species recognized as belonging to the *nasus* group are: *Hylodes asper* Muller, 1924; *H. meridionalis* Mertens, 1927; *H. nasus* Lichtenstein, 1823 and *H. perplicatus* Miranda-Ribeiro, 1926 (Frost, 1996). *Hylodes dactylocinus* is the smallest species of the *nasus* group (24-31 mm SVL in adults; 32-50 mm in other species). It further differs from all other members in the group in having numerous dorsolateral granules, and a conspicuous coloration around vent in males. *Hylodes dactylocinus* differs from *H. nasus* in having more extensive fringing on the fingers. *Hylodes nasus* has small dark and regular spots on the back that are not observed in *H. dactylocinus*. *Hylodes perplicatus* also differs from the new species in having a more slender body and only a few dorsolateral granules. Additionally, *H. perplicatus* has a distinctive supralabial white stripe (absent in *dactylocinus*) and a dorsolaterally discontinuous white bright stripe. *Hylodes meridionalis* differs from *Hylodes dactylocinus* in having few dorsolateral granules.

Description of the holotype: Body robust (Fig. 1), head slightly longer than wide, its length contained about three times in snout-vent length; snout subovoid and slightly acuminate in dorsal view, rounded acute in lateral view (Fig. 2A), its foremost projection well beyond the jaw; eyes large, lateral, their diameter much larger than the eye-nostril distance and slightly shorter than internasal distance; interorbital space approximately equal to the width of the superior eyelid; eye-nostril distance smaller than width of the superior eyelid and that of interorbital space; canthus rostralis distinct, straight; loreal region concave vertical; nostril small, protuberant, directed laterally, closer to the snout tip than to the eyes; tympanum distinct, circular, its diameter about half of the eye diameter; supra tympanic fold weak; well-developed paired lateral vocal sacs; vomerine teeth between and behind choanae, in two small and distinctive clusters; tongue large, oval; ventral margin of upper jaw with horny asperities.

Arm long and robust without dermic fold; arm and forearm approximately of the same thickness; hand large with well-developed lateral fringing on fingers; (Fig. 2B), finger discs large, with a pair of scutes on upper surface; subarticular tubercles simple, round and moderately developed; outer and inner metacarpal

tubercles rounded, the inner smaller, 1/2 to 1/4 of the outer; finger lengths I < IV < II < III; thumb without spines or nuptial asperities. Leg long, thigh and tibia together longer than snout-vent length; toe discs large, upper surfaces with well-developed scutes (Fig. 2B); well-developed toe fringing; a trace of basal webbing due to confluence of fringing on sides of toes; toe lengths I < II < V < III < IV; subarticular tubercles round, pronounced; well-developed tarsal flaplike fold, extending continuously from the base of the first toe to the tibio-tarsal articulation; metatarsal tubercles developed, the outer conical, about three times smaller than elongated inner. Dense array of irregularly disposed granules in the skin of dorsum, extending from behind the eye, concentrated on the flank, to level of vent. Belly smooth with a transverse semicircular dermic fold in the posterior part of the abdomen.

Color in life: Dorsum dark gray with olive green irregular spots and gold reflections. Lateral tubercles on body bright, whitish. A wide, white-gold dorsolateral stripe extends from midbody to groin. Belly whitish and bright, with small dark spots; throat bright white. A series of bright and conspicuous pearly white spots below the tympanum and the eye. A series of large, bright pearly spots on ventral surface of leg and internal area of the arm; armpit yellowish. Dorsal surface of the fingers I and II, distal half of finger III and, dorsal surface of foot and toes bright white in males. Dorsal surface of the feet gray with darker spots in females. External dorsolateral surface of the feet gilded, extending to fingers IV and V. A dark small area below vent, and a dorsolateral red-copper colored on vent in males; below vent the ground color is gold with some small brighter gold spots reaching the inner part of thigh.

Color in preservative: In preservative (70% alcohol), the colors are similar to those in life, except the red coloration laterally to vent and the gilded tonality of the spots on the dorsum have faded or disappeared.

Measurements of the holotype (mm): SVL 25.4; HL 9.2; HW 8.1; IND 2.7; END 1.9; ESD 3.8; IOS 2.4; ED 3.1; TD 1.8; HAL 8.5; THL 12.0, TBL 12.7; TAL 7.1; FL 12.0.

Etymology: Of the Greek *dactylos* (fingers) and *cineo* (I move), in allusion to the conspicuous behavior of this frog, which characteristically moves its toes in an alternating and oscillatory way during intraspecific displays.

Variation: Snout-vent length of adult males 24-27 mm (\bar{x} = 25.2; SD = 0.76; N = 74); adult females 24.4-31 mm (\bar{x} = 26.9; SD = 1.34; N = 63) (Narvaes, 1997). In adult females and young the finger fringe is much less developed than in adult males, and the toe fringe is slightly less extensive. The dorsolateral

white stripe can be continuous or interrupted, forming small discontinuous spots. Its length also varies in both sexes, extending from the armpit level to groin. The anal region is usually dark olive in females, without the red-copper coloration characteristic of males. The amount of grayish spots on the belly varies according to the sex and locality. In specimens from the type locality, males have few or no ventral spots at all, while several belly spots are present in females. Females from Itariri possess a uniform white belly and males and females from Morro da Boa Vista, have grayish spots on the belly.

In specimens from Itariri, the dorsal parts of the body and the limbs have a uniform grayish color, with lighter tones than those observed in frogs from the type locality. In the former the dorsolateral area is also frequently sprinkled with small white spots. In contrast, at Morro da Boa Vista, dorsal parts of arms and legs are more brownish colored and the corresponding ventral part of appendices are yellowish.

Description of tadpole: This description is based on a tadpole in stage 37 (Gosner, 1960) collected at the type locality. Body ovoid in dorsal view, about 1/3 of the total length (Fig. 3). Snout truncate; eyes dorsolateral; nostrils circular, directed laterally; weakly developed spiracle sinistral, opening at middle of body; cloacal tube short, opening dextral. Oral disc directed ventrally, bordered by an agglomerate of papillae forming two small loops on the sides of the labium, papillae broadly interrupted on the anterior labium; tooth row formula 2(2)/3(1); jaw sheaths strongly developed and serrate, with an indented inferior projection in the anterior jaw, posterior jaw sheath almost right angle-shaped (Fig. 3). Length of tail about twice of the body; tail musculature very developed, with low fins; tail higher than body, dorsal fin slightly higher than ventral, tail narrowing from the middle towards end. Body dark brown; from above a light middorsal area, containing scattered dark spots, extending from the base to the middle of tail; in lateral view, dark chestnut pigments on the anterior part of tail defining a longitudinal stripe extending from above musculature to the middle of the tail. Distal part of tail with large and rounded dark chestnut spots on the musculature, smaller on the membrane.

Tadpole Variation: In some individuals, the spots of the distal part of the tail are replaced by a blackened uniform coloration, not reaching the extremity of the unpigmented tail. In most of the tadpoles collected at Morro da Boa Vista, this last pattern is accentuated and black pigmentation is more intense in the younger tadpoles, becoming progressively lighter during their development.

Vocalizations: Two call types were observed in *Hylodes dactylocinus*. The advertisement call consists of a long, high-pitched whistled trill and is

emitted during foot-flagging behaviour as well as without it (Fig. 4). At an air temperature of 23-25 °C, the advertisement call has an average of 3083 ms (1958-4883, SD 666, N=44) and consists of a mean number of 71 (44-110, SD 16, N=44) regularly repeated pulses (Fig. 5A). Its frequency range is broad, with most energy spread between 2000 and 10000 Hz. The mean dominant frequency of 29 analysed calls is found at 2973 Hz (2608-6618, SD 995, N=29). The intervals between 21 analysed advertisement calls lasted from 8.6 to 14.1 seconds (8 individuals analysed). The close-range encounter call is given stationary or during approaches among agonistic males, and during courtship. Close-range encounter calls consist of a varying number of squeaks (1-32, N=50) emitted in irregular sequences, lasting less than 50 msec in duration. The squeaks show a dominant frequency around 5000 to 6000 Hz. Its frequency range is broad, with energy spread between 4000 Hz and 10000 Hz. (Fig. 5B).

Natural History- *Hylodes dactylocinus* is diurnal and inhabits small streams in the Atlantic Forest. The olive gray or olive brown dorsal ground color, and the wrinkled aspect of flanks render these frogs extremely cryptic on the rocky substratum rich in lichens and mosses. Males are territorial and call from rocks along the streams to attract females and to keep conspecific males at distance. These frogs are wary, jumping to the water when disturbed. After emerging they generally stay concealed among rock crevices. Calling behavior is complemented by leg stretching and foot-flagging (Narvaes, 1997). Similar visual displays have been observed in *H. asper*, (Heyer, *et al.* 1990; Hödl, *et al.*, 1997) and *H. nasus* (Pavan, pers. obs.). Oviposition takes place in submerged nests, previously excavated by the male in sand and gravel (Narvaes, in prep). The reproductive habits are very similar to those observed in *H. asper* (Haddad & Giaretta, 1999).

Distribution - The Serra dos Itatins is part of the Serra do Mar. The Serra do Mar is a Precambrian mountain range, which extends along the coast from the State of Rio Grande do Sul in southern Brazil to the northern part of the State of Espírito Santo (Almeida, 1976; IPT 1981a, 1981b). In the eastern part of the Serra dos Itatins the mountains reach the coast of the State of São Paulo. The region is characterized by sharp and pronounced valleys drained by streams and creeks varying in size. The mountain region and most of the adjacent coastal plain are covered with forest. This lowland region was deeply affected and molded by the sea level oscillations during the Quaternary period. The Maciço da Juréia, for example, is a relictual mountain range close to the Serra dos Itatins; topographically, it is presently isolated from adjacent areas of sharp relief by an extensive coastal plain set in place during the last marine transgressions (Suguió, in prep.). The type locality of Maciço do Guaraú is still

connected with the Serra dos Itatins at some places, but otherwise isolated from adjacent mountains by sandy coastal plains (Suguio & Martin, 1978). The area is nowadays protected as the Estação Ecológica da Juréia-Itatins (E.E.J.I.).

Hylodes dactylocinus was found at Guaraú, in the elevations of the eastern face of Maciço do Guaraú, Serra dos Itatins. Administratively the region composes one of the subregions of the Ecological Station (Núcleo Arpoador). Individuals of *H. dactylocinus* were also found at Morro da Boa Vista, Vale do Rio Taquaruçu, on the western side of the massif in another subregion of the protected area (Núcleo Despraiado/E.E.J.I.). It was additionally obtained in the district of Itariri, an adjacent area to the Serra dos Itatins. *Hylodes dactylocinus* was exclusively found in areas with pronounced relief and never in the low course of streams crossing the coastal plain (Fig. 6). In all these areas the species is sympatric with *H. phyllodes*.

Remarks: Haddad *et al.* (1996) mentioned the difficulty of recognizing *nasus* and *lateristrigatus* species groups of *Hylodes* utilizing the external morphological features as proposed by Heyer (1982). In the present study many observations strengthen Haddad's opinions. *Hylodes heyeri* and *H. perplicatus* are very similar species, both presenting large size, very slightly rugose dorsal skin and a conspicuous bright dorsolateral stripe. The current literature has recognized *H. perplicatus* in different groups, but both *Hylodes heyeri* and *H. perplicatus* have characteristics of the *nasus* and *lateristrigatus* species groups (Heyer, 1982; Frost, 1996; Haddad *et al.*, 1996). Except for the small body size, *Hylodes dactylocinus* has the diagnostic characteristics of the *nasus* group. The recognition of species groups based on body size is not presently arguable because these characteristics do not necessarily reflect phylogenetic relationships.

The number of dorsal granules (smooth to granular), the body shape (slender to robust) and the distinctiveness of the dorsolateral light stripe (large and conspicuous to absent) have a relatively continuous variation between the species of the *nasus* and *lateristrigatus* groups. These characters, as presently described, clearly do not permit a clear cut separation of these two species groups. *Hylodes heyeri*, *H. perplicatus* and *H. meridionalis* are less wrinkled, less robust and with more conspicuous dorsolateral light stripes. Specimens of *Hylodes nasus* have these characteristics in intermediate states. *Hylodes dactylocinus* and *H. asper* are at the other extreme of this continuum with rugose and robust bodies and a discontinuous or absent dorsolateral stripes. In all these species, stripes are formed by irregularly aligned whitish granules extending from the midbody level to groin.

In our opinion, a systematic revision is needed to clarify the specific status of *H. heyeri* relative to *H. perplicatus* as well as the relationships among *Hylodes* species

DISCUSSION

The species of the *Hylodes nasus* group present a geographic distributional pattern related to the sharp relief of mountainous areas in southern and southeastern Brazil. *Hylodes dactylocinus* is endemic to the Serra dos Itatins and adjacent areas. We found *H. asper* in the Serra de Paranapiacaba approximately 30 km from Itariri where *H. dactylocinus* occurs. *Hylodes asper* occurs along the Serra do Mar, from Teresópolis in the state of Rio de Janeiro to São João da Graciosa, in the state of Paraná (Fig. 6). This encompasses a range of approximately 750 Km in a straight line. *Hylodes nasus* seems to be restricted to the mountains of Maciço da Tijuca near the coast of the state of Rio de Janeiro. *Hylodes meridionalis* seems to be a disjunct member of the *nasus* group occurring at São Francisco de Paula in the state of Rio Grande do Sul in the southernmost portion of the Serra do Mar (Fig. 7).

Other leptodactylid frogs are adapted to live in Atlantic forest streams and some of them show similar patterns of geographical distribution that are related with occurrence of areas of sharp relief. The genus *Cycloramphus* assembles a very diversified group of leptodactylid frogs (25 species) that occur exclusively in the Atlantic Forest region (Frost, 1996; Heyer & Maxson, 1983). Species of *Cycloramphus* are nocturnal and most of them are specialized stream dwellers. In some cases, they are strictly syntopic with *Hylodes* spp., but there are differences in time activity (Heyer & Maxson, 1983). *Cycloramphus juimirim* is apparently endemic to the Maciço da Juréia in the southern coast of the State of São Paulo (Haddad & Sazima, 1989). Coincidentally the Maciço da Juréia is adjacent to the Serra dos Itatins and is now completely isolated from it and from other mountainous chains by the extensive Quaternary coastal plain. Indeed, admitting an insular or almost insular differentiation for *C. juimirim* and *H. dactylocinus*, it is possible to suggest that reduction in body size evolved convergently among these two stream-adapted species in response to insularity.

The distribution of perennial streams where *Hylodes* and *Cycloramphus* live is directly related to the increase of declivity and pluviosity of the area. In southern and southeastern Brazil the areas of higher precipitation occur along the mountainous reliefs due to the occurrence of orographic rains (Ab' Saber, 1977). As Heyer and Maxson (1983) remarked, climatic changes and uplifting of the coastal mountains would act as distributional barriers to the stream-adapted frogs. Beyond this, the dissection of the relief and changes in sea level would act causing modifications in the continuity of distribution of streams, permitting species to differentiate allopatrically.

Additional endemisms of terrestrial or stream-adapted frogs from this area



Fig. 1. *Hylodes dactylocinus*, adult male in life. (Photograph by G. M. Acaccio).

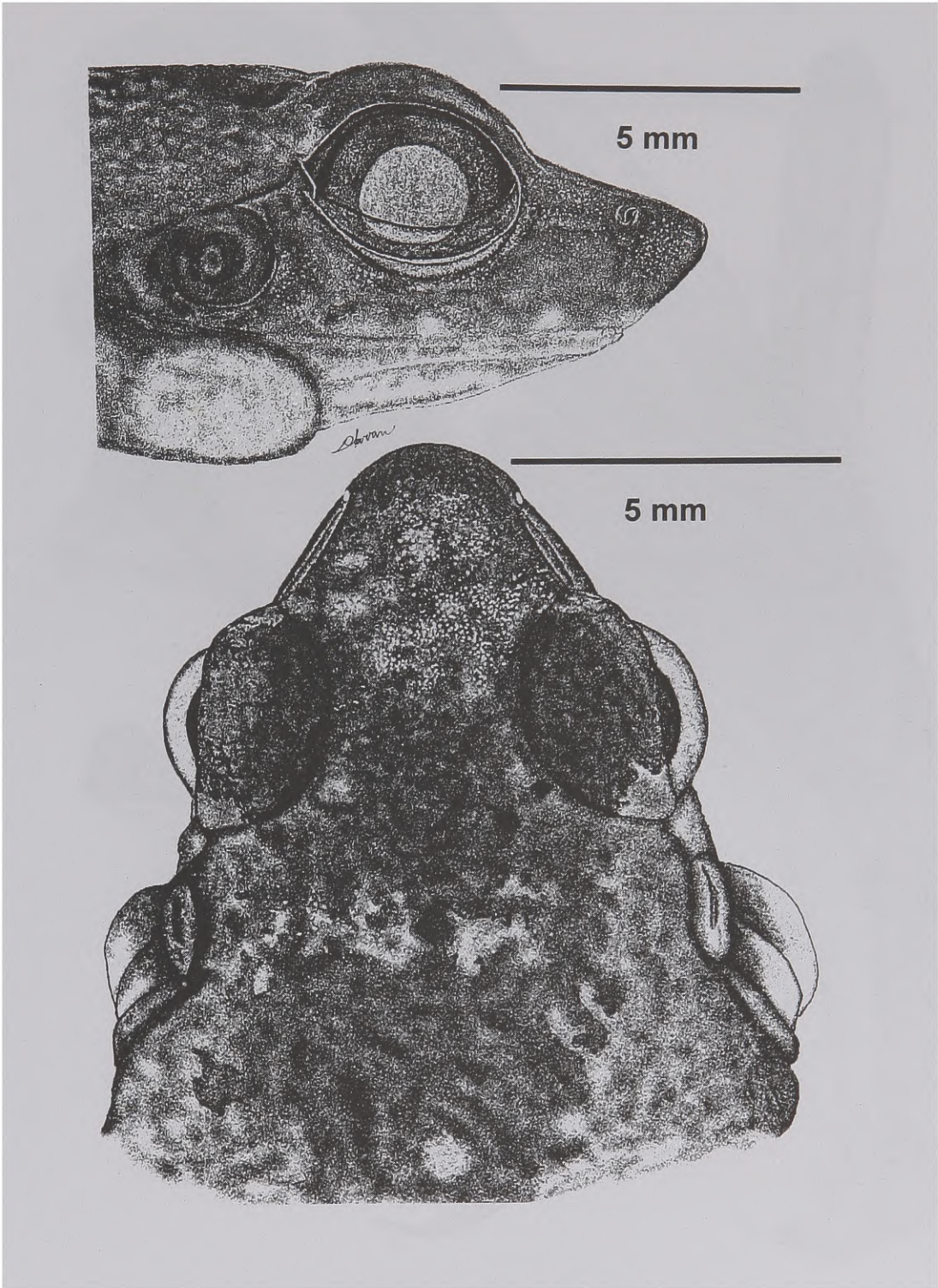


Fig. 2A. *Hylodes dactylocinus*, MZUSP 89904 (holotype). Lateral and dorsal views of head.

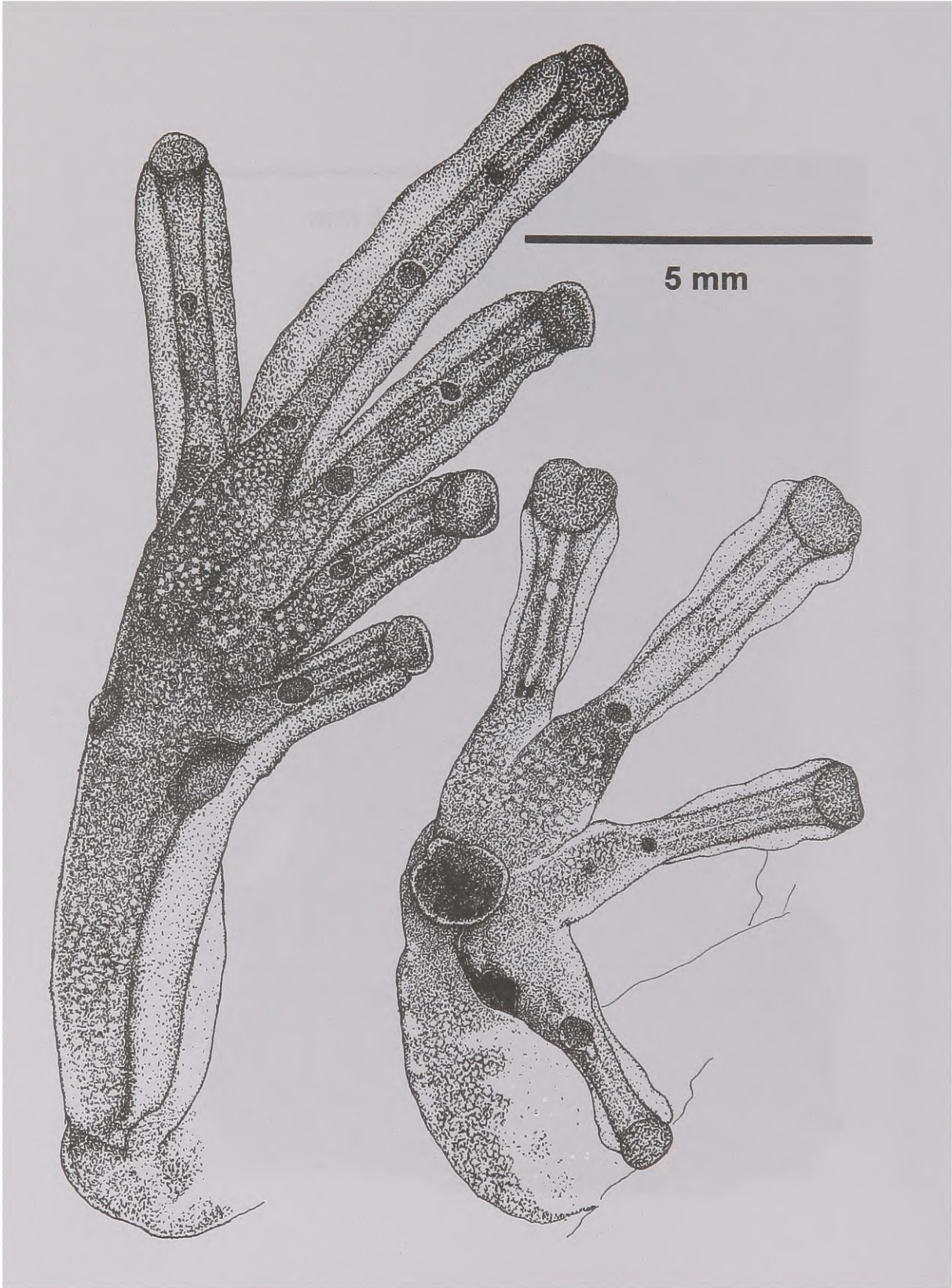


Fig. 2B. *Hylodes dactylocinus*, MZUSP 89904 (holotype). Ventral views of hand and foot.

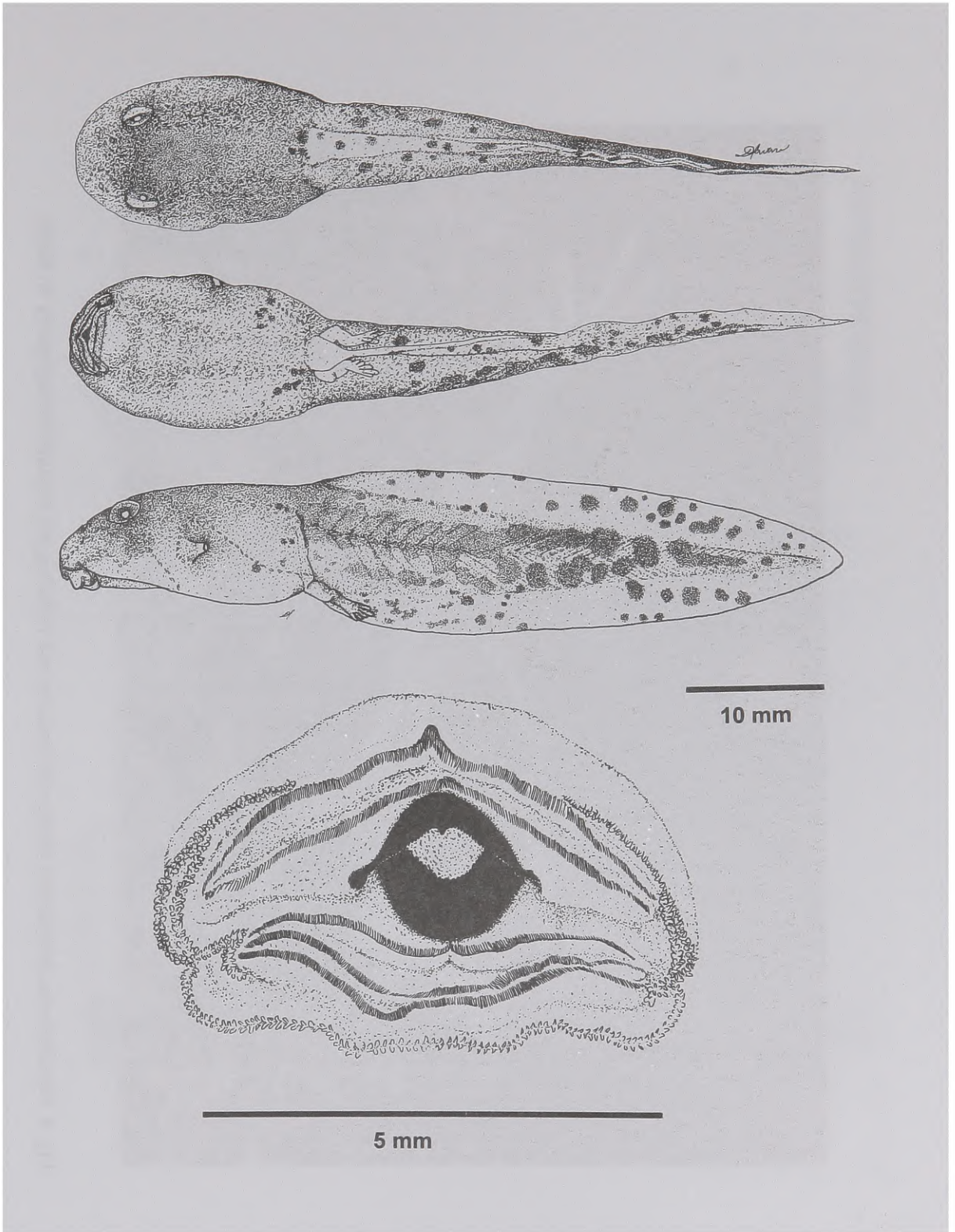


Fig. 3. Tadpole of *Hylodes dactylocinus*, stage 37. Dorsal, ventral and lateral view; and oral disc.



Fig. 4. Male *Hylodes dactylocinus* during call emission and foot-flagging display (Photograph by W. Hödl).

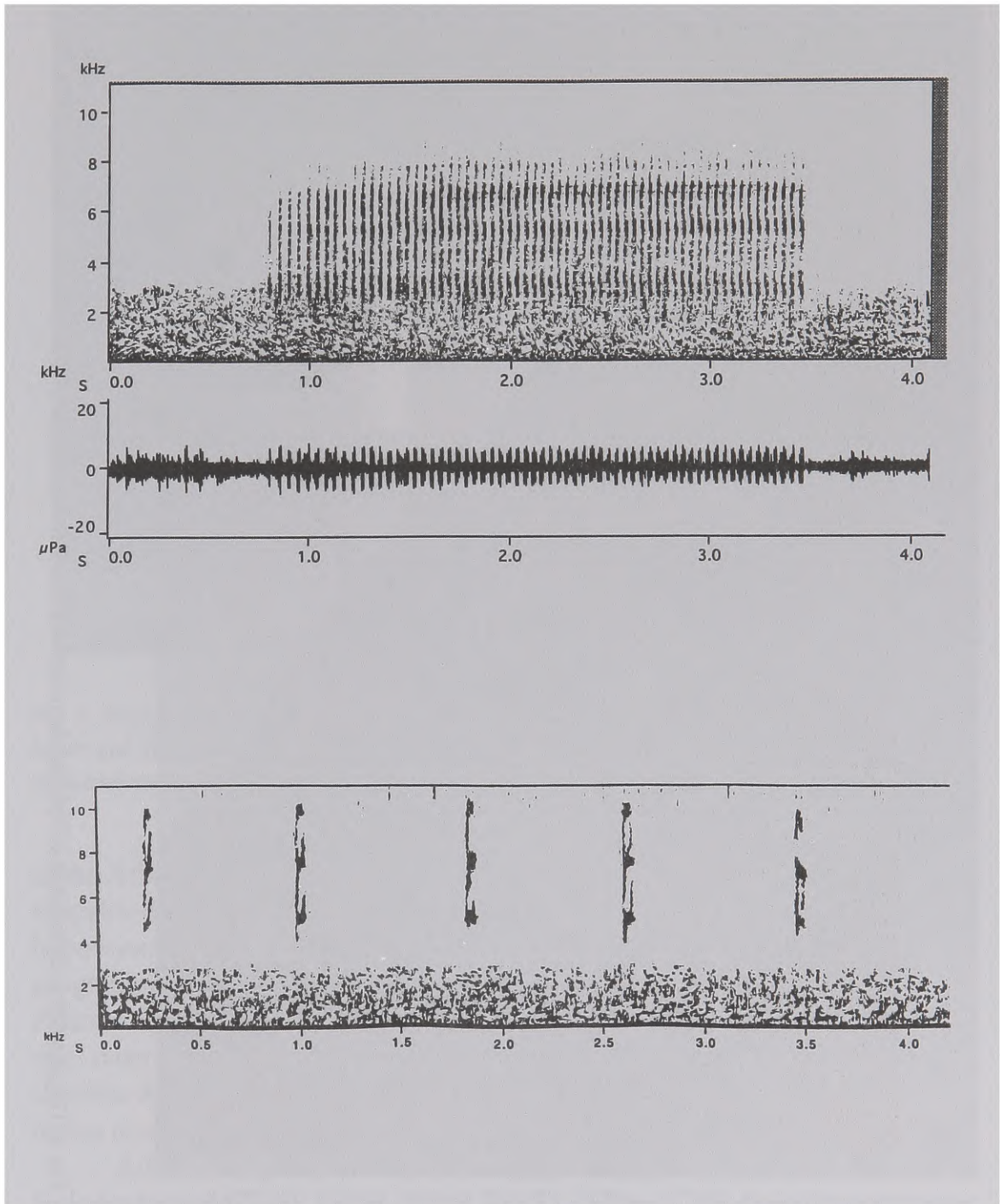


Fig. 5. (A) Advertisement call of *Hylodes dactylocinus*. Sonogram (above), oscillogram (below) and (B) The close-range encounter call of *Hylodes dactylocinus*.

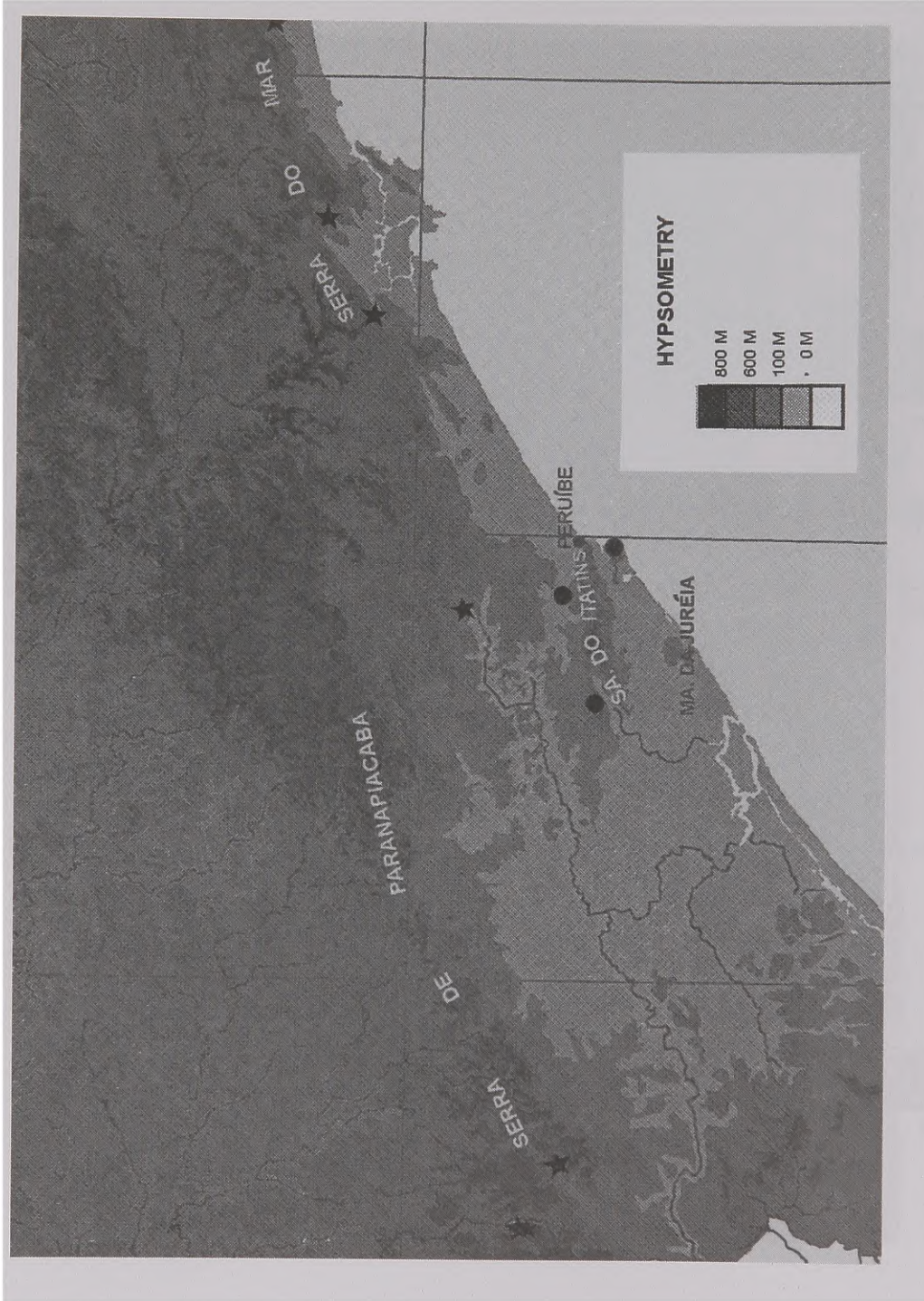


Fig. 6. The geographic distribution of *Hylodes dactylocinus* (●) and *Hylodes asper* (★) in the South of the State of São Paulo.

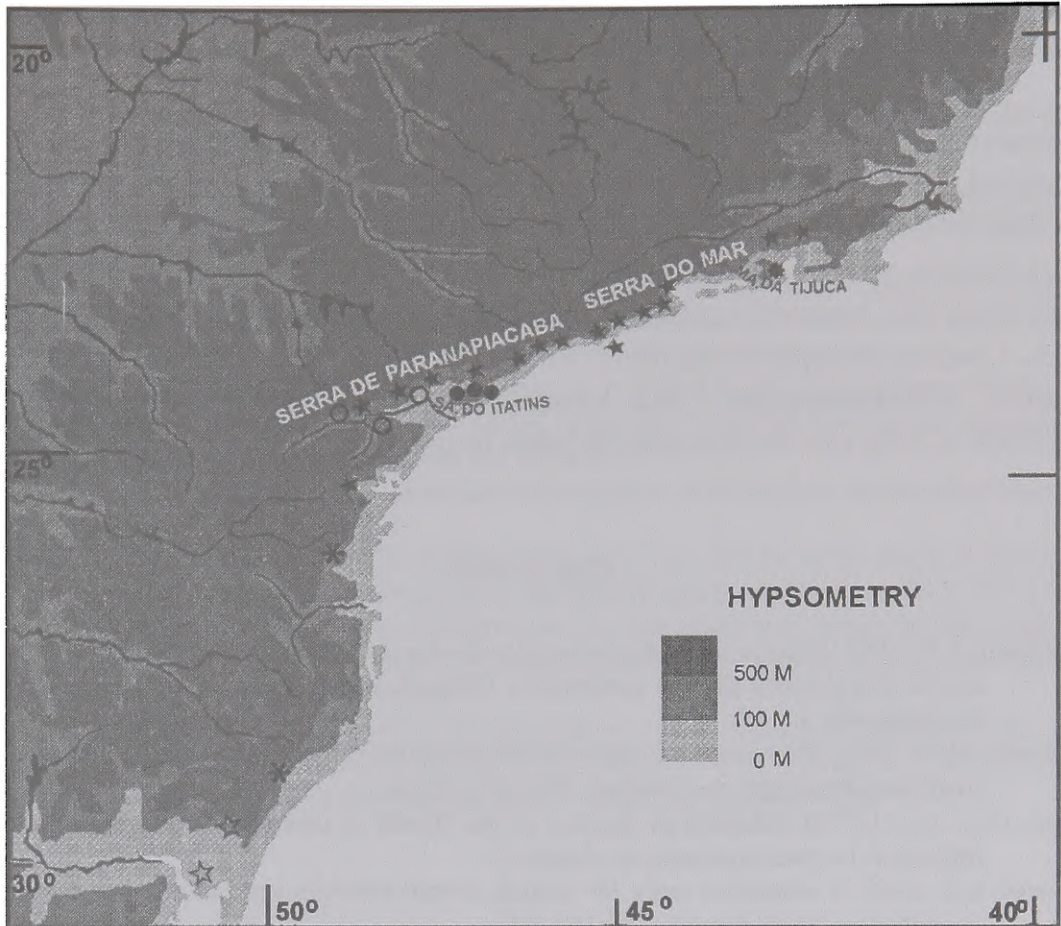


Fig. 7. Topographic map of the southeastern Brazil with the geographic distribution of *Hylodes heyeri* and the species of *Hylodes nasus* group. *H. asper* (★); *H. dactilocinus* (●); *H. heyeri* (○); *H. meridionalis* (☆); *H. nasus* (●); *H. perplicatus* (✱).

of the Atlantic Forest brings further support for the idea speciation has been via allopatric differentiation. Another example is the casque-head hylid *Aparasphenodon bokermanni*, apparently endemic to the Maciço da Juréia (Pombal, 1993). The geographically close and related *Aparasphenodon brunoi* occurs northward in the Atlantic Forest from Ubatuba on the northern coast of the state of São Paulo. The only other species known in the genus is from the Orinoco Basin of Venezuela (Paolillo & Cerda, 1981). Fortunately, the area of the Estação Ecológica da Juréia-Itatins is now under permanent preservation, facilitating future research.

Additional specimens examined. *Hylodes asper* MZUSP 23497-23507. *Hylodes nasus* MZUSP 20859-20869; MNRJ 13704-13709. *Hylodes perplicatus* MZUSP 60697-60700 (paratypes), 73588-73590. *Hylodes heyeri* ZUEC 8238, 8242-8243, 8249-8250, 8253-8254. *Hylodes meridionalis* ZUEC 3449, 4932-4934, 6247-6248, 10400-10404, 11173-11174, 11242.

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