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JORGE D. WILLISeroprotein Patterns in the *Bufo marinus* Complex

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The systematic relationships of the large species of neotropical toads of the *Bufo marinus* complex have not been defined since the studies of Lutz (1925). On the basis of recent contributions (Lutz and Kloss, 1952; Cochran, 1955; and Vellard, 1959) the following fundamental taxonomic units can be recognized: 1) an Amazonian population extending north to Mexico, corresponding to *Bufo m. marinus* (Linnaeus) with some subspecies bordering its range, as *B. marinus poeppigii* (Tschudi); 2) a well-defined eastern form, *Bufo ictericus* Spix, from the humid coastal Brazilian realm; 3) a central, latitudinally widespread giant form, *Bufo paracnemis* Lutz, adapted to the dry and open uplands or catingas; 4) two closely related southern and southeastern forms, *Bufo arenarum* Hensel extending from Matto Grosso and Rio Grande do Sul to the paragonian meseta of Río Negro, and *Bufo rufus* Garman in the Brazilian states of Matto Grosso and Minas Gerais (see Fig. 1). The specific interrelation of *B. arenarum* and *B. rufus* have not been studied. *Bufo ictericus* and *B. paracnemis* were formerly described as geographical forms of *B. marinus* (Müller, 1927; Mertens, 1930; Müller and Hellmich, 1936; Lutz and Kloss, 1952) but their specific status was recently re-evaluated (Cochran, 1955). *Bufo paracnemis* appears to be sympatric with *B. arenarum*,

B. rufus and *B. ictericus*. *B. ictericus* is probably sympatric with *B. arenarum* and *B. rufus* (see Fig. 1).



FIG. 1.—Distribution of the toads of the *marinus* complex in South America.

Bufo marinus southern limit indicated by dashed line; +, *B. marinus poeppigii*; x, *B. rufus*; hatched area, *B. ictericus*; stippled areas, *B. paramemis*; solid line denotes limits of *B. arenarum*.

Numbered localities are the populations of the various species that were studied: 1. Paramaribo, Surinam. 2. Sao Paulo, Brasil. 3. Formosa, Argentine Chaco; 4. Tucuman; 5. Cordoba; 6. Buenos Aires and 7. Mendoza, Argentina.

Recent studies (Buzzati-Traverso and Rechnitzer, 1953; Lanza and Antonini, 1955; Dessauer and Fox, 1956; Boyden and Paulsen, 1957; Zweig and Crenshaw, 1957; Van Sande and Karcher, 1960), indicate the value of biophysical tests in elucidating the relationship of closely related species. The studies here reported are an attempt to check independently the status of the species of the *Bufo marinus* complex by an electrophoretic analysis of the seroproteins.

MATERIALS AND METHODS

Sera were analyzed by paper electrophoresis, with paper Whatman 3MM (utilizing Veronal Buffer, 0.05 ionic strength, with 9V per centimeter, run 6 hours at 8° to 10°C. The recognizable bands were cut, eluted and measured by colorimetric methods. Characteristic electrophoretic curves were made by densitometry (Elphor H Densitometer).

All the specimens were received alive in the laboratory, and the sera studied within a week after their extraction. Specimens were from the following localities: *Bufo marinus*, Paramaribo, Surinam; *Bufo ictericus*, Sao Paulo, Brasil; *Bufo paracnemis*, Formosa, Argentine Chaco, and Tucuman, Argentina; *Bufo arenarum*, Tucuman, Cordoba, Mendoza, and Buenos Aires, Argentina.

RESULTS AND DISCUSSIONS

As suggested in a preliminary note (Bertini and Cei, (in press), four fundamental fractions of these toads are easily separated in the patterns by their electrophoretic mobility. Such a serological system presents analogies with those observed in other genera of bufonids and leptodactylids (Cei and Bertini, in press *a*). The fast band, which is indicated as A (or albumin-like fraction) is similar in the four species. The relative concentration (Table 1, and Fig. 2) is 27 per cent in *B. marinus*, but increases in *B. arenarum* (31 per cent) and in *B. paracnemis* (33.5 per cent). However, *B. ictericus* presents a strikingly low A-concentration (14 per cent).

Bufo marinus probably had an Amazonian origin. It is a very versatile, invasive and adaptative species, as indicated by its secondary colonization of many different regions of the world. *Bufo arenarum* is a typical inhabitant of dry or semi-arid areas, and its variable resistance to desiccation has been reported (Cei, 1959). *Bufo paracnemis* is a xerophilic form, characteristic of the hot and seasonally very differentiated arid centro-neotropical realm, extending from Southern Chaco in Argentine to Bahia, Brasil. In contrast, *Bufo ictericus* is recorded as a toad from the eastern humid forest region. Cochran (1955:29) states: ". . . It was interesting to note that well-marked individuals of *paracnemis* are found in the same places as *ictericus*, proving the ability of

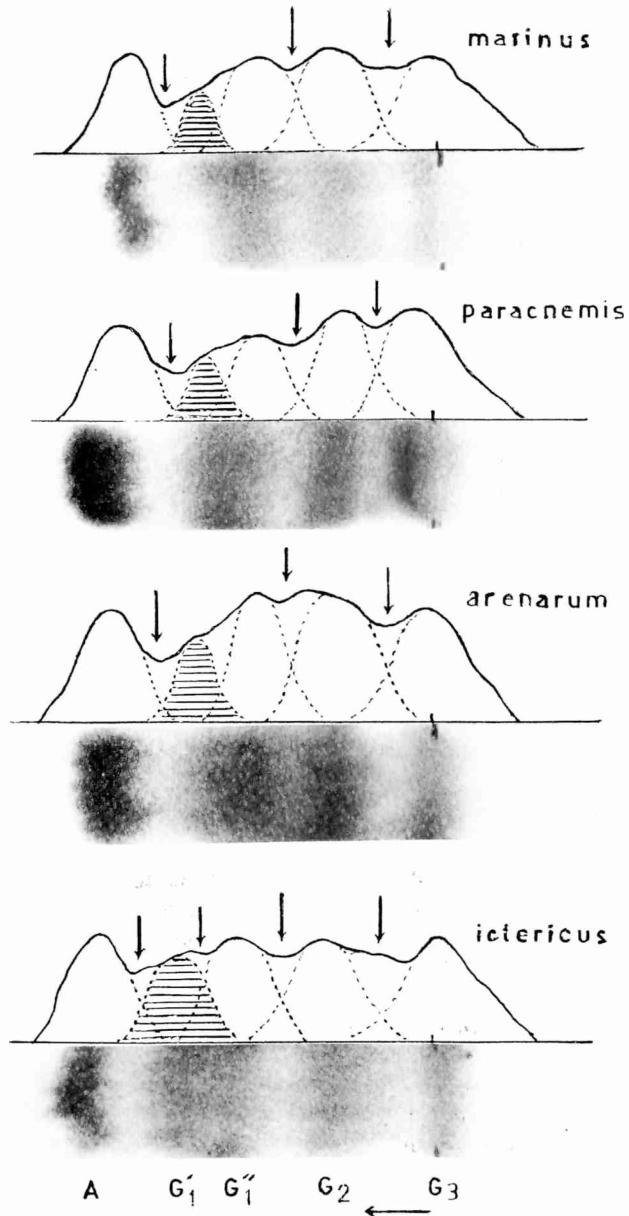


FIG. 2.—Densitometric curves and electrophoretic patterns in the four species studied. Arrows indicate the position of the cuts made for elution.

both to exist as distinct species without intergrading. Apparently *ictericus* frequents streams all of the time, while *paracnemis* roams

widely on the drier parts of the mountain ridges except during the actual breeding season when it also must resort to the water” “. . . . *Bufo ictericus* seems to be completely divided geographically, at least in eastern Brasil, from the northern *marinus* by the species *paracnemis*, which occupies Minas Gerais, Bahia and Pernambuco, living in dry upland regions which are impossible to the more aquatic *marinus* and *ictericus*.”

Thus considering the well-recognized physiological function of albumin as onco-osmotic regulating factor of the body-water, our electrophoretic results fit the ecological position of the toads in the order of their relative water independence. Many authors have demonstrated that the albumin component is lacking or in low concentration in aquatic vertebrates (e.g. Irisawa and Irisawa, 1954). Frieden *et al.* 1957 show electrophoretically that a sudden increase of the albumin peak in anurans is correlated with metamorphosis.

The following globulin fractions, indicated as G_1 , G_2 , G_3 in our patterns, demonstrate other specific characteristics. In the four species the G_1 band can be divided densitometrically into two fractions (G_1 and G_1'). However, only in *Bufo ictericus* are the two fractions clearly separable so that they can be eluted independently and their relative concentrations determined.

The ratio of relative concentration of bands G_1 and G_2 reveals some significant specific trends. The mean of the individual ratios is higher in *B. marinus* (1.24-1.41) than in *B. paracnemis* (1.12-1.16), but very low in *arenarum* (0.73-1.10) where some remarkable populational differences are reported (Bertini and Cei, 1960). If both G_1 fractions of *ictericus* were considered together the ratio G_1/G_2 would be strikingly elevated in this species (1:54).

In some individual samples of *B. paracnemis* the G_3 band is divided into two similar fractions. Due to the variability of such division we have considered both the fractions as one band in all calculations of concentration of G_3 . The G_3 band does not present evident differences between the four species.

The four toads show related electrophoretic patterns and can be clearly distinguished from other species of the genus *Bufo*. For comparison in Fig. 3 the electrophoretic pattern of a Chilean population of *Bufo spinulosus* is presented (Cei and Bertini, in press b). It is obvious that this pattern corresponds to another species of bufonids not in the *marinus* complex.

Bufo paracnemis can be defined as a *B. marinus*-like toad with a very high albumin concentration and a lower ratio of G_1/G_2 globulin bands. *Bufo arenarum* can be distinguished from *B. marinus* and *B. paracnemis* by a very low G_1/G_2 ratio. *Bufo ictericus* presents a very low albumin concentration, an evident division of the

G₁ band into two similar fractions, and the highest G₁/G₂ ratio. *B. ictericus* is therefore the most differentiated form of the group.

Perhaps *B. arenarum* and *B. paracnemis* are evolutionary lines from a *marinus*-like stock, while the peripheral species *B. ictericus* represents an independent evolution from *B. marinus* of a species adapted to less arid conditions than *B. arenarum* and *B. paracnemis*.

TABLE 1.—Relative concentration of the seroprotein fractions in the toads of the *marinus* complex.

SPECIES and NO.	ALBUMIN		GLOBULINS			Ratio, G ₁ /G ₂
	A	G ₁	G ₂	G ₃		
<i>Bufo marinus</i> SURINAM April, 1960	♂ 11 268.±3.7 (18.9-37.7)	24.3±1.4 (18.5-31.0)	21.5±2.9 (17.3-36.1)	26.2±4.0 (20.7-42.6)	1.24	
	♀ 6 27.1±8.7 (19.7-37.6)	26.3±2.6 (22.0-31.0)	17.3±2.5 (14.4-24.0)	27.4±5.3 (20.3-34.9)	1.41	
<i>Bufo ictericus</i> SAO PAULO Nov., 1959	♂ 11 14.2±1.5 (6.0-23.6)	15.2±1.4° (7.6-24.3)	23.9±1.3 (15.5-31.8)	25.8±2.9 (13.1-47.6)	1.54**	
<i>Bufo paracnemis</i> TUCUMAN Dec., 1959	♂ 6 33.5±7.0 (23.9-43.5)	23.5±0.9 (20.0-25.7)	20.4±1.7 (16.9-25.5)	22.8±1.9 (19.2-27.8)	1.16	
	♀ 4 25.6±16.5 (14.8-33.5)	23.5±1.9 (20.9-26.8)	20.7±1.9 (18.8-24.9)	30.1±3.9 (26.1-35.5)	1.14	
FORMOSA March, 1960	♂ 11 23.6±1.3 (7.1-29.2)	26.7±0.9 (20.1-32.5)	26.2±6.7 (16.8-43.9)	24.2±2.6 (17.3-33.5)	1.12	
<i>Bufo arenarum</i> MENDOZA Aug., 1959	♂ 24 31.1±1.0 (18.2-39.8)	21.6±0.7 (14.4-26.5)	27.1±1.3 (15.6-23.7)	27.1±1.3 (17.2-47.3)	1.07	
	♂ 10 23.9±1.1 (20.4-30.1)	23.8±0.8 (19.0-27.1)	21.5±0.7 (17.9-24.7)	30.5±1.9 (21.5-44.2)	1.10	
CORDOBA Aug., 1960	♂ 11 22.5±1.7 (14.9-33.7)	25.7±0.9 (18.4-27.7)	25.1±1.4 (20.4-33.0)	26.3±1.5 (18.9-36.4)	1.02	
TUCUMAN Aug., 1959	♂ 10 27.3±1.1 (22.0-31.3)	22.1±0.6 (19.1-25.0)	26.6±0.6 (24.0-29.5)	23.7±1.0 (16.8-27.1)	0.87	
BUENOS AIRES Aug., 1959	♂ 10 30.2±0.8 (25.8-35.0)	20.6±0.8 (17.3-24.6)	28.0±0.9 (22.7-32.9)	21.1±0.7 (19.0-26.4)	0.73	
	♀ 4 29.1±1.2 (26.3-32.0)	22.6±1.1 (20.4-25.0)	26.8±1.6 (22.1-29.2)	21.6±2.3 (17.0-27.0)	0.84	

*In this species a division of Globulin G₁ into two parts has been demonstrated. The second fraction we choose to call G₁'. It has the following value:

$$\frac{21.7 \pm 0.9}{(16.0-26.3)}$$

$$**(G_1 + G_1' / G_2)$$

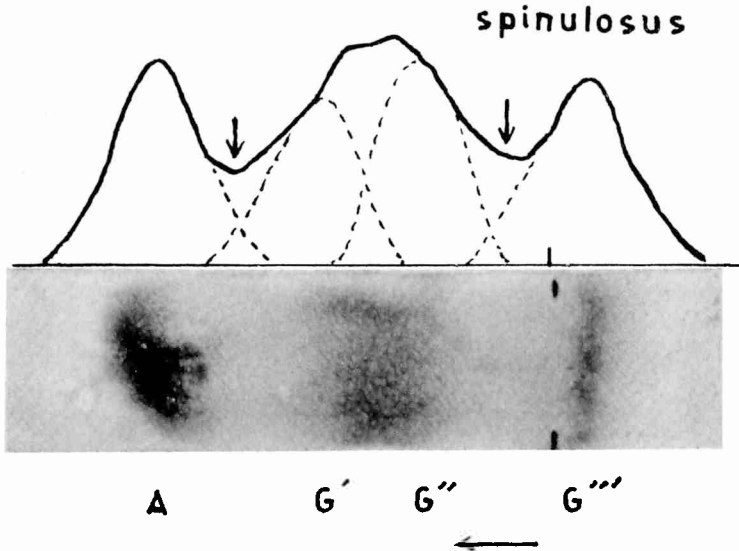


FIG. 3.—Electrophoretic patterns of *Bufo spinulosus* from S. Pedro de Atacama, Chile. This pattern is markedly different from that of the *marinus* complex.

In any case, the seroprotein patterns of *B. paracnemis* and *B. ictericus* support the classification of each form as a distinct species (Cochran, 1955).

The analyzed seroproteins characteristic of these species can be summarized as follows:

	A-concentration (%)	G ₁ band	G ₁ /G ₂ ratio
<i>marinus</i>	high	not well divided	1.24-1.41
<i>paracnemis</i>	high	not well divided	1.12-1.16
<i>arenarum</i>	high	not well divided	0.73-1.10
<i>ictericus</i>	low	divided, two fractions	1.54

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