PLASMODIUM KENTROPYXI N.SP. (APICOMPLEXA: HAEMOSPORINA: PLASMODIIDAE) AND A PLASMODIUM TROPIDURI-LIKE PARASITE IN THE LIZARD KENTROPYX CALCARATA (LACERTILIA: TEIIDAE) IN NORTH BRAZIL

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Summary :

Plasmodium kentropyxi n.sp. is described in the teiid lizard *Kentropyx calcarata* from north Brazil. Young asexual stages and gametocytes are at first polar in the erythrocyte but with elongation, move to a lateral position. Largest meronts seen contained from 30-40 nuclei and conspicuous greenish-black pigment granules located in a distinct vacuole. With growth the gametocytes eventually assume a smooth, curved cylindrical shape, with evenly rounded ends. Pigment is scattered or concentrated around a conspicuous vacuole which is slowly developed as the gametocytes mature. Mature male parasites measured $11.8 \times 4.0 \mu\text{m}$ ($9.6 \times 4.2 - 13.2 \times 3.6 \mu\text{m}$), shape-index 2.9 (2.2 - 5.0), and females $13.5 \times 4.5 \mu\text{m}$ ($12.0 \times 4.5 - 15.0 \times 4.8 \mu\text{m}$), shape-index 3.0 (2.2 - 3.8). Some larger meronts may slightly enlarge the erythrocyte, but most asexual stages and the mature gametocytes rarely do so. A second, *P. tropiduri*-like parasite encountered in *K. calcarata* possessed small rounded or fan-shaped meronts producing from 4-14 merozoites, and spherical to subspherical gametocytes of approximately $6.0 \times 5.0 \mu\text{m}$. The parasite was consistently polar in its position in the erythrocyte.

KEY WORDS : *Plasmodium kentropyxi* n.sp., *Plasmodium* sp. (*tropiduri*-like), *Kentropyx calcarata*, lizards, Brazil.

Résumé : *PLASMODIUM KENTROPYXI* N.SP. (APICOMPLEXA: HAEMOSPORINA: PLASMODIIDAE) ET UN PARASITE PROCHE DE *PLASMODIUM TROPIDURI* DU LÉZARD *KENTROPYX CALCARATA* (LACERTILIA: TEIIDAE) DU NORD DU BRÉSIL

Description de *Plasmodium kentropyxi* n.sp. Les jeunes stades asexués et les gamétocytes sont situés d'abord en position polaire dans l'hématie puis s'allongent et prennent une position latérale. Les plus grands mérontes contiennent de 30 à 40 noyaux et de gros grains de pigment noir-verdâtres dans une vacuole distincte. En mûrissant, les gamétocytes prennent une forme allongée, courbe, avec des extrémités régulièrement arrondies. Le pigment est dispersé ou concentré autour d'une grande vacuole qui se développe lentement.

Les microgamétocytes mûrs mesurent $11,8 \times 4,0 \mu\text{m}$ ($9,6 \times 4,2 - 13,2 \times 3,6 \mu\text{m}$), les macrogamétocytes $13,5 \times 4,5$ ($12 \times 4,5 - 15,0 \times 4,8 \mu\text{m}$). Certains mérontes particulièrement grands peuvent légèrement hypertrophier l'érythrocyte, mais la plupart des stades asexués et des gamétocytes mûrs ne le font pas. Un deuxième parasite observé chez *K. calcarata* présente de petits schizontes ronds ou en forme d'éventail, produisant quatre à 14 mérozoïtes, et des gamétocytes sphériques ou sub-sphériques mesurant environ $6,0 \times 5,0 \mu\text{m}$. Le parasite occupe toujours un pôle de l'érythrocyte et est proche de *Plasmodium tropiduri*.

MOTS CLÉS : *Plasmodium kentropyxi* n.sp., *Plasmodium* sp. (*tropiduri*-like), *Kentropyx calcarata*, lézards, Brésil.

INTRODUCTION

Since 1965, an on-going study of protozoal parasites of the Amazonian fauna in Pará State, north Brazil (Lainson, 1992) has included specimens of the teiid lizard *Kentropyx calcarata* Spix, 1825, and a number of these were found to have large, elongated

gametocytes occupying a lateral position in the mature erythrocytes. They contained abundant greenish-black pigment and a large spherical vacuole which was usually placed to one end of the organism. Continued failure to detect stages of merogony that could confidently be associated with these gametocytes at first precluded identification of the parasite and even raised the intriguing question as to whether or not it might be a species of *Haemoproteus*, unknown in lizards of the New World. The situation was further complicated by the fact that the blood films of some lizards also contained small meronts and round gametocytes of a *P. tropiduri*-like parasite. A continued search eventually revealed large meronts accompanying the elongated gametocytes in blood films from other specimens of *K. calcarata*, confirming our suspicion that the parasite was a species of *Plasmodium*. It is described below as *Plasmodium kentropyxi* n.sp., and a description is also given of the smaller *Plasmodium tropiduri*-like parasite.

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MATERIALS AND METHODS

Specimens of *K. calcarata* were captured by hand in secondary forests principally in the neighbourhood of Capanema (1° 12' S; 47° 11' W), Belém (1° 27' S; 48° 29' W), and the Island of Outeiro, near Icoaraci (1° 18' S; 48° 28' W), all in the State of Pará, north Brazil.

They were bled from the orbital sinus, using finely drawn out Pasteur pipettes, and thin blood films were stained by Giemsa's method. All measurements of the parasites are in μm . They are given as means, followed by the range in parentheses and the shape-index (ratio of length/width). Photomicrographs were prepared using a Zeiss "Photomicroscope III" and Kodak TMX 100 film. *K. calcarata* survives well in captivity on a diet of *Tenebrio* larvae, thus enabling some infections to be studied over prolonged periods.

DESCRIPTION

PLASMODIUM KENTROPYXI N.SP. (Figs a-i; 1-20)

Development is in the mature erythrocytes. In early infections, parasitaemia may be intense and multiple infection of erythrocytes very common (Figs a; 2, 10, 14).

Asexual stages. The smallest forms seen were tiny uninucleate rings of approximately 2.0 x 1.0 in diameter and occupying a polar or lateral position in the erythrocyte (Fig. a). With growth and nuclear division the parasite elongates and assumes a variety of forms. Many of these are amoeboid, with a small number of spiky pseudopodia (Figs a; 1) while others may have a smoother outline: the cytoplasm stains poorly and is highly vacuolated. Pigment is rarely detectable in the uninucleate trophozoite but appears during nuclear division and become clustered as numerous, coarse greenish-black granules in a distinct cytoplasmic vacuole (Figs b-d; 5-7). Most of the growing meronts are lateral in position, sometimes occupying almost the entire length of the erythrocyte and may curve round its nucleus (Fig. d). The largest meronts seen contained approximately 40-50 nuclei. On rare occasions large, semi-spherical meronts may maintain a lateropolar position and force the host cell nucleus to one end of the erythrocyte. No exoerythrocytic meronts were detected in the blood of any of the infected lizards.

Gametocytes. Young gametocytes initially occupy a polar to lateropolar position in the erythrocyte, and at first are broadly ellipsoidal to subspherical in shape (Figs e, f; 8-10). As with other haemosporines stained with Giemsa's stain, the sexes are already differentiated

by the blue cytoplasm of the female and the pink colouration of the male. At this stage small greenish-black pigment grains are scattered in the cytoplasm and a few gametocytes may already show a tiny cytoplasmic vacuole (Fig. e). The parasites elongate to occupy most of the erythrocyte's length and the pigment granules increase in number: they tend to be of a finer texture than those of the meronts. At first the elongated gametocytes are rather irregular in shape: if present at this stage the cytoplasmic vacuole is still very small, and in some lizards it may be completely absent in the majority of the parasites (Figs 11-13). With increasing age of the gametocytes, however, the vacuole appears and, over a period of several weeks, it grows steadily (Figs 15-17) as the parasites plump up and develop smoothly rounded ends. The pigment granules are dispersed throughout the cytoplasm but tend to be concentrated around the fully developed vacuole which may reach from 2-3 in diameter: it has a strikingly "punched out" appearance (Figs g, h; 18,19). Females almost always possess a single vacuole while males, although mostly with one, may occasionally have two or three of variable size (Figs i; 20). In both sexes the vacuoles are situated towards one extremity of the parasite. When mature, as judged by their smooth, curved outline, evenly rounded ends and well developed vacuole, male and female gametocytes measured 11.8 x 4.0 (9.6 x 4.2-13.2 x 3.6) shape-index 2.9 (2.2-5.0), and 13.5 x 4.5 (12.0 x 4.5-15.0 x 4.8), shape-index 3.0 (2.2-3.8) respectively (50 of each measured). The estimated sex ratio in a blood film showing only mature gametocytes was four females to one male (100 randomly selected parasites).

Effects on the host cell. In spite of the large size of fully developed meronts and gametocytes, enlargement of the host cell is minimal. Thus, the mean measurements for 50 cells with large meronts or mature gametocytes was 15.3 x 9.0 and 15.6 x 9.2 respectively, and that of 50 uninfected erythrocytes 15.0 x 9.0: uninfected erythrocytes in the same blood film may, in fact, appear the same size or even larger. Double infections with advanced meronts may increase the length of the erythrocyte (Fig. 7), while erythrocytes containing two mature gametocytes undergo little alteration other than a very slight increase in width (Fig. 14). The nucleus of erythrocytes containing fully developed meronts is of normal appearance, but is usually displaced or slightly indented and may become more rounded. That of cells with mature gametocytes, however, becomes pushed to one side of the erythrocyte and considerably flattened.

Type host. The lizard *Kentropyx calcarata* Spix, 1825 (Reptilia: Lacertilia: Teiidae).

Type locality. The Island of Outeiro, near Icoaraci, Pará (1° 18' S; 48° 28' W), north Brazil, in varzea type

Figs 1-20. – Photomicrographs of *Plasmodium kentropyxi* n.sp. in the lizard *Kentropyx calcarata*. Fig. 1. Amoeboid trophozoites. Fig. 2. Multiple infection of an erythrocyte with three young meronts. Figs 3-6. Growth of developing meronts round the host cell nucleus from a polar to a lateral position: p = pigment, clustered in a cytoplasmic vacuole. Fig. 7. Two well developed meronts in a single erythrocyte. Figs 8-13. Growth of developing gametocytes from a polar to a lateral position in the erythrocyte: these young forms have yet to develop a cytoplasmic vacuole. Fig. 14. Young male (left) and female (right) gametocytes in the same erythrocyte. Figs 15-17. Progressive development of the vacuole (arrows) in a male (left) and two female gametocytes. Fig. 18. Mature female gametocytes with fully developed vacuoles. Figs 19-20. Mature male gametocytes with fully developed vacuoles. Note the tendency of males to produce one, two or even three vacuoles. Bar = 10 µm, and applies to all Figs. Giemsa staining.

Figs a-i. – *Plasmodium kentropyxi* n.sp., in the lizard *Kentropyx calcarata*. Fig. a. Double infection of an erythrocyte with a young ring stage and a binucleate meront. Figs b-d. Nuclear division and growth of the meronts to a lateral position in the erythrocyte: note the clumping of pigment granules in a distinct cytoplasmic vacuole. Figs e, f. Young female and male gametocytes, commencing growth into a lateral position in the host cell. Fig. g. Mature female gametocyte, with fully developed cytoplasmic vacuole. Figs h, i. Mature male gametocytes with one and two vacuoles. Bar = 10 µm. Giemsa staining.

Figs j-r. – *Plasmodium* sp. (*P.tropiduri*-like) in the lizard *Kentropyx calcarata*. Figs j, k. Binucleate and tetranucleate meronts. Fig. l. Mature fan-shaped meront producing six merozoites. Figs m-o. Larger meronts with six, eight and ten nuclei. Fig. p. Mature female gametocyte. Figs q, r. Almost mature female and male gametocytes. Bar = 10 µm. Giemsa staining.

forest and predominantly in sunny clearings. Infection-rates were also high in similar capture sites on the outskirts of Belém, and Capanema.

Prevalence. Of 151 specimens of *Kentropyx calcarata* examined, 102 were infected. In the Outeiro area the infection-rate was 31/39; in Capanema 36/55; and in Belém 35/57. Among the 102 infected lizards, 13 had mixed infections with the *P. tropiduri*-like parasite.

Pathology. All infected lizards appeared to be in good condition and survived well in captivity, including those with very high parasitaemia.

PLASMODIUM SP. (*TROPIDURI*-LIKE) (Figs j-r; 21-28)

The following description is based on rather light infections seen in specimens of *K. calcarata* with apparently pure infections and others that also harboured *P. kentropyxi* n.sp.

Asexual stages. These were compact little parasites, consistently occupying a polar or latero-polar position in the erythrocyte. Early uninucleate or binucleate stages were impossible to differentiate from similar stages of *P. kentropyxi*, but with continuing division most of the parasites maintain a round to ovoid shape and have the nuclei arranged at the periphery of the meront in rosette fashion (Figs k, m, n; 21-23). Others were fan-shaped (Figs l; 24, 25). Segmented meronts measuring approximately 4 x 4 to 5 x 4 produced only

four or six merozoites, while the largest undivided ones seen were only 5 x 4 to 6 x 5 and contained 12-14 nuclei (Figs o; 25). Scanty, fine granules of dark pigment were visible in the larger meronts but were often difficult to detect without the use of polarized light. No exoerythrocytic meronts were detected in any of the blood films.

Gametocytes. These were also restricted to a polar or latero-polar position in the erythrocyte, and were usually spherical to subspherical, sometimes assuming a kidney shape due to pressure against the host cell nucleus (Figs p-r; 26-28). Presumably mature forms, which sometimes possessed a small cytoplasmic vacuole, had a mean measurement of 6.0 x 5.0 (5.0 x 3.7-6.2 x 6.2) shape-index 1.2 (1.0-1.3) for the females and 5.9 x 4.9 (5.0 x 5.0-6.2 x 5.0) shape-index 1.2 (1.0-1.6) for the males: 15 of each measured. The two sexes showed the usual colour difference when stained with Giemsa's stain. Fine grains of dark yellowish-black pigment were scattered in the cytoplasm.

Effects on the host cell. Infected erythrocytes were not enlarged or deformed, either by the largest meronts or the mature gametocytes. The host cell nucleus was sometimes slightly displaced, indented or otherwise deformed, by the mature gametocytes.

Host. The lizard *Kentropyx calcarata* Spix, 1825 (Reptilia: Lacertilia: Teiidae).

Figs 21-28. *Plasmodium* sp. (*P. tropiduri*-like) in the lizard *Kentropyx calcarata*. Figs 21-23. Rounded meronts. Figs 24, 25. Fan-shaped meronts. Number of merozoites produced by both forms, 4-14. Fig. 26. Mature female gametocyte. Figs 27, 28. Mature rounded and kidney-shaped male gametocytes. Bar = 10 μ m, and applies to all Figs. Giemsa staining.

Locality. Infected lizards were found in all three capture sites in Pará State, north Brazil.

Prevalence. Of the 151 lizards examined, 20 were infected: seven were seemingly pure infections, while 13 were mixed with *P. kentropyxi* n.sp. Infection-rates for the three capture sites were 6/39 in Outeiro, 6/55 in Capanema and 8/57 in Belém.

Pathology. None of the infected lizards showed any ill effects from mixed or pure infections.

DISCUSSION

The morphology of the saurian *Plasmodium* species is immensely varied, even in a given species during the course of the infection. Provision of a simple and clear-cut taxonomic key based purely on morphology has consequently been extremely difficult.

When only 23 saurian species of *Plasmodium* were generally accepted, Garnham (1966) divided them into three subgenera. In the subgenus *Sauramoeba* he placed "...Those species with large schizonts..." , while those "...with small schizonts" were grouped in the subgenus *Carinamoeba*. At the time only a single species of *Plasmodium* had been described in snakes, and this was placed in the subgenus *Ophidiella*, with Garnham's admission that this unusual host was "...the sole justification of introducing a new name".

Garnham was only too well aware that "...the number of merozoites in a schizont of the larger species is quite often unstable" and that morphologically the saurian malaria parasites "...do not fall into the clear-cut subgeneric groups, so distinctive of the avian and mammalian plasmodia". Nevertheless, these subgenera have continued to form a useful basis for taxonomy in more recent times, when the number of described saurian plasmodia has approached almost a hundred. Telford (1988) used them in an elaborated classification and, appreciative of Garnham's admission regarding the limitations of his classification, erected further subgenera based on a wider range of criteria, largely morphological, involving both asexual stages and gametocytes.

Following this classification, *Plasmodium kentropyxi* n.sp. clearly belongs to the subgenus *Sauramoeba* and needs to be distinguished from the New World species already included in this group: namely, *P. diploglossi* Aragão & Neiva, 1909 (type); *P. cnemidophori* Carini, 1941; *P. beltrani* Peláez & Perez-Reyes, 1952; *P. brumpti* Peláez & Perez-Reyes, 1952; and *P. achiotense* Telford, 1972.

Unlike the large meronts and mature gametocytes *P. kentropyxi* n.sp., those of *P. diploglossi* considerably enlarge the host erythrocyte, and sometimes may com-

pletely encircle the host cell nucleus. Although the pigment may be clumped in mature meronts, it does not occupy a distinct vacuole as seen in the former parasite. The mature gametocytes of *P. diploglossi* are much broader than those of *P. kentropyxi* n.sp., and do not assume the smoothly curved cylindrical shape with evenly rounded ends. Like the meronts, they may sometimes almost encircle the host cell nucleus. Although a small cytoplasmic vacuole may be present in some gametocytes, it is not as consistent and pronounced as that of *P. kentropyxi*.

The meronts of *P. cnemidophori* are usually polar in position, rounded in shape, and may produce over 100 merozoites. Their pigment is not located in a distinct vacuole. While the gametocytes of this parasite are similar to those of *P. kentropyxi* in that they are elongated and lateral in position, they do not assume the distinctive form of those described for *P. kentropyxi*. Large meronts and mature gametocytes visibly enlarge the erythrocyte.

Meronts of *P. beltrani* are lateral in the erythrocyte but produce only from 23-29 merozoites. The gametocytes, particularly the females, are very much broader and more bulky than *P. kentropyxi* n.sp., and may be both lateral (elongated) and polar (rounded) in position.

The meronts of *P. brumpti* may be lateral (elongated) or polar (more rounded) in the red blood cell, and produce only from 15-20 merozoites. The gametocytes may be lateral (elongated) or polar (spherical to reniform). The larger meronts and mature gametocytes of both *P. beltrani* and *P. brumpti* cause enlargement of the erythrocyte to an extent not seen in *P. kentropyxi*. *P. achiotense* is readily differentiated by its round to ovoid gametocytes. They occupy a polar position in the red blood cells, which are substantially enlarged and deformed.

Plasmodium tropiduri was first found by Carlos Chagas in the iguanid lizard *Tropidurus torquatus* from Bicudos, Minas Gerais State, Brazil, and later described by Aragão & Neiva (1909). Unfortunately no type slides were preserved. Garnham (1966) placed the parasite in the subgenus *Sauramoebae* in spite of its small meronts "...of about 6-8 μ in diameter". Since that time the host range of *P. tropiduri* sensu lato has been extended not only to several species of the genus *Anolis* within the family Iguanidae (Telford, 1988), but to lizards in families as distinctly different as the Teiidae (Walliker, 1966) and the Scincidae (Lainson & Shaw, 1966). In an attempt to put some order into the increasing confusion, Telford (1979) gave a more elaborated definition of the species *P. tropiduri* and suggested its division into a number of subspecies parasitizing different species of the iguanid genera *Tropidurus* and *Anolis*, based on small morphological differences. He placed these subspecies in his newly

erected subgenus *Lacertamoeba*, together with other plasmodia "...characterized by medium sized schizonts and gametocytes". He cautiously commented, however, that his taxonomic arrangement "...will certainly be modified once more basic, non-morphological data become available" (Telford, 1979), and that "The classification.....should be tested by studies on sporogony and exoerythrocytic schizogony and by biochemical procedures to determine the relevance of morphometrics to systematics of the Haemosporidia" (Telford, 1988). At present we feel it only possible to regard the small polar meronts and gametocytes described here in *K. calcarata* as those of a *P. tropiduri*-like parasite (sensu Telford, 1979) until more precise methods are available with which, if necessary, to separate similar parasites found in different lizard genera, and in particular those recorded in families of lizards other than the Iguanidae.

Ayala (1977) and Telford (1988) have both drawn attention to confusion that can arise following the production of "crisis stage schizonts" that may appear at peak infection of saurian plasmodia. These may be smaller than those seen in infections of lesser intensity, and produce fewer merozoites. While some smaller than normal meronts may well be produced by *P. kentropyxi* n.sp. during peak infection, we do not consider that the parasites we describe here as *P. tropiduri*-like represented such stages because they were encountered in lizards with both active and chronic infections of *P. kentropyxi* n.sp., and in some lizards occurred in the apparent absence of of the latter parasite.

Finally, in our description of the gametocytes of *P. kentropyxi* n.sp., we have mentioned the appearance and gradual growth of the cytoplasmic vacuole that is such a conspicuous and consistent feature of the mature sexual stages. The fact that a vacuole appeared to be absent in 100 % of otherwise quite well developed gametocytes in some lizards (Figs 11-13) at first made us think we might be dealing with yet another parasite and prompted the preparation of a sequence of blood films from two such animals over a period of 24 days. On the third day of these observations a very small number of the parasites now showed a tiny vacuole (Fig. 15); on day 7 the number had risen to approximately 70 %, although the vacuoles were still small (Fig. 16); on day 12 the number was 75 %; on day 24 virtually all the gametocytes now possessed a conspicuous vacuole (Fig. 17). Fully developed gametocytes with a large vacuole (Figs 18-20) were first seen on day 28. It seems that growth of the vacuole is part of the maturation process of the gametocytes, which appears to be a slow affair taking over a month to complete. During this period the morphology of the early, non-vacuolated stages differs considerably from that of the mature parasites: a clear indication of the

hazard in basing diagnostic conclusions and descriptions on a single blood sample from one lizard.

The ultrastructure of gametocytes and merogonic stages of the *P. tropiduri*-like parasite of *K. calcarata* will be described separately (Paperna & Lainson, in preparation).

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