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Effect of Season on Oral and Gastric Nematodes in the Frillneck Lizard from Australia

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ABSTRACT: The prevalence and intensity of nematodes from the stomach and the prevalence of nematodes in the oral cavity were recorded in the frillneck lizard, *Chlamydosaurus kingii,* in Kakadu National Park (Australia) between 1991 and 1994, in order to determine whether or not a seasonal pattern was evident. Seven species were recorded; *Strongyluris paronai, Skrjabinoptera goldmanae, Abbreviata confusa, Abbreviata anomala, Physalopteroides filicauda, Kreisiella* sp. and a species of Trichostrongyloidea. Only *S. paronai* showed a seasonal pattern. Only larval *S. paronai* occurred in stomach samples and larvae of this species occurred seasonally in the oral cavity of *C. kingii,* substantiating earlier findings that this genus migrates within the host. The occurrence of *S. paronai* in the oral cavity coincided with the highest prevalence and intensity of *S. paronai* in stomach samples. This shows a previously unrecorded aspect in the life cycle of this nematode species. Prevalence of *S. paronai* was positively correlated with ambient temperature which is highest in the months preceding the monsoonal rains, and coincides with an increase in field metabolic rate and general activity of the host.

Key words: Ambient temperature, *Chlamydosaurus kingii,* frillneck lizard, monoxenous, nematodes, oral cavity, seasonal tropics, *Strongyluris paronai.*

Many reptiles posses a diverse gastrointestinal nematode fauna, but little is known of the relationship of the nematodes and their reptile hosts with the physical environment. The prevalence (number of hosts infected/by number of hosts examined) and intensity (number of parasite specimens per infected host) (after Margolis et al., 1982) of nematodes in reptiles may be affected by previous parasite exposure, as well as by rainfall, parasite life cycles, foraging strategy and seasonality of intermediate hosts (Aho, 1990).

The frillneck lizard, *Chlamydosaurus kingii* (Agamidae), is a large arboreal lizard that inhabits woodland and open forest of northern Australia. Seasonality in the life-history of this species is evident. The wet season is characterised by conspicuous behaviour and reproduction (Shine and Lambeck, 1989; Griffiths and Christian, 1996). In the dry season there is a decrease in activity coinciding with a reduction in field metabolic rates (Christian and Green, 1994) and body temperatures (Christian and Bedford, 1995). Frillneck lizards have a diverse gastrointestinal nematode fauna (Jones, 1994), similar to that of other Australian agamids in northern Australia (Jones, 1986).

The purpose of this paper is to report the monthly prevalence and intensity of stomach nematode fauna present in *C. kingii.* From this, we examine the relationship between prevalence and intensity of this fauna with rainfall, temperature and food consumption of the host.

All field work was done between April 1991 and April 1994 at Kapalga Research Station in Kakadu National Park (12°43′S, 132°26′E), 250 km east of Darwin (Northern Territory, Australia). This region experiences a distinct seasonal monsoonal climate, with high maximum daytime ambient temperature (33 C), and high rainfall (1,450 mm/yr) which falls between October and May (Bureau of Meteorology, Darwin, Australia).

Lizards were captured by hand at regular intervals. Each lizard was weighed (g), their snout-vent length measured (SVL mm), and the oral cavity was inspected for the presence of nematodes. Nematodes present in the oral cavity were initially collected and identified, but collection ceased in October 1992 because all specimens

TABLE 1. Prevalence and intensity of adult and larval nematodes from 226 stomach samples of *Chlamydosaurus kingii* in the Northern Territory, Australia.

Species	Adult		Larval	
	Prevalence (%)	Intensity (range)	Prevalence (%)	Intensity (range)
Strongyluris paronai	—	—	24	4.64 (1–63)
Skrjabinoptera goldmanae	9	2.4 (1–10)	—	—
Abbreviata confusa	4	1 (1)	—	—
Abbreviata anomala	1	1 (1)	—	—
Physalopteroides filicauda	2	1.2 (1–2)	—	—
Kreisiella sp.	—	—	<1	2 (1–2)
Trichostrongyloidea	—	—	<1	1 (1)

were identified as being a single species. The prevalence and intensity of nematodes in stomachs of lizards were determined by stomach flushing, which began in April 1992. Lizards were released immediately after stomach flushing at the point of capture. Nematodes were fixed in 10% formalin, cleaned, cleared with chlorolactophenol for examination and subsequently stored in 70% alcohol. Representative specimens of each species were deposited in Western Australia Museum (Perth, Western Australia, Australia).

Seasonal data were examined by pooling samples into four 3 mo periods (January to March, April to June, July to September, October to December). All tests were analysed with the $P < 0.05$ significance level, using the program Statistix® (Analytical Software, Tallahassee, Florida, USA). Differences in nematode prevalence between years and among seasons were tested using Kruskal-Wallis ANOVA for proportions (Zar, 1984). The difference in nematode intensity between years was tested using a two sample *t*-test (1992 and 1993 data), and among seasons (years pooled) using a one-way ANOVA (Zar, 1984). All intensity data were tested for normal distribution using a Wilk-Shapiro test (Zar, 1984) and were log-transformed if they departed from normality. The relationship between monthly prevalence and intensity of *S. paronai* in the stomach and oral cavity, environmental variables and food availability were examined using Spearman Rank correlations (Zar, 1984).

Seven species of nematodes were collected from 226 stomach samples (Table 1). *Strongyluris paronai* was the most prevalent species. *Skrjabinoptera goldmanae* occurred less frequently, and *A. confusa, A. anomala, P. filicauda, Kreisiella* sp. and a species of Trichostrongyloidea occurred at low prevalences and intensities. All *S. goldmanae, A. confusa, A. anomala* and *P. filicauda* were adults. All *S. paronai* specimens examined were large (16 to 25 mm) larvae. There was no size difference between larvae found in the oral cavity and those from the stomach. The decomposed condition of many nematodes precluded precise larval staging. Those larvae whose stage could be ascertained were fourth-stage larvae, many of which were in the process of moulting to adults. Larval *S. paronai* were identified by the degree of development of the sexual organs, where their condition permitted, and by the presence of lateral somatic alae, which are absent in adult nematodes.

The two most abundant nematode species (*S. paronai* and *S. goldmanae*) showed considerable variation in monthly prevalence and intensity (Fig. 1). *Strongyluris paronai* exhibited a seasonal pattern in prevalence and intensity. In both years high prevalence and intensity values were recorded from August to November, and low values from February to June. In each

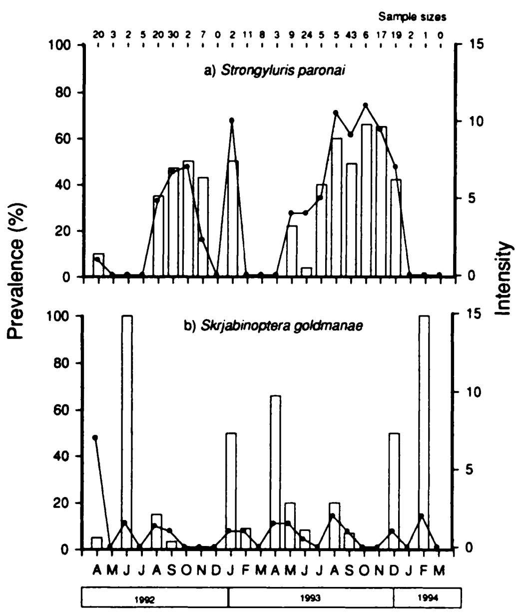

FIGURE 1. Monthly prevalence and intensity of stomach nematode fauna (a) larval and immature *Strongyluris paronai* and (b) adult *Skrjabinoptera goldmanae* obtained by stomach flushing of *Chlamydosaurus kingii* (n = 226) in the Northern Territory, Australia. Bars represent prevalence and lines are intensity.

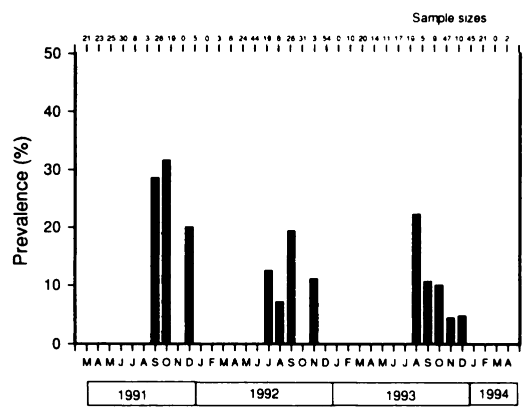

FIGURE 2. Monthly prevalence of larval and immature *Strongyluris paronai* in the oral cavity of *Chlamydosaurus kingii* (n = 630) over a 3-yr-period in the Northern Territory, Australia.

year there was some variation in the months in which *S. paronai* was first and last recorded. Prevalence of *S. paronai* did not vary significantly between the two years (H = 3.509, P = 0.173), but was significantly higher in the two last quarters of the year (H = 11.55, P = 0.009). Mean intensity was similar between years (t = 1.36, P = 0.177), and among the four seasons (years combined, F = 0.110, P = 0.949). Prevalence of *S. goldmanae* remained constant between years (H = 0.118, P = 0.913) and among seasons (years combined, H = 1.416, P = 0.492). Similarly, the intensity of *S. goldmanae* between years and among seasons was not significantly different (years, t = 0.02, P = 0.903; seasons, F = 0.560, P = 0.666).

Strongyluris paronai was the only species of nematode present in the oral cavities of *C. kingii*; it was found in the mouth of 40 of 630 individuals examined. The prevalence of *S. paronai* showed a strong seasonal pattern over the 3 yr sampling period. *Strongyluris paronai* was detected in the oral cavity of *C. kingii* between July and December in three consecutive years, although there was some variation in the first and last months of detection between years (Fig. 2). The monthly prevalence of *S. paronai* in the oral cavity of *C. kingii* ranged from 0 to 34% in these months, and was significantly correlated to the monthly prevalence of larval *S. paronai* collected from stomach samples (months pooled n = 12; r = 0.85, P < 0.001).

In order to examine the effects of environmental conditions or availability of food on the monthly prevalence and intensity of *S. paronai* in the stomach samples of *C. kingii*, we correlated *S. paronai* monthly prevalence and intensity with the following variables; monthly volume of food from *C. kingii* stomach samples (Christian et al., 1996), and monthly mean ambient temperature and rainfall (Jabiru, Bureau of Meteorology). A significant positive correlation between the prevalence of *S. paronai* and mean ambient temperature was recorded (months pooled n = 12; r = 0.76, P = 0.004). None of the remaining variables showed any significant relationships with either prevalence or intensity of *S. paronai*.

All of the nematode species collected in this study, apart from *Kreisiella* sp., are previously reported from the stomach of this host (Jones, 1994). *Kreisiella lesueurii* was described from the agamid genus *Pogona* (Jones, 1986).

Stomach-flushing is a useful technique which enables stomach helminth fauna to be examined without harming the host. However, it may underestimate helminth numbers, particularly in such species as *S. goldmanae,* in which adults are characteristically firmly attached with their anterior ends buried in the stomach wall (Mawson, 1970). This method of sampling is unlikely to record species that inhabit the intestine, where *S. paronai* have been recovered previously in this host (Jones, 1994). This may account for the lower prevalence and intensity of these two species, and the absence of adult *S. paronai* in the present study compared with results reported by Jones (1994).

Seasonality in the intensity of gastrointestinal nematode fauna has been reported in other lizard species (Bursey and Golberg, 1992). Higher monthly intensity of adult *Spaulidogon giganticus,* was recorded in the lizard *Sceloporus jarrovii* in summer months, with larvae having higher intensities in winter months. Such seasonal changes may be an adaptation by the parasite to the environment, ecology and physiology of the host, which maximise the chances of survival and successful reproduction. Heterakid nematodes like *S. paronai* are monoxenous, but details of the life-cycle of this species have not been elucidated. *Strongyluris* spp. occur in the intestine (*S. paronai*) or the rectum (*S. brevicaudata*) of their hosts (Jones, 1994; Bain, 1970). The collection of larval *S. paronai* from the stomach and the oral cavity substantiate earlier findings which indicate that this species undergoes a migration within its reptile host (Bain, 1970). *Strongyluris paronai* was originally described from specimens in the nasal fossae of *Amphibolurus muricatus* by Stossich (1902); it is not possible to ascertain from this description whether these were mature specimens, but the small size (male = 12 mm, female = 15 mm) indicates that they were probably immature adults. Four larval *S. paronai* were collected from lungs of *Pogona microlepidota* (H. I. Jones, unpubl. data). Whether or not such movements of the nematode follow a natural pattern of migration within the host and are a true adaptation to survival, cannot yet be ascertained.

The prevalence of *S. paronai* increased with ambient temperatures, becoming more prevalent in the months which precede the monsoonal rains. The presence of *S. paronai* in the months with lower ambient temperatures, suggests that ambient temperature is not the only factor contributing to this relationship. Frillneck lizards show a considerable increase in activity during the months of high prevalence of *S. paronai* in the oral cavity (Griffiths and Christian, 1996). This period coincides with an increase in field metabolic rate (Christian and Green, 1994), possibly increasing the rate of infection of this monoxenous parasite by increased activity and thus foraging by the host. Alternatively, it is possible that it is related to the biology of *S. paronai,* there being seasonality in some unknown life-cycle event.

These results illustrate that the nematode fauna of the frillneck lizard in Kakadu National Park is relatively similar to that in other populations studied. However, the specific relationships between the frillneck lizard and the nematode species' life cycles in the monsoonal tropics of northern Australia remains unclear. A distinct seasonal pattern is evident in *S. paronai,* and that life cycle involves migration to the host's oral cavity. However, the significance of this also remains unclear.

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