

SHORT NOTES

HERPETOLOGICAL JOURNAL Vol. 5, pp. 195-199 (1995)

PREVALENCE OF ENDOPARASITES
IN ROUND ISLAND REPTILES

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Round Island is a half-eroded volcanic cone rising out of the 50 m deep coastal shelf 21 km NNE of Mauritius in the Indian Ocean. This 151 hectare outcrop of tuff holds a reptile population consisting of three species of gekkonid lizards, three species of skink and two species of bolyeriid snakes (Vinson & Vinson, 1969; Bullock, 1986). Of these eight species, four, the gecko *Phelsuma guentheri*; the skink *Leiolopisma telfairii* and the bolyeriid snakes *Casarea dussumieri* and *Bolyeria multocarinata*, are found solely on Round Island, whilst two others (the gecko *Nactus serpensinsula* and the skink *Scelotes bojerii*) also occur on smaller nearby islets, with *S. bojerii* having a further small relict population on mainland Mauritius. Fossil evidence shows that most of these reptiles previously occurred on mainland Mauritius (Arnold, 1980); therefore, Round Island represents a last refuge for an important relict herpetofauna.

It is thought that this unique fauna has only survived due to the lack of carnivorous mammals; however, the introduction of rabbits (*Oryctolagus cuniculus*) and goats (*Capra hircus*) sometime between the early 1600's and 1840's has led to decimation of the native vegetation and severe loss of soil cover (North & Bullock, 1986; Bullock, 1986). Rabbits and goats have now been eradicated (Merton, 1988) but despite the subsequent increase in soil cover, one of the endemic snakes (*Bolyeria multocarinata*) has not been seen since 1975 and is now almost certainly extinct (Bullock, 1986). The reptile fauna remains extremely endangered and at risk from ecological disturbances such as introduction of rats and mice, introduction of non-indigenous weed species, and cyclone damage.

Parasitic infections of reptiles have been studied by numerous authors, and their pathological implications are fairly well known (see Cooper & Jackson, 1981). It has recently been shown that parasitic infection may cause a major loss of reproductive capacity in wild reptiles (Schall & Dearing, 1987; Pence & Selcer, 1988). Papers have been published concerning parasite prevalence in reptiles (see Telford, 1970) and descriptions of new species often contain prevalence data. There appears to be no information pertaining to the parasites of Round Island species in the refereed literature. Goldberg & Bursey (1990) undertook a study of en-

doparasite prevalence in the endangered island night lizard (*Xantusia riversiana*) and found that prevalence of the gall bladder protozoon *Eimeria noctisauris* was higher than that of similar parasites in similar mainland reptiles. These results suggest that parasitic infection is naturally elevated in island populations, and therefore represents another ecological pressure on these species.

The present study was undertaken as part of a Raleigh International expedition to Round Island (Daszak, 1994). The aims were to ascertain as far as possible the prevalence and identity of the endoparasites infecting the populations of Round Island reptiles and to deduce the possible impact of parasitism on this fragile fauna. In the present paper, information on prevalence of coccidial infection in wild reptiles is collated from 150 sets of data in 44 papers published between 1923 - 1994 describing new species of coccidia. These data are used to investigate the influence of insularity and other factors on coccidial infections of reptiles.

Faecal samples were collected between 1 August and 15 September 1993 during a Raleigh International expedition to Mauritius, Round Island and Rodrigues. Due to the rarity of the animals it was considered unethical to kill specimens; therefore, presence of infection was ascertained by examination of faecal samples for parasite eggs. Reptiles were captured by hand and placed in cloth bags for up to two days and subsequently released at the site of capture. Faecal samples were removed from the bags, split into two and portions placed in one of either 5% aqueous formalin (to fix helminth eggs) and 2.5% aqueous potassium dichromate (to allow sporulation of coccidian oöcysts for subsequent identification). Suspensions of faeces were examined in the UK by wet mounts on a Zeiss photomicroscope. Samples which showed no parasite ova were filtered and treated with saturated saline to float off parasite eggs (see Whitlock, 1948). It was decided that counts of parasite eggs or oöcysts present in individual samples or incidence scores would yield no useful information, since counts may vary over the course of a single day or throughout an infection (Levine, 1942; Stanton *et al.*, 1992).

Table 1 shows the results of the faecal survey. In addition to the data in Table 1., dual infections of two species of coccidia were observed in 16.7% (2/12) *P. guentheri*, 33.3% (2/6) *P. ornata* and 31.2% (5/16) *N. serpensinsula*. Dual infections of coccidia and helminths were observed in 11.1% (2/18) *S. bojerii* and 20.0% (2/10) *C. dussumieri*. 40.0% (4/10) specimens of *P. ornata* of mainland Mauritius origin (Flic en Flac, Rivière-noire) contained coccidial oöcysts, with 0.0% (0/10) containing helminth eggs.

Identification of the helminth parasites was hampered since internal examinations were not possible and therefore no adult worms could be retrieved. Identification down to class or genus was possible using egg morphology. In 62.5% (10/16) of the *L. telfairii*

TABLE 1. Prevalence of endoparasite infection in Round Island reptiles.

Reptile species	% prevalence coccidia	% prevalence helminths	% infected (total)
Gekkonidae			
<i>Phelsuma guentheri</i>	33.3 (4/12)	0 (0/12)	33.3 (4/12)
<i>Phelsuma ornata</i>	66.7 (4/6)	0 (0/6)	6.6 (4/6)
<i>Nactus serpensinsula</i>	50 (8/16)	0 (0/16)	50 (8/16)
Scincidae			
<i>Leiolopisma telfairii</i>	0 (0/40)	40 (16/40)	40 (16/40)
<i>Scelotes bojerii</i>	61.1 (11/18)	44.4 (8/18)	66.6 (12/18)
<i>Cryptoblepharus boutonii</i>	No specimens collected from this species		
Bolyeriidae			
<i>Casarea dussumieri</i>	60 (6/10)	20 (2/10)	60 (6/10)
<i>Bolyeria multocarinata</i>	No specimens collected from this species		

samples positive for helminths, an unidentified species of nematode was found, and in 37.5% (6/16) of the positive samples, one species of the Order Oxyurida. One hundred percent (8/8) of the *S. bojerii* samples positive for helminth ova appeared to represent an unidentified oxyurid species, similar to those from *Leiolopisma telfairii*. Helminth eggs from *C. dussumieri* samples belong to an unidentified species of nematode.

Measurements of the coccidian oöcysts were taken and it appears that the majority of the species found have not previously been described (Daszak & Ball, in prep.). One hundred percent (6/6) of the coccidia-positive *P. guentheri* faeces contained a subspherical *Eimeria* species, and 33.3% (2/6) of the positive samples contained *Isospora* oöcysts mixed with the *Eimeria* sp. All (6/6) of *P. ornata* *Eimeria*-positive samples contained oöcysts which were subspherical and 33.3% (2/6) of the samples contained both the *Eimeria* sp. and a subspherical *Isospora* species. It is interesting to note that 16.7% (2/12) of the mainland Mauritius *P. ornata* samples contained three different groups of oöcysts: a subspherical *Eimeria* sp. similar to those from the Round Island samples, a more ellipsoidal *Eimeria* sp. with larger oöcysts and an *Isospora* species similar to those from the Round Island samples. All (8/8) coccidia-positive *N. serpensinsula* samples contained subspherical *Eimeria* oöcysts, with 62.5% (5/8) of these positive samples showing the presence of a spherical *Isospora* species. All *S. bojerii* oöcysts examined were of a similar morphology (ellipsoidal *Eimeria* sp.) and measurement range. The coccidium found in samples from *C. dussumieri* is a *Caryospora* sp. and has a fairly uniform morphology and size range between samples. *Caryospora* spp. have a life cycle which alternates between asexual division in muscle cysts within a prey host, and the sexual reproduction within the intestine of a predator host

(see Upton, Current & Barnard, 1986). It is probable that the asexual cycle occurs within the skeletal muscle of one of the Round Island lizard species which appear to be the snake's main prey (Bullock, 1986; Jones, 1988; Cundall & Irish, 1989); however, none were examined for cysts.

In addition to the data in Table 1, 2.5% (1/40) *Leiolopisma telfairii* faecal samples contained very low numbers (two observed) of coccidian oöcysts. The oöcysts were measured and appeared conspecific with the *Eimeria* species found in *Scelotes bojerii*. *L. telfairii* was observed to eat *Scelotes bojerii* during the course of this study (Daszak, 1994) and it is probable that the presence of these oöcysts is spurious. Oöcysts of an *Adelina* species were identified in 18.7% (3/16) of *Nactus serpensinsula*. Measurements of these oöcysts fell within the range of an *Adelina* species (Daszak & Ball - in prep.) isolated from Round Island centipedes (*Scolopendra abnormis* sp. nov. - Lewis & Daszak, in prep.), and it is likely that *N. serpensinsula* preys on these.

To make sense of the prevalence data it is important to realise the limitations of faecal egg surveys. Firstly for helminth infections, it may be that not all females present in the host intestine are laying eggs at the time of sample collection. Secondly, for the coccidian infections, it is known that oöcyst counts (and by deduction the number of individuals passing detectable numbers of oöcysts) vary over the duration of an infection and throughout each day (Levine, 1942; Stanton *et al.*, 1992). Therefore, estimates of prevalence will tend to be slightly lower than actual prevalence.

Goldberg & Bursey (1990) showed that prevalence of *Eimeria noctisauris* infection in the island night lizard *Xantusia riversiana* from small islets off California is higher than the prevalence of similar eimeriid parasites from similar mainland lizards (comparison of three sets of island lizard prevalence data with seven

sets of mainland lizard prevalence data). The present study investigates this phenomenon further - by collating the prevalence data of 105 species of coccidia in 2038 individual reptiles ($n = 2205$ due to some individuals harbouring more than one species). The sources of data were 44 papers describing new species of reptile coccidia published between 1923 and 1994 in addition to the data from Round Island reptiles presented in the present paper. The scope was worldwide, with data from reptiles of Africa, North and South America, Europe, Russia, India, the Far East and islands in the Pacific, Indian and Atlantic Oceans. Infection was assessed by microscopic examination of faeces.

Reptiles show a wide range of prevalences with often 50.0 - 100% reported. For *Caryospora* species from snakes the mean prevalence is 58/151 (38.4%). For lizard *Eimeria/Isospora* spp. the mean prevalence from 75 sets of data is 677/2051 (33.0%). Coccidial prevalence in island-dwelling lizard data is higher (43.6%, $n=626$) than mainland species (26.7%, $n=1425$). However, the possibility that host insularity leads to elevated levels of coccidial infection must be questioned, since the mainland data include a high proportion of desert-dwelling lizards (62.9% of the total number of mainland reptiles). It is known that coccidial oöcysts require moisture for survival and that a higher percentage will survive under higher relative humidity (Fayer & Reid, 1982). Furthermore, it has been suggested that prevalence of coccidial infection in desert-dwelling reptiles is limited by the low resistance of oöcysts to desiccation, and therefore low numbers of viable oöcysts present in the environment for infection of new host individuals (Ovezmukhammadov, 1974).

In order to test the influence of insularity and desert habitation on prevalence of infection, the data in the present study have been divided into three groups. The snake data have not been analysed by habitat since there is a paucity of information on *Caryospora* prevalence in desert- and island-dwelling hosts. Island host lizards (defined as having been captured on a landmass with an area of less than 2000 km²) showed a prevalence of 275 infected out of 626 examined (43.9%). Desert mainland hosts were defined as having been captured in a region having an average annual precipitation of less than 250 mm and in a landmass of area greater than 2000 km², and revealed a prevalence of 134 infected out of 896 individuals examined (15.0%). Non-desert mainland hosts (originating from area of land greater than 2000 km² and with more than 250 mm rainfall p.a.) had a prevalence of 243 out of 529 infected (45.9%). All of the islands studied (including those in the California channel studied by Golberg & Bursey, 1990) had rainfall substantially greater than 250mm per annum, and therefore cannot be classified as desert habitat (Moore, 1975). Chi-squared analysis showed that the three sets of data differed highly significantly ($\chi^2=137.4$, $df=2$, $P<0.001$). Testing the

island against the non-desert mainland data showed no significant difference ($\chi^2=0.241$, $df=1$, $P>0.05$). Finally, testing island and non-desert mainland data against desert mainland data revealed a highly significant difference ($\chi^2=137.7$, $df=2$, $P<0.001$).

Thus it appears that insularity is not a significant factor in coccidial prevalence, whereas occurrence in desert hosts is highly significant. The effect of high humidity habitats (e.g. rainforests) on prevalence was not tested. Other factors affecting prevalence are host population density, age structure of the population, altitude, sunlight and most probably behaviour (e.g. territoriality), season (especially with respect to mating), and weather prior to collection of samples (Telford, 1970; Fayer & Reid, 1982; Aquino-Shuster, Duszinski & Snell, 1990).

Publications particularly pertinent to the Round Island data are those by Brygoo (1963), Upton & Barnard (1987), Upton *et al.* (1990) and Daszak & Ball (1990) concerning parasites of reptiles from Madagascar (the nearest landmass to Round Island greater than 2000 km²). Barré (1982) published parasite data from a survey of 23 reptiles collected on the island of Réunion 200 km southwest of Mauritius. Barré (1982) found 20.0 - 66.7% prevalence of various species of nematodes and cestodes in three species of geckoes and one species of iguanid, and 50.0% prevalence of a cestode in one snake species. These results cannot be usefully compared with the Round Island data as they concern only non-native reptiles. The prevalence data from Upton & Barnard (1987) and Daszak & Ball (1990) cannot be used for comparison with the data presented in this paper, since these studies concern imported reptiles, which often show elevated levels of infection (see Telford, 1970). Brygoo (1963) reported coccidial infection in the gall bladders of *Phelsuma lineata* from Madagascar however, no prevalence data was presented. Upton *et al.* (1990) published eight sets of prevalence data for five species of *Caryospora* and listed prevalences of 16.6% up to 100% with a mean of 45.0% ($n=29$). The Round Island boa *Caryospora* data is well within this range although higher than the mean prevalence for all reports analysed (38.4%, $n=151$). The data on helminth prevalence compare well to data on similar helminths from mainland species of reptiles (see McAllister *et al.*, 1991); however, helminth prevalence data were not analysed by habitat.

Therefore it seems that Round Island reptiles support parasitic infections of average prevalence. No unduly large parasite burdens were observed, and no clinical signs of illness (eg. diarrhoea) were seen other than an emaciated juvenile Round Island boa (no parasite ova were detected in the faeces of this animal). The parasites infecting Round Island reptiles belong to groups that are not usually associated with acute disease in reptiles (Cooper & Jackson, 1981). However, it has been demonstrated that intestinal parasitic infec-

tion in reptiles may lead to a lowering of the reproductive output of females (Pence & Selcer, 1988). Furthermore, it is known that the presence of other disease agents in the host, environmental factors such as nutritional status of the host, the close confinement with other infected individuals and stress related to lowering of external temperature may significantly affect the prevalence, incidence and pathogenicity of coccidial infections (Hammond, 1973; Long, 1973; Fernando, 1982). On Round Island, drought or prolonged cyclone conditions may lead to an increase in coccidial prevalence and outbreak of disease - however, no data on this has been collected. Recent increases in the population of the reptiles (Tonge, 1989; North, Bullock & Dulloo, 1994) suggest that the population is healthy despite the prevalences reported in the current paper.

It is known that captive reptiles may continue to pass coccidian oöcysts for several months following confinement, and this is thought to be due to continual reinfection with oöcysts from the substrate (Ball & Daszak, in press). It would be extremely difficult to ensure that captive stock of Round Island reptiles (maintained as part of the captive-breeding programme) are free of coccidia. It would therefore be interesting to compare the prevalence of parasites in the captive colonies of Round Island reptiles with those in the wild populations. Should the captive-bred animals be free of parasites, this could lead to problems if or when they are reintroduced to the wild population (Jacobson, 1993).

Acknowledgements. This work was made possible by the generosity of the Percy Sladen Memorial Fund. I am indebted to the Mauritian Government (represented by Y. Mungroo and E. Dulloo), for permission to work on Round Island. C. Jones of the Mauritian Wildlife Appeal Fund, B. and M. Bell of Wildlife Management International Ltd. and E. Dulloo of the Mauritian Government Conservation Department all helped to make my stay on Round Island an interesting and pleasurable one. Field work was greatly assisted by the Raleigh International staff, in particular J. Marfell and R. Jackson at the field headquarters, Nicole Mariner, Round Island medic, S. Belbin at Raleigh International, London, and the teams of volunteers on Round Island ("Sharkbait", "Dodo Commitments" and "Noddy Stools"). I am grateful to the staff of the Jersey Wildlife Preservation Trust for searching their records for parasite data. Finally I would like to acknowledge Dr. A. Seddon, Kingston University, who assisted with the statistical analysis and Professors R. M. Pittilo and S. J. Ball, Kingston University, for their comments on and support of this work.

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Accepted: 16.5.94