ARE THE HELMINTH COMMUNITIES FROM UNISEXUAL AND BISEXUAL LIZARDS DIFFERENT? EVIDENCE FROM GASTROINTESTINAL PARASITES OF DAREVSKIA SPP. IN TURKEY

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Specimens of three species of parthenogenetic lizards (Darevskia uzzelli, D. bendimahiensis, and D. sapphirina) from northeastern Turkey were examined for gastrointestinal parasites. Only one species, the nematode *Spauligodon saxicolae* (Pharyngodonidae), was found. The extremely low infection and diversity parameters, falling among the lowest within the Palearctic saurians, support depauperate helminth communities for these parthenogenetic lacertid lizards. Our results suggest that parthenogenetic *Darevskia* follow a pattern of parasitism similar to other unisexual lizards (*i.e.* *Aspidocelis*). The low rates of infection and diversity may be explained by the decreasing opportunities for interchanging helminths rather than factors of susceptibility of unisexual hosts.

Key words: parasites, parthenogenetic lizards, Darevskia, Turkey.

**INTRODUCTION**

Caucasian rock lacertid lizards (*Darevskia* spp.) are small saurians from western Asia and south-eastern Europe. They are similar to the European rock lizards, and they include both bisexual and parthenogenetic species (*Arnold et al. 2007, Tarkhiyishili 2012*). Among the unisexual forms, *Darevskia uzzelli* (Darevsky et Daniellyan, 1977), *D. bendimahiensis* (Schmidtler, Eiselt et Darevsky, 1994), and *D. sapphirina* (Schmidtler, Eiselt et Darevsky, 1994) are endemic to northeastern Turkey (*Schmidtler et al. 1994, Baran & Atatürk 1998, Baran et al. 2012*). On the basis of genetic markers, all three parthenogenetic forms are believed to have originated by separate hybridization events between the bisexual Valentin’s lizard, *D. valentini* (Boettger, 1892) (paternal parent), and Radde’s lizard, *D. raddei* (Boettger, 1892) (maternal parent) (*Fu
et al. 2000, Murphy et al. 2000). *D. bendimahienis* has been recorded from few localities from eastern Anatolia and it is listed as endangered because its extent of occurrence is less than 5000 km² (Kaska et al. 2009b). *D. uzzelli* and *D. sapphirina* are even more endangered species because they are rarest and narrower distributed species restricted only to small areas from eastern Turkey (Akarsu et al. 2009, Kaska et al. 2009a).

Several studies on both bisexual and unisexual Caucasian rock lizards have paid attention on morphology, taxonomy, ecology, phylogeny, reproductive traits or distribution of these saurians (Moritz et al. 1992, Schmidtler et al. 1994, Fu et al. 1995, 1997, MacCulloch et al. 2000, Murphy et al. 2000, Arnold et al. 2007, Danielyan et al. 2008, Tarkhivisiniili 2012). Nevertheless much less attention has been paid to their parasites, and thus no helminthological data are known for most of the Daresvksia species while known data for some of them are partial and scarce, focusing mainly on taxonomy and faunistics (Schad et al. 1960, Markov & Bodganov 1962, Sharpio 1962, 1976, Saygi 1993).

One version of the Red Queen hypothesis (Van Valen 1973) suggests that selective pressure from parasites is strongest on the most common genotype in a population, and thus genetically identical clonal lineages with low genetic variability are expected to be more vulnerable to parasitism over time than genetically diverse sexual lineages. Sexual reproduction is maintained in populations because of the need to continually create genotypes that confer resistance against parasites (Hamilton et al. 1990, Ladle 1992). Among reptiles, some studies on ecto- and endoparasites have rendered conflicting results regarding this hypothesis. Moritz et al. (1991) reported that parthenogenetic individuals of the Heteronotia binoei species complex (Australian geckos) were much more prone to infection by haematophagous mites than were their sexual relatives. Contrarily, Hanley et al. (1995) reported lower mite infections in parthenogenetic Lepidodactylus (Pacific Island geckos) compared with their sexual ancestors; and Menezes et al. (2004) pointed out the low infection rates by helminths of Ameivula nativo contrasting with the high values exhibited by the closely related bisexual congener *A. littoralis* in southeastern Brazil.

Most helminthological data on parthenogenetic lizards are known from teiid species, namely the whiptail lizards of the New World genus *Aspidocelis* (former Cnemidophorus) from North and Central America. Within the 41 species of *Aspidocelis*, numerous unisexual taxa are common inhabitants of the desert areas of the southwestern United States and adjacent Mexico (McAllister 1992). McAllister (1990a,b,c), McAllister et al. (1986, 1991a,b,c) studies, show poor helminth communities on several species of these parthenogenetic lizards and evidence that, the species of *Aspidocelis* usually share parasites, regardless of geographic location or even ancestry (McAllister 1992).
Table 1. Collecting localities of the lizard hosts.

<table>
<thead>
<tr>
<th>Species</th>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Altitude (m)</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. uzzelli</td>
<td>Horasan</td>
<td>39.936667</td>
<td>42.303667</td>
<td>1812</td>
<td>stepic vegetation with rock cliffs</td>
</tr>
<tr>
<td>D. uzzelli</td>
<td>Ağrı</td>
<td>39.723639</td>
<td>43.002821</td>
<td>1638</td>
<td>stepic vegetation with rock cliffs</td>
</tr>
<tr>
<td>D. bendimahiensis</td>
<td>Muradiye</td>
<td>39.033783</td>
<td>43.757500</td>
<td>1760</td>
<td>stepic vegetation and river bank</td>
</tr>
<tr>
<td>D. sapphirina</td>
<td>35 km</td>
<td>39.188099</td>
<td>43.001953</td>
<td>1793</td>
<td>stepic vegetation and isolated rocks</td>
</tr>
</tbody>
</table>

Similar findings have been reported for the parthenogens among the 10 species of *Ameivula* (i.e. Menezes et al. 2004), another teiid genus from South America, ecologically similar to *Aspidoscelis* (Harvey et al. 2012).

Finally, from a demographic point of view, parthenogenetic lizards and particularly *Darevskia* tend to attain higher densities than their bisexual relatives (Galoyan 2013). This, together with the low aggressiveness of parthenogenetic females allowing smaller home ranges (Galoyan 2013), might enhance parasite transmission.

In accordance with the findings above mentioned, we here predict low or moderate gastrointestinal parasite infection in parthenogenetic *Darevskia* spp. Thus, here we analyze the helminth communities of three parthenogenetic forms inhabiting saxicolous restricted habitats from northeastern Anatolia.

**MATERIAL AND METHODS**

Due to the capture restrictions for these endangered species escaping extremely restricted ranges or even single localities, only 20 specimens of *D. uzzelli* were collected from two localities, five specimens of *D. bendimahiensis*, and two specimens of *D. sapphirina* from single localities, respectively, all of them in Northeast Anatolia and separated by no more than 100 km (Table 1). Climate of the region is characteristic of the Anatolian Plateau with strong continental influence contrasting between cold, snowy winters (~30°C) and dry, hot summers (>30°C) and with total annual precipitation averaging 400 mm (Senson et al. 2008).

Lizards were collected by hand, euthanized and dissected. While invasive, this method still ensures a better detection and quantification of intestinal parasites with a few specimens (Jorax et al. 2013). The gastrointestinal tracts were sent to the Laboratory of Parasitology of the University of Valencia for parasitological analysis. Helminths were processed in accordance with the usual techniques in parasitology (Horner 1991). We follow Busut et al. (1997) in the use of descriptive ecological terms. Nematodes, voucher specimens are deposited in collection of Department of Zoology, Faculty of Biological Sciences, University of Valencia (Spain). Other data obtained from the searched hosts (taxonomy, thermoregulation, feeding habits, phylogeny, ecology), related with the geographical characteristics of the searched area are being object of other complex studies, according to DAMA protocol (Brooks et al. 2014).

Table 2. Comparative values of helminth infection and diversity among some Palaearctic lacertid lizards.

<table>
<thead>
<tr>
<th>Host species</th>
<th>Helminth species found</th>
<th>Global prevalence</th>
<th>Mean intensity of infection</th>
<th>Mean abundance of infection</th>
<th>Brillouin’s index of diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darevskia uzzelli (n = 20)</td>
<td>1</td>
<td>10%</td>
<td>1±1 (1–1)</td>
<td>0.1±0.3 (0–1)</td>
<td>0</td>
</tr>
<tr>
<td>Darevskia bendimahiensis (n = 5)</td>
<td>1</td>
<td>20%</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Zootoca vivipara (n = 129)</td>
<td>2</td>
<td>39.4%</td>
<td>2.4±2 (1–10)</td>
<td>0.9±1 (0–10)</td>
<td>0.002±0.02 (0–0.34)</td>
</tr>
<tr>
<td>Podarcis bocagei (n = 249)</td>
<td>5</td>
<td>13.7%</td>
<td>3.4±4.1 (1–27)</td>
<td>0.2±1.3 (0–27)</td>
<td></td>
</tr>
<tr>
<td>Podarcis carbonelli (n = 257)</td>
<td>4</td>
<td>4%</td>
<td>4.2±5.3 (1–32)</td>
<td>0.1±1.2 (0–32)</td>
<td>0.001±0.02 (0–0.34)</td>
</tr>
</tbody>
</table>

RESULTS

Only one species of helminth, Spauligodon saxicolae (2 males and 2 females), was found in D. uzzelli and D. bendimahiensis. No parasites were found in D. sapphirina. The low number of helminths found and the poor conditions of conservation made impossible the specific identification of the parasites based in morphological characters. Prevalence of infection was 10% in D. uzzelli, 20% in D. bendimahiensis. Only one individual of D. bendimahiensis was infected. Mean intensity and mean abundance of infection in D. uzzelli were 1±1 (1–1) and 0.1±0.3 (0–1), respectively. Brillouin’s diversity index was 0 in all the three hosts (Table 2).

DISCUSSION

Morphological species identification was compromised by the specimens conservation state. However, genetic analysis retrieved the specimens as closely related to Spauligodon saxicolae Sharpilo, 1961, as occurs with several similar morphotypes found in other Darevskia spp. from Armenia (Jorge et al. 2014).

Obviously, and considering the low number of examined hosts, we can only provide a preliminary description of the composition and structure of their helminth communities. Nevertheless these results are already extremely valuable because of the low probability to analyse more specimens of these endangered hosts in the next future.

The very low values of parasite infection and diversity cannot be attributed to sample size and suggest very poor helminth communities for these parthenogenetic host species. The Darevskia spp. analysed show the lowest diverse helminth communities reported to date within the Palearctic lacertid lizards. Only Podarcis bocagei and P. carbonelli from North West of the Iberian Peninsula (Galdón et al. 2006), and Zootoca vivipara from Pyrenees (north of Iberian Peninsula) (Sanchis et al. 2000) harboured equivalent impoverished helminth communities (Table 2). Is this the typical pattern in unisexual lizards? In this regard little is known on the parasites of other parthenogenetic lizards. Most data available come from Aspidocelis and Ameivula whiptail lizards (Teiidae). Studies of McAllister (1990a,b,c, 1992), McAllister et al. (1986, 1991a,b,c) and Menezes et al. (2004) provide descriptions on the parasite infection of this group characterizing their helminth communities as follows.

Aspidocelis spp. harbour poor helminth communities, in many cases most lizards of a population contained only one helminth species (McAllister et al. 1991b). This agrees with our finding of a single species of the nematode Spauligodon saxicolae. Moreover, the infection and diversity values of the study parthenogenetic Darevskia spp. were poorer than those found in lizards which helminth communities have been considered as “extremely poor infracommunities” (Galdón et al. 2006) as the saurians mentioned above.

Usually parthenogenetic Aspidocelis spp. tend to be parasitized by the same helminths found in their parental species. For all the three Darevskia species studied, D. valentini is the paternal parent and D. raddei is the maternal parent (see Introduction). In D. valentini, four helminth species were found (Roca et al., unpubl. data) Spauligodon saxicolae being one of them. In D. raddei, only one species also belonging to Spauligodon saxicolae was recorded (Roca et al. unpubl. data).

Parthenogenetic lizards usually share parasites with parthenogenetic and bisexual congeners, regardless of geographic location or even ancestry. Spauligodon spp. (sometimes named as Skrjabinodon, see Jorge et al. 2014) has been recorded in many saurian hosts in many geographical regions. Namely, they have been found in lacertids as Podarcis spp., Algyroides marchi or Gallotia galloti (Roca & Hornero 1994, Lafuente & Roca 1995, Roca et al. 2005), and geckos as Tarentola mauritanica (Roca 1985a), in many areas of the Palearctic and Macaronesia (see Roca 1985b, Hornero 1991, Martín 2005). Consequently, it seems that unisexual Darevskia spp. would share parasites with many other lacertid lizards.

Pharyngodonidae nematodes represent a substantial part of these deparate helminth communities. This is also a typical pattern in Palearctic lacertid lizards (see Hornero 1991, Martín 2005, Roca 1985b). In the present case the nematode Spauligodon saxicolae (Pharyngodonidae) encompasses the complete helminth communities present in all the three unisexual Darevskia hosts.
Thus, the pattern observed in parthenogenetic *Darevskia* spp. appears very similar to that in *Aspidocelis* spp. These very poor helminth communities could be explained by the decreasing of opportunities for interchanging helminths of direct life cycles, since there are neither male-female (reproductive) nor male-male contacts (territorial fights). Apparently, this effect takes precedence over the high lizard densities (GALOYAN 2013) in modelling the helminth communities of parthenogenetic *Darevskia* spp. Remarkably MENEZES et al. (2004) suggest that males of *Ameiva nativo* from Brazil would be more susceptible than females to infection by some nematodes. The fact that this host was also all-female, could also be associated with its relatively low infection rates.

The small body size of the host, and a low number of interactions with other reptile and amphibian species, have been cited as cause of very low diversity of helminths in the case of *Zootoca vivipara* (SANCHIS et al. 2000). Sandy areas, as zones where recruitment of parasites by lizard hosts is low (eggs being highly susceptible to desiccation), have been also cited as cause for low helminth community diversity for *P. bocagei* and *P. carbonelli* (GALDÓN et al. 2006). Nevertheless, infection rates were not significantly influenced either by host body size or by environmental factors in the case of the parthenogenetic whiptail lizard *Ameiva nativo* (MENEZES et al. 2004).

Although MORITZ et al. (1991) assume that differences in parasitism are attributable to differences in susceptibility between the sexual and the asexual lizards, CLAYTON et al. (1992) pointed out that parasite load alone does not accurately predict host susceptibility. HANLEY et al. (1995) argue that the Red Queen model predict shifts in host susceptibility to parasites within a population, but adds that other factors are important in determining patterns of parasitism such as transmission rates (ANDERSON & MAY 1982) or parasite virulence. The high densities attained by parthenogenetic lizards including *Darevskia* spp. (GALOYAN 2013 pers. obs.) should have increased infection opportunities but this was not the case here. Nevertheless, further studies with more populations and with other parthenogenetic forms of *Darevskia* are needed to untangle the factors modelling helminth parasitisation.

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