Research Article

Time Since Fire Affects Ectoparasite Prevalence on Lizards in the Florida Scrub Ecosystem

Earl D. McCoy*, Joseph M. Styga, Carol E. Rizkalla, and Henry R. Mushinsky

Department of Integrative Biology, University of South Florida,
SCA 110, 4202 East Fowler Avenue, Tampa, Florida 33620, USA

*Corresponding author: Tel.: 001-813-974-5219; e-mail: edm@mail.usf.edu

ABSTRACT

Prevalence of parasites can be an indicator of individual and population health of hosts. Populations of parasites can be affected by habitat management practices, however, which in turn can affect prevalence on hosts. We assessed the influence of varying fire histories on the prevalence of ectoparasites, primarily chiggers (mite larvae of the genus *Eutrombicula*), on the three most common lizard species resident in the Florida scrub ecosystem. Few individuals of the Florida sand skink (*Plestiodon reynoldsi*) harbored ectoparasites. The Florida scrub lizard (*Sceloporus woodi*) and the six-lined racerunner (*Aspidoscelis sexlineata*) had the highest prevalence of ectoparasites in recently burned (within 3 years) plots. Change in habitat structure or increased mobility of hosts following a recent burn may increase the host-parasite encounter rate.

Keywords: ectoparasites, Florida, Florida sand skink, Florida scrub Lizard, habitat structure, scrub ecosystem, six-lined racerunner, time since fire

Citation: McCoy, E.D., J.M. Styga, C.E. Rizkalla, and H.R. Mushinsky. 2012. Time since fire affects ectoparasite prevalence on lizards in the Florida scrub ecosystem. Fire Ecology 8(3): 32-40. doi: 10.4996/fireecology.0803032

INTRODUCTION

Parasite prevalence is used in wildlife management and ecological studies to gauge population health (Schultz *et al*. 1993). Prevalence can vary with habitat conditions, landscape fragmentation, the host's habitat use patterns (Thamm *et al*. 2009), the host's population size (Schall and Marghoob 1995), and the degree of host stress (Esch *et al.* 1975, Karr 1981, Krist *et al*. 2004). Among the consequences for individuals of parasite infestations, especially when infestations are heavy, are increased immune response and decreased ability to acquire resources, which in turn may lead to decreased weight gain, stamina, activity, and longevity, and increased reproductive failure (Main and Bull 2000, Reardon and Norbury 2004, Curtis and Baird 2008, Hare *et al*. 2010).

Lizards harbor a variety of ectoparasites. Most numerous among these ectoparasites are ticks. After ticks (Acari: Ixodidae), larvae of mites within the genus *Eutrombicula* (Acari: Trombiculidae), chiggers, are the most frequent ectoparasite of wild lizard species (Walter and Shaw 2002). These larval mites are barely macroscopic, but can form masses of individuals of considerable size on hosts (Walter and Shaw 2002). They also are found on terrestrial amphibians (Duellman and Trueb 1994), snakes (Hyland 1950), and the tuatara (*Sphenodon punctatus*; Godfrey *et al.* 2008). All life stages of ticks are parasitic, and individuals may require as many as three different hosts to complete their lifecycles (Baker and Wharton 1952). In contrast, only the larval stage of members of the genus *Eutrombicula*, which are closely related to ticks, are parasitic, and individuals may require only one host to complete their lifecycles (Baker and Wharton 1952). Adults of the genus *Eutrombicula* occur in soil and litter.

Fire often is used as a tool to reduce the population sizes of ectoparasites, although not typically ectoparasites of wildlife. Fire has been shown to reduce tick populations in many locations by direct mortality and by reducing tall grass cover (e.g., Cully 1999, Fyumagwa *et al*. 2007). The effect of fire on mites is less definitive. Fire appears to reduce population sizes of soil mites in some cases (e.g., Camaan *et al.* 2008), but increase population sizes in others (e.g., Krasnoshchekov *et al*. 2004). Regardless of their immediate response to burning, populations of soil mites often return to pre-burn numbers quickly (e.g., Krasnoshchekov *et al*. 2004, Barratt *et al*. 2006). The objective of the current study was to determine if time since fire in a naturally pyrogenic habitat could be shown to affect ectoparasite prevalence on resident lizards. Not much is known about the potential effects of fire on ectoparasite prevalence on lizards, particularly in naturally pyrogenic ecosystems. We examined ectoparasite prevalence on three lizard species inhabiting an area of the Florida scrub ecosystem that is maintained by planned burning to determine if prevalence is related to time since fire.

METHODS

We conducted the study at Archbold Biological Station during spring 2011. Archbold Biological Station, which is located on the Lake Wales Ridge in Highlands County, Florida, USA (27°10’50” N, 81°21’00” W), contains more than 2000 ha of mostly xeric, naturally pyrogenic habitats. Included in this study are three habitat types within the Florida scrub ecosystem: flatwoods, scrubby flatwoods, and rosemary balds (Abrahamson 1984). Regular planned burning of these habitats has been carried out at Archbold Biological Station beginning in the mid-1970s, with full implementation in the mid-1980s (Main and Menges 1997). The management staff strives to maintain a natural fire regime while, at the same time, promoting habitat that will support the many rare and unique organisms living there (Main and Menges 1997). Plots used in this study were last burned 1, 2, 3, 7, 9 to 10, 12, or 25 years prior to the study.

The host species were the Florida sand skink (*Plestiodon reynoldsi*), the Florida scrub lizard (*Sceloporus woodi*), and the six-lined racerunner (*Aspidoscelis sexlineata*). These species are the most common lizards in the Florida scrub ecosystem (Ashton and Knipps 2011, McCoy *et al*. 2012). They are known to harbor many different types of internal and external parasites (Telford 1959, Telford and Bursey 2003, McCoy *et al*. 2010). Chief among the ectoparasites are small, bright orange mites of the genus *Eutrombicula* (Telford 1959, Telford and Bursey 2003). The Florida sand skink is a threatened species precinctive (Frank and McCoy 1990) to the ridges of central Florida (USFWS 1999), which occupies a variety of xeric scrub habitats (Greenberg *et al*. 1994, Sutton 1996, USFWS 1999, Chrisman 2005). The Florida scrub lizard occupies habitats similar to those of the Florida sand skink on the central ridges of Florida, but also occupies coastal scrubs of the peninsula (Jackson 1973, Hokit and Branch 2003). The six-lined racerunner is more widely distributed, both ecologically and geographically, than the other two species, and is common in most xeric habitats within its broad geographic range (Hoddenbach 1966, Hokit *et al*. 1999).

We collected data within a set of 36 enclosures used for a variety of other studies (e.g., Schrey *et al*. 2011). Enclosures were constructed of aluminum flashing and measured 20 m × 20 m. Each enclosure contained 76 pitfall traps, which were 3.8 L plastic buckets buried in the sand to their openings. Twelve of the pitfall traps were spaced evenly around the inside of the enclosure boundary, and the remaining 64 were arranged in 16 arrays evenly spaced within the enclosure. Each array was composed of four pitfall traps, two at each end of a 2 m strip of aluminum buried to the same depth as the enclosure boundary. The flashing directed lizards into the pitfall traps.

We conducted preliminary surveys for ectoparasites on the Florida scrub lizard in late winter within a subset of the enclosures. We transported individuals captured by noosing to the laboratory at Archbold Biological Station for examination. Examination consisted of brushing the entire surface of each individual over a piece of white paper, followed by location of remaining ectoparasites with a hand lens (see Huyghe *et al*. 2010). After examination, we measured snout-vent length (SVL), sexed, weighed, and released each individual at its point of capture.

Once pitfall traps were opened in the spring, we checked each one every three days for captures. We measured and marked captured individuals of the Florida scrub lizard and six-lined racerunner, and examined them for ectoparasites in the field. The preliminary surveys indicated that careful examination of individuals was enough to establish ectoparasite presence, so we did not brush individuals. We marked individuals by toe-clipping, to avoid double-counting. After examination for ectoparasites and marking, we released each individual near its point of capture. We transported captured individuals of the Florida sand skink to the laboratory to be measured, marked (if necessary, as many had been marked previously), and examined for ectoparasites. We used the brushing technique described previously to locate ectoparasites. We marked individuals with visible implant elastomer, VIE (Penney *et al*. 2001). Subsequently, we released each individual near its point of capture. We did not count the number of ectoparasite individuals per host individual (parasite load) for two reasons: (1) every host individual captured later in the trapping season that harbored ectoparasites was heavily infested with them (Figure 1), and (2) previous recapture results (E.D. McCoy, University of South Florida, unpublished data) indicated that the additional handling time required could have been detrimental to the health of host individuals.

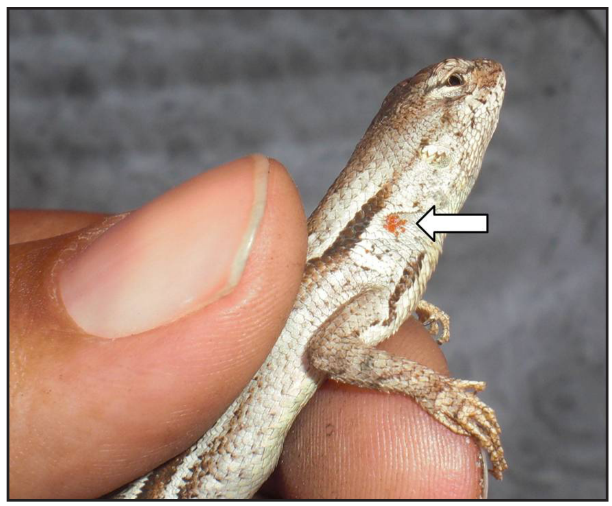

Figure 1. An individual of the Florida scrub lizard with mites crowded into a nuchal pocket (arrow).

We used chi-squared tests of independence to determine if a difference in ectoparasite prevalence existed between individuals captured from enclosures with different times since fire. We employed an exploratory data analysis approach. Keeping the chronological ordering intact, we compared all possible pairs of groups of sites. Thus, one comparison was sites with a 1 yr time since fire versus all others; a second comparison was sites with 1 yr plus 2 yr since the last burn versus all others, and so on. We then chose the comparison with the greatest difference. We performed the analysis in SigmaPlot, version 11.2 (Systat

Software, Chicago, USA). We also used chi-squared tests of independence to determine if sex ratio differed between groups of enclosures with different times since fire. We used logistic regression analysis (*Z*-statistic) to determine if a relationship existed between the presence of ectoparasites and weight or sex. Because SVL and weight were strongly related (r = 0.88, $P < 0.01$, Florida scrub lizard; r = 0.71, $P < 0.01$, six-lined racerunner), we did not include SVL in the model. We performed the analysis in R, version 2.12.2 (R Development Core Team, Vienna, Austria). We used the Mann-Whitney U-Test (T-statistic) to determine relationships among weight, sex ratio, and time since fire. We performed the analysis in SigmaPlot, version 11.2.

RESULTS

Ectoparasite prevalence varied over time and among species. None of the 20 individuals of the Florida scrub lizard examined during the preliminary surveys in late winter had ectoparasites. Trapping in the spring revealed overall ectoparasite prevalence of 3% (4 of 117 individuals) for the Florida sand skink, 64% (44 of 69 individuals) for the Florida scrub lizard, and 78% (31 of 40 individuals) for the six-lined racerunner. Except for an unidentified tick species found on one individual of the Florida sand skink, the ectoparasites encountered all were larval mites of the genus *Eutrombicula*. Because of the low prevalence of ectoparasites on the Florida sand skink, we did not use the species in any further analyses. Ectoparasite prevalence increased over time for both the Florida scrub lizard and six-lined racerunner (Figure 2).

Ectoparasite prevalence was related to time since fire. Prevalence on the Florida scrub lizard and six-lined racerunner showed similar responses to time since fire (Figure 3); therefore, we combined the data for analysis. The greatest difference was between times since fire of 1 yr + 2 yr + 3 yr versus longer times since fire. Ectoparasite prevalence tended to be higher in more-recently burned plots (χ^2 = 3.20, $P = 0.07$; n = 53 and 56). When the most recent burn was excluded, the relationship improved (Fischer's Exact Test, $P = 0.02$).

The relationship between ectoparasite prevalence and time since fire was not a spurious result of differences in morphology or sex ratio among lizards living in habitats with different times since fire. Although the logistic

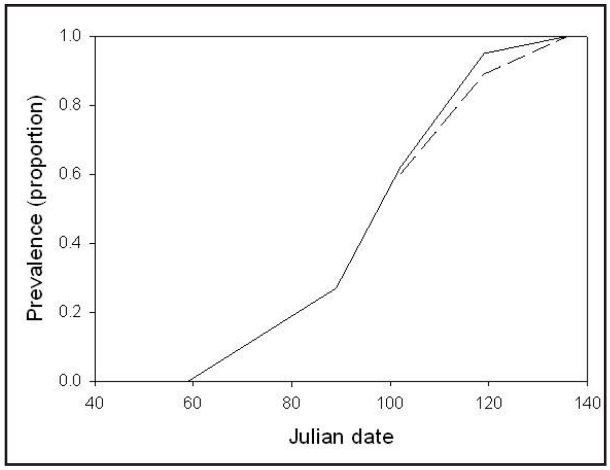

Figure 2. Prevalence of ectoparasites on the Florida scrub lizard (solid line) and the six-lined racerunner (dashed line) over the course of the study at Archbold Biological Station.

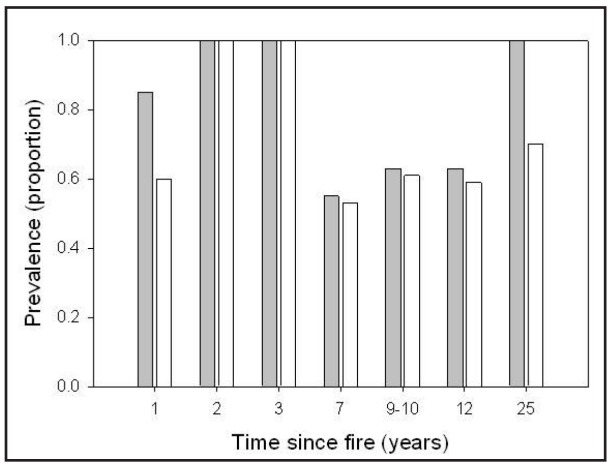

Figure 3. Prevalence of ectoparasites on the six-lined racerunner (filled bars) and the Florida scrub lizard (open bars) in plots of different times since fire.

regression models, which were well supported (Residual deviance 52.23 on 57 df, Florida scrub lizard; 34.72 on 34 df, six-lined racerunner), revealed a strong association between ectoparasite prevalence and weight for both the Florida scrub lizard (Z = 2.16, P = 0.03) and the six-lined racerunner (Z = –1.93, P = 0.05), we could detect no strong difference in weight of individuals between groups of plots with different times since fire for either species (T = 485.0, P = 0.40, n = 46, Florida scrub lizard; T = 189.5, P = 0.18, n = 34, six-lined racerunner). Neither weight (T = 327.5, P = 0.70, n = 41, Florida scrub lizard; T = 212.0, P = 0.28, n = 31, six-lined racerunner) nor ectoparasite prevalence (Z = 0.69, P = 0.49, Florida scrub lizard; Z = 0.65, P = 0.52, six-lined racerunner) was strongly related to sex for either species. We could detect no strong difference in sex ratio between groups of plots with different times since fire (χ^2 = 0.06, P = 0.81, Florida scrub lizard; χ^2 = 0.07, P = 0.93, six-lined racerunner).

DISCUSSION

Individuals of one of the three species examined, the Florida sand skink, were remarkably devoid of ectoparasites. The fossorial habit of this species likely accounts for this result. Individuals are not often exposed to ectoparasites in the first place, and their smooth surfaces being repeatedly abraded by the sand through which they "swim" likely promotes removal of virtually all ectoparasites that do manage to attach. However, the other two species, the Florida scrub lizard and six-lined racerunner, commonly harbored ectoparasites. We found ectoparasite individuals in abundance on the abdomen of the six-lined racerunner and in the nuchal pockets (Arnold 1986, Bauer *et al*. 1990) of the Florida scrub lizard. Both species showed high ectoparasite prevalence; in fact, ten times higher than prevalence recorded for individuals farther north, at Ocala National Forest (Telford and Bursey 2003). Prevalence increased with time during the lizards' active season, the onset of which coincides with the onset of the ectoparasite's active season (Koehler *et al.* 2011). The mite's relatively rapid lifecycle, combined with the long periods of warm temperatures and abundant rainfall in southern Florida, allow production of several generations per year (Koehler *et al.* 2011; e.g., Badejo 1990, Schall *et al*. 2000, Klukowski 2004, Rubio and Simonetti 2009).

The six-lined racerunner tended to have greater ectoparasite prevalence than the Florida scrub lizard. The former species generally is more active than the latter (Jackson and Telford 1974, Paulissen 1988). The former species also likely has a greater capacity to move through a wide range of habitat types, including types with the dense structure favored by mites (Curtis and Baird 2008), whereas the latter species prefers open habitats with substantial bare ground (Hokit and Branch 2003). Finally, the former species tends to remain on the surface, whereas the latter may temporarily burrow in the sand when disturbed (E.D. McCoy, J.M. Styga, C.E. Rizkalla, and H.R. Mushinsky, University of South Florida, personal observations). Within species, prevalence was related to body weight. Heavier individuals of the Florida scrub lizard and lighter individuals of the six-lined racerunner had higher prevalence. We have no ready explanation for these patterns. Also, we could not detect a strong tendency for individuals to be either lighter or heavier in plots with different times since fire. Nor could we determine sex ratios to be different among plots with different intervals. Size and sex do not appear to influence differences in ectoparasite prevalence among plots.

The general relationship of ectoparasite prevalence to time since fire was similar between the Florida scrub lizard and the six-lined racerunner. A tendency existed for prevalence to be higher in more recently burned plots, although prevalence did tend to increase in plots burned at the longest time since fire (25 yr;

Figure 3). Based on what is known about mite densities, we might have expected prevalence actually to be higher in plots burned less recently, because of the denser vegetation there. Mites favor areas with relatively dense vegetation structure and shading over their soil refugia (Dobson *et al*. 1992, Roy and Roy 2006), which provide conditions of relatively low temperature, high humidity, and high host density (Rubio and Simonetti 2009, Koehler *et al.* 2011). The higher prevalence in more recently burned plots, therefore, may be attributable more to host biology than to parasite biology. One possible explanation is that host density is greater in more recently burned plots, resulting in an increased encounter rate between host and parasite. However, we could detect no strong difference in the abundance of host individuals among plots (McCoy *et al*. 2012). Other possible explanations stem from the changes in vegetation structure accompanying burning (cf., Ashton and Knipps 2011). More recently burned plots are structurally simplified, which may enhance host mobility. More recently burned plots support mainly sparse clumps of grassy vegetation, which may concentrate parasites in areas where the host seeks shelter. Either of these potential explanations based on change in vegetation structure also would account for an increase the encounter rate between host and parasite.

Some evidence concerning responses of individuals to fire suggests the importance of mobility in influencing ectoparasite prevalence. Studies of the Florida sand skink (Schrey *et al*. 2011; C.E. Rizkalla *et al*., University of South Florida, unpublished data) have indicated that individuals move increased distances in response to burning, effectively reshuffling local populations. If similar responses to burning occur for the Florida scrub lizard and the six-lined racerunner, then the tendency that we noted for prevalence to be higher in plots burned one year ago versus plots burned two or three years ago may be explained by such movements. However, the Florida scrub lizard is a relatively poor disperser (Hokit *et al*. 1999); therefore, the mobility explanation may not be a complete one. The causes of differences in prevalence accompanying differences in time since fire is a subject in need of further research, employing a more sophisticated experimental design (cf., Godfrey *et al.* 2008).

ACKNOWLEDGMENTS

A. Catenazzi was responsible for installing the enclosures. M. Grundler and several volunteers aided in data collection. The Director of Archbold Biological Station, H. Swain, provided logistical support. Two anonymous reviewers provided useful comments. Funding was provided by US Fish & Wildlife Service, FFWCC Permit 6473, USF IACUC Permit 3866.

LITERATURE CITED

Abrahamson, W.G. 1984. Post-fire recovery of Florida Lake Wales Ridge vegetation. American Journal of Botany 71: 9-21. doi: 10.2307/2443618

Arnold, E.N. 1986. Mite pockets on lizards, a possible means of reducing damage by ectoparasites. Biological Journal of the Linnean Society 29: 1-21. doi: 10.1111/j.1095-8312.1986.tb01767.x

Ashton, K.G., and A.C.S. Knipps. 2011. Effects of fire history on amphibian and reptile assemblages in rosemary scrub. Journal of Herpetology 45: 497-503. doi: 10.1670/09-193.1

Badejo, M.A. 1990. Seasonal abundance of soil mites (Acarina) in two contrasting environments. Biotropica 22: 382-390. doi: 10.2307/2388555

Baker, W.B., and G.W. Wharton. 1952. An introduction to acarology. The Macmillan Company, New York, New York, USA.

Barratt, B.I.P., P.A. Tozer, R.L. Wiedemer, C.M. Ferguson, and P.D. Johnstone. 2006. Effect of fire on microarthropods in New Zealand indigenous grassland. Rangeland Ecology and Management 59: 383-391. doi: 10.2111/05-190R1.1

Bauer, A.M., A.P. Russell, and N.R. Dollahon. 1990. Skin folds in the gekkonid lizard genus *Rhacodactylus:* a natural test of the damage limitation hypothesis of mite pocket function. Canadian Journal of Zoology 68: 1196-1201. doi: 10.1139/z90-178

Camaan, M.A., N.E. Gillette, K.L. Lamoncha, and S.R. Mori. 2008. Response of forest soil Acari to prescribed fire following stand structure manipulation in the southern Cascade Range. Canadian Journal of Forest Research 38: 956-968. doi: 10.1139/X07-245

Christman, S.P. 2005. Densities of *Neoseps reynoldsi* on the Lake Wales Ridge. Final Report, Part 1 Surveys for *Neoseps reynoldsi* and *Eumeces egregius lividus.* US Fish and Wildlife Service, Vero Beach, Florida, USA.

Cully, J.F., Jr. 1999. Lone star tick abundance, fire, and bison grazing in tallgrass prairie. Journal of Range Management 52: 139-144. doi: 10.2307/4003507

Curtis, J.L., and T.A. Baird. 2008. Within-population variation in free-living adult and ectoparasitic larval Trombiculid mites on collared lizards. Herpetologica 64: 189-199. doi: 10.1655/07-052.1

Dobson, A.P., S.V. Pacala, J.D. Roughgarden, E.R. Carper, and E.A. Harris. 1992. The parasites of Anolis lizards in the northern Lesser Antilles. I. Patterns of distribution and abundance. Oecologia 91: 110-117.

Duellman, W.E., and L. Trueb. 1994. Biology of amphibians. Johns Hopkins University Press, Baltimore, Maryland, USA.

Esch, G.W., J.W. Gibbons, and J.E. Bourque. 1975. An analysis of the relationship between stress and parasitism. American Midland Naturalist 93: 339-353.

Frank, J.H., and E.D. McCoy. 1990. Endemics and epidemics of shibboleths and other things causing chaos. Florida Entomologist 73: 1-9.

Fyumagwa, R.D., V. Runyoro, I.G. Horak, and R. Hoare. 2007. Ecology and control of ticks as disease vectors in wildlife of the Ngorongoro Crater, Tanzania. South African Journal of Wildlife Research 37: 79-90. doi: 10.2307/2424167

Godfrey, S.S., C.M. Bull, and N.J. Nelson. 2008. Seasonal and spatial dynamics of ectoparasite infestation of a threatened reptile, the tuatara (*Sphenodon punctatus*). Medical and Veterinary Entomology 22: 374-385. doi: 10.1111/j.1365-2915.2008.00751.x

Greenberg, C.H., D.G. Neary, and L.D. Harris. 1994. Effect of high-intensity wildfire and silvicultural treatments on reptile communities in sand-pine scrub. Conservation Biology 8: 1047-1057. doi: 10.1046/j.1523-1739.1994.08041047.x

Hare, K.M., J.R. Hare, and A. Cree. 2010. Parasites, but not palpation, are associated with pregnancy failure in a captive viviparous lizard. Herpetological Conservation and Biology 5: 563-570. doi: 10.1071/RD09195

Hoddenbach, G.A. 1966. Reproduction in western Texas *Cnemidophorus sexlineatus* (Sauria: Teiidae). Copeia 1966: 110-113. doi: 10.2307/1440767

Hokit, D.G., and L.C. Branch. 2003. Habitat patch size affects demographics of the Florida scrub lizard (*Sceloporus woodi*). Journal of Herpetology 37: 257-265. doi: 10.1670/0022-1511(2003)037[0257:HPSADO]2.0.CO;2

Hokit, D.G., B.M. Stith, and L.C. Branch. 1999. Effects of landscape structure in Florida scrub: a population perspective. Ecological Applications 9: 124-134. doi: 10.1890/1051-0761(1999)009[0124:EOLSIF]2.0.CO;2

Huyghe, K., A.van Oystaeyen, F. Pasmans, Z. Tadić, B. Vanhooydonck, and R. van Damme. 2010. Seasonal changes in parasite load and a cellular immune response in a colour polymorphic lizard. Oecologica 163: 867-874. doi: 10.1007/s00442-010-1646-9

Hyland, K.E. 1950. The copperhead snake as a host for the chigger mite *Trombicula* (*Eutrombicula*) *alfreddugèsi.* Journal of Parasitology 36: 494. doi: 10.2307/3273179

Jackson, J.F. 1973. Distribution and population phenetics of the Florida scrub lizard, *Sceloporus woodi.* Copeia 1973: 746-761. doi: 10.2307/1443075

Jackson, J.F., and S.R. Telford, Jr. 1974. Reproductive ecology of the Florida scrub lizard, *Sceloporus woodi.* Copeia 1974: 689-694. doi: 10.2307/1442682

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. American Fisheries Society 6: 21-27. doi: 10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2

Klukowski, M. 2004. Seasonal changes in abundance of host-seeking chiggers (Acari: Trombiculidae) and infestations on fence lizards, *Sceloporus undulatus.* Journal of Herpetology 38: 141-144. doi: 10.1670/127-03N

Koehler, P.G., F.M. Oi, and A. Chaskopoulou. 2011. Chiggers. Publication ENY-212, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, USA.

Krasnoshchekov, Y.N., E.N. Valendik, I.N. Bezkorovainaya, N.D. Sorokin, V.V. Kuz'michenko, S.V. Verkhovets, and E.K. Kislyakhov. 2004. Changes in ecological features of soils after controlled fires in forests defoliated by the Siberian moth in the southern taiga subzone of the Yenisei Region, Siberia. Biology Bulletin 31: 310-318. doi: 10.1023/B:BIBU.0000030154.43175.fc

Krist, A.C., J. Jokela, J. Wiehn, and C.M. Lively. 2004. Effects of host condition on susceptibility to infection, parasite developmental rate, and parasite transmission in a snail-trematode interaction. Journal of Evolutionary Biology 17: 33-40. doi: 10.1046/j.1420-9101.2003.00661.x

Main, A.R., and C.M. Bull. 2000. The impact of tick parasites on the behaviour of the lizard *Tiliqua rugosa.* Oecologia 122: 574-581. doi: 10.1007/s004420050981

Main, K.N., and E.S. Menges. 1997. Archbold Biological Station, station fire management plan. Land Management Publication 97-1, Archbold Biological Station, Lake Placid, Florida, USA.

McCoy, E.D., E.J. Britt, A. Catenazzi, and H.R. Mushinsky. 2012. Managing fire to maintain herpetofaunal diversity in the Florida scrub ecosystem. Natural Areas Journal: in press.

McCoy, E.D., N. Ihász, E.J. Britt, and H.R. Mushinsky. 2010. Is the Florida sand skink (*Plestiodon reynoldsi*) a dietary specialist? Herpetologica 66: 432-442. doi: 10.1655/09-045.1

Paulissen, M.A. 1988. Ontogenetic and seasonal comparisons of daily activity patterns of the six-lined racerunner, *Cnemidophorus sexlineatus* (Sauria: Teiidae). American Midland Naturalist 120: 355-361. doi: 10.2307/2426007

Penney, K.M., K.D. Gianopulos, E.D. McCoy, and H.R. Mushinsky. 2001. The visible implant elastomer marking technique in use for small reptiles. Herpetological Review 32: 236-241.

Reardon, J.T., and G. Norbury. 2004. Ectoparasite and hemoparasite infection in a diverse temperate lizard assemblage at Macraes Flat, South Island, New Zealand. Journal of Parasitology 90: 1274-1278. doi: 10.1645/GE-3326

Roy, S., and M.M. Roy. 2006. Spatial distribution and seasonal abundance of soil mites and collembolan in grassland and *Leucaena* plantation in a semi-arid region. Tropical Ecology 47: 57-62.

Rubio, A.V., and J.A. Simonetti. 2009. Ectoparasitism by *Eutrombicula alfreddugesi* larvae (Acari: Trombiculidae) on *Liolaemus tenuis* lizard in a Chilean fragmented temperate forest. Journal of Parasitology 95: 244-245. doi: 10.1645/GE-1463.1

Schall, J.J., and A.B. Marghoob. 1995. Prevalence of a malarial parasite over time and space: *Plasmodium mexicanum* in its vertebrate host, the western fence lizard *Sceloporus occidentalis*. Journal of Animal Ecology 64: 177-185. doi: 10.2307/5753

Schall, J.J., H.R. Prendeville, and K.A. Hanley. 2000. Prevalence of the tick, *Ixodes pacificus,* on western fence lizards, *Sceloporus occidentalis:* trends by gender, size, season, site, and mite infestation. Journal of Herpetology 34: 160-163. doi: 10.2307/1565257

Schrey, A.W., A.M. Fox, H.R. Mushinsky, and E.D. McCoy. 2011. Fire increases variance in genetic characteristics of Florida sand skink (*Plestiodon reynoldsi*) local populations. Molecular Ecology 20: 56-66. doi: 10.1111/j.1365-294X.2010.04925.x

Schultz, S.R., M.K. Johnson, R.X. Barry, and W.A. Forbes. 1993. White-tailed deer abomasal parasite and fecal egg counts in Louisiana. Wildlife Society Bulletin 21: 256-263.

Sutton, P.E. 1996. A mark and recapture study of the Florida sand skink *Neoseps reynoldsi* and a comparison of sand skink sampling methods. Thesis, University of South Florida, Tampa, USA.

Telford, S.R. 1959. A study of the sand skink, *Neoseps reynoldsi* Stejneger. Copeia 1959: 110-119. doi: 10.2307/1440062

Telford, S.R., and C.R. Bursey. 2003. Comparative parasitology of squamate reptiles endemic to scrub and sandhill communities of north-central Florida, USA. Comparative Parasitology 70: 172-181. doi: 10.1654/4060

Thamm, S., E. Kalko, and K. Wells. 2009. Ectoparasite infestations of hedgehogs (*Erinaceus europaeus*) are associated with small-scale landscape structures in an urban-suburban environment. EcoHealth 6: 404-413. doi: 10.1007/s10393-009-0268-3

USFWS [US Fish and Wildlife Service]. 1999. Multi-species recovery plan for south Florida: sand skink (*Neoseps reynoldsi*). US Fish and Wildlife Service, Atlanta, Georgia, USA.

Walter, D.E., and M. Shaw. 2002. First record of the mite *Hirstiella diolii* Baker (Prostigmata: Pterygosomatidae) from Australia, with a review of mites found on Australian lizards. Australian Journal of Entomology 41: 30-34. doi: 10.1046/j.1440-6055.2002.00272.x