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High Seroprevalence of *Toxoplasma gondii* in an Urban Caracal (*Caracal caracal*) Population in South Africa

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ABSTRACT: We investigated *Toxoplasmosis gondii* antibody seroprevalence in free-ranging caracals (*Caracal caracal*) in Cape Town, South Africa, from 2014 to 2017. Seropositivity was 83% (24/29), which is substantially higher than that detected in sympatric feral domestic cat (*Felis catus*) populations. The impact of this pathogen on local human and wildlife communities may be of concern.

Toxoplasma gondii is an obligate intracellular protozoan parasite able to infect most bird and mammal species (Tenter et al. 2000). Globally, *T. gondii* is one of the most common parasitic zoonoses (Furtado et al. 2011), and it is acquired mainly through the ingestion of food and water contaminated with oocysts or meat contaminated with tissue cysts (Tenter et al. 2000). Sexual reproduction by *T. gondii* only occurs in felids, resulting in the production and shedding of oocysts (vanWormer et al. 2014). Within the ecosystems they inhabit, free-ranging felids are valuable indicator species of *T. gondii* prevalence (Castillo-Morales et al. 2012). We investigated the prevalence of antibodies against toxoplasmosis in caracals (*Caracal caracal*) inhabiting Cape Town, South Africa. The caracal is a medium-size felid with a widespread geographic distribution ranging throughout Africa, the Middle East, and Asia (Hunter 2015). We assessed seroprevalence across all individuals and potential seroprevalence differences among age and sex classes. We predicted that seroprevalence would mirror recent findings of *T. gondii* seroprevalence (37.1%) in feral domestic cats in Cape Town (Hammond-Aryee et al. 2015), given that they may overlap in habitat use and diet.

We used cage-traps to capture 29 caracals from 2014 to 2017 throughout Table Mountain National Park (TMNP), representing 220 km^2 of protected area, and nearby city reserves and residential areas. Four individuals were recaptured. We chemically immobilized caracals with ketamine HCl (7 mg/kg) and medetomidine HCl (0.08 mg/kg). We recorded age class, sex, and morphologic measurements. Individuals were classified as juveniles (<2 yr old) or adults (≥2 yr old) based on body size, weight, tooth wear, and reproductive status (Schroeder et al. 2005). Animal handling was approved by the University of Cape Town (2014/V20/LS), Cape Nature (AAA007-0147-0056), and South African National Parks (SERL/AGR/017–2014/V1). We collected blood via saphenous venipuncture and centrifuged the blood within 24 h of collection. Serum was collected and stored at –80 C until tested. We analyzed sera for the presence or absence of immunoglobulin M (IgM) and immunoglobulin G (IgG) to *T. gondii* using indirect immunofluorescence test (IFAT) commercial kits (Euroimmun AG, Luebeck, Germany; Hammond-Aryee et al. 2015). The presence of IgM is indicative of recent infections, while IgG reflects a history of exposure (Fricker-Hidalgo et al. 2013). Recaptured individuals were counted only once and were considered seropositive if the sample from either capture was positive (Bevins et al. 2012). We calculated seroprevalence and associated 95% confidence intervals for all individuals togeth-

TABLE 1. Percent of caracals (*Caracal caracal*) sampled from 2014 to 2017 in Cape Town, South Africa, that were seropositive using indirect immunofluorescence test for immunoglobulin G (IgG) and immunoglobulin M (IgM) against *Toxoplasma gondii* overall (combined IgG and IgM), and to each type of antibody (IgG or IgM). Results were grouped by sex and age class. Associated 95% confidence intervals (CI) are in parentheses.

	Percent seropositive (95% CI)				
	All individuals (n=29)	Males (n=17)	Females (n=12)	Adults (n=18)	Juveniles (n=11)
Overall	83 (64–93)	82 (56–95)	83 (51–97)	89 (64–98)	73 (39–93)
IgG	79 (60–91)	76 (50–92)	83 (51–97)	83 (58–96)	73 (39–93)
IgM	38 (21–58)	53 (29–76)	17 (03–49)	33 (14–59)	55 (25–82)

er and for individuals grouped by age or sex (Table 1). We performed Fisher's exact tests to determine whether antibody prevalence differed significantly between age and sex classes. Analyses were performed in R (R Development Core Team 2014), and results were considered significant if $P<0.05$.

Overall (combined IgG and IgM) seroprevalence was 83% (24/29, 95% confidence interval [CI]: 64–93; Table 1). Across all individuals, IgG seroprevalence was 79% (23/29, 95% CI: 60–91). The IgM seroprevalence was 38% (11/29, 95% CI: 21–58). While seroprevalence varied across age and sex classes, we did not detect any statistically significant differences. Overall seropositivity was similar for males (82%, 11/14, 95% CI: 56–95) and females (83%, 10/12, 95% CI: 51–97). Seropositivity of IgG was slightly lower in males (76%, 13/17, 95% CI: 50–92) compared with females (83%, 10/12, 95% CI: 51–97). Seropositivity of IgM was higher in males (53%, 9/17, 95% CI: 20–76) than in females (17%, 2/12, 95% CI: 77–64). Overall, IgM and IgG seropositivity was higher in adults (89%, 16/18, 95% CI: 58–96 and 83%, 15/18, 95% CI: 64–98, respectively) than in juveniles (73%, 8/11, 95% CI: 64–98 and 73%, 8/11, 95% CI: 39–93, respectively). Seropositivity of IgM was lower in adults (33%, 6/18, 95% CI: 14–59) compared with juveniles (55%, 6/11, 95% CI: 25–82). Nine individuals (adults, n=4; juveniles, n=5) were both IgG and IgM positive, reflecting chronic exposure (Castillo-Morales et al. 2012) or the seroconversion of transient (IgM) to persistent antibodies (IgG; Fricker-Hidalgo et al. 2013). Our findings demonstrated an active, widespread infection cycle within this system.

The patterns of seropositivity to *T. gondii* that we observed were consistent with expectations from the literature (Bevins et al. 2012; vanWormer et al. 2014; Carver et al. 2016), although the lack of statistically significant differences among age or sex groups may be an artifact of sample size. We found considerably higher seroprevalence in caracal compared with sympatric feral cat populations (37.1%; Hammond-Aryee et al. 2015), pointing to differences in exposure rates or routes, as suggested by Bevins et al. (2012). In a study of three sympatric felid species in the US, Bevins et al. (2012) found a similar pattern of higher seroprevalence in wild felids (bobcats [*Lynx rufus*] and pumas [*Puma concolor*]) compared with feral domestic cats. The differences were attributed to differences in habitat use, diet, and efficiency of transmission in sylvatic versus urban settings. Given our findings, caracals are also likely exposed to *T. gondii* more frequently than feral cats in the study area via intermediate hosts such as their prey (native rodents inhabiting TMNP). Seroprevalence also appears to be high in wild free-ranging felids in other regions of South Africa, ranging from 74% to 100% in leopard (*Panthera pardus*), lion (*Panthera leo*), and cheetah (*Acinonyx jubatus*; Cheadle et al 1999; Penzhorn et al. 2002). The ecologic significance of high *T. gondii* seroprevalence in wild felids is unknown. However, within the study area, consumption of bushmeat caracal could lead to detrimental toxoplasmosis within local human communities. There may be consequences for other wildlife species as

well. For example, marine waters contaminated with *T. gondii* oocysts from freshwater runoff have been implicated in the decline of the endangered North American sea otter (*Enhydra lutris*; vanWormer et al. 2014). Whether a similar dynamic occurs in South Africa for Cape clawless otters (*Aonyx capensis*) could be of concern. This exploratory study provides the basis for further research to be conducted into *T. gondii* infection in these important hosts and co-occurring species.

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