PARASITE SURVEY OF WOODRATS (GENUS *NEOTOMA*) IN SOUTHWEST USA

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Abstract

Animals host many types of parasites that affect host health and persistence, but we have yet to fully understand the extent of parasitism in many species. The aim of the current work was to survey intestinal parasites in woodrats (genus *Neotoma*). Here we present findings of parasite screens of 141 animals from six *Neotoma* species. Feces were collected from each animal during live-trapping efforts at 13 populations in Utah, Arizona, and California, and fecal floats were conducted to determine parasite infection. Surveyed animals hosted nematodes (families: Heteroxynematidae and Trichostrongylidae) and coccidians (genera: *Eimeria* and *Isospora*), and parasite prevalence varied by population. We discuss our results in the context of previous *Neotoma* parasite surveys.

Background

Woodrats (*Neotoma* spp.) are a group of New World herbivorous rodents that typically inhabit arid and semi-arid habitats in North America (Betancourt et al. 1990). The desert southwest of the United States is the most speciose region of their distribution, hosting nine of the 25 *Neotoma* species (Betancourt et al., 1990, Patton et al. 2007). Due to their nesting behavior, woodrats act as keystone ecological engineers in their environments (Whitford and Steinberger, 2010). Understanding patterns of parasitism in woodrat populations can improve conservation strategies.

Past surveys of parasitism in *Neotoma* have used a variety of different survey methods (e.g., fecal floats, necropsies). These studies are useful to establish a taxonomic database for future diagnoses, but do not give a comprehensive view of parasite fauna across the genus as most include only a small geographic range or limited number of individuals (e.g., Cudmore, 1986; Wilson, 1997). There are few endoparasite surveys that extensively characterize the parasite community of a population (e.g., Charles et al., 2012; Bechtel et al., 2015), and there have not been endoparasite surveys that span multiple locations. Our goal was to assess the parasite diversity and prevalence in six species of woodrats, from 13 populations at 9 localities. Here, we present the results of an intestinal parasite survey of 141 animals across this distribution.
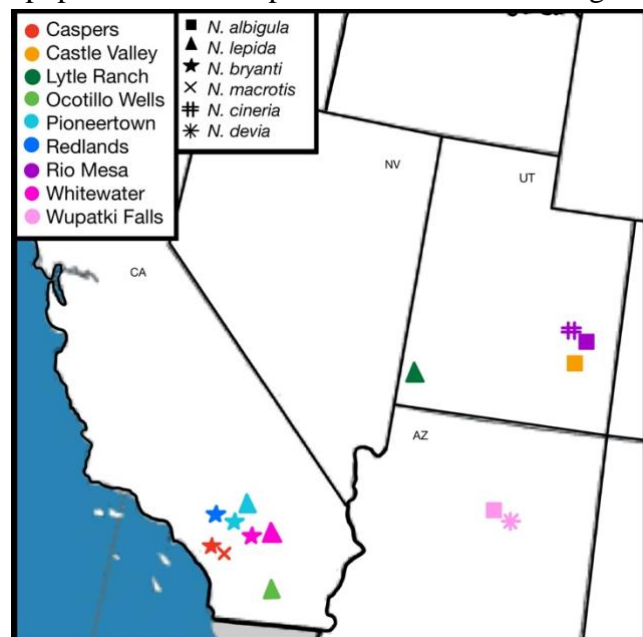
Figure 1. Map of southwestern USA woodrat collection localities. Sites are labeled by color, and species are labeled by shape. Sites with two species are labeled by two shapes on either side of the exact GPS location.

Methods

Animals were live-trapped in Sherman traps at 9 locations across the Southwest United States between 2017–2020 (Figure 1). We identified the woodrat species based on Dearing lab familiarity with these species distributions from extensive trapping and Patton et al. (2007). Feces were collected from the traps and preserved in 10% buffered formalin or 95% ethanol within 10 h of defecation. Each population had a different sample size – Castle Valley *N. albigula* the largest and Rio Mesa *N. albigula* the smallest. Feces were examined for parasite eggs by fecal float (e.g., Dryden et al. 2005). For each fecal float, approximately 1g of feces was mixed in water to form a slurry that was strained through fine mesh. Two mL of the flow-through mixture was combined with 12 mL Sheather's sugar solution (specific gravity 1.27) and centrifuged in a test tube covered by a glass cover slip. Parasite eggs and oocysts adhered to coverslip after centrifugation. The coverslip was used to make a wet mount slide, then scanned for parasite stages under a light microscope at 100X total magnification. Parasite eggs were identified to family or genus level based on morphology according to expertise of author, S.B. Weinstein, and primary literature (Reduker and Duszynski, 1975). Infection prevalence is reported as the proportion of animals hosting parasites.

Results. Woodrats hosted nematodes in the families Heteroxynematidae and Trichostrongylidae) and coccidians in the genera *Eimeria* and *Isospora* (Figure 2). No populations hosted more than one morphospecies of nematode or coccidian, although animals in several populations were coinfected by both nematodes and coccidians (Table 1). Infection prevalence varied by population, and egg intensity in feces varied within a population. Some samples yielded fewer than 10 eggs while others had hundreds of eggs. The highest nematode prevalence was in *N. bryanti* from Pioneertown, CA (75%). We found that both *N. bryanti* and *N. macrotis* at Casper's had the highest prevalence of coccidian (50%) infection of all populations, and the *N. bryanti* at this site also had the highest coinfection (33%) prevalence. Some populations hosted low parasite prevalence – Whitewater *N. bryanti/N. lepida* hybrid population was the second largest sample size (N=32) and hosted only a 6% coccidian prevalence, with no nematode infections detected.

Discussion

Parasite presence and prevalence varied across the 13 surveyed *Neotoma* populations. Despite sampling across 6 species and 9 locations, we found a relatively low total parasite diversity compared to past studies. For example, full necropsy survey of 104 Texas *N. micropus* revealed nine helminth and four coccidian species (Charles et al., 2012), and a fecal float survey of 25 *N. fuscipes* and 25 *N. macrotis* in central California revealed four helminth and three coccidian species (Bechtel et al., 2015). Although we did not identify parasites to species, we only found two helminth and two coccidian morphospecies based on egg morphology (Figure 2). Despite having a lower parasite diversity than
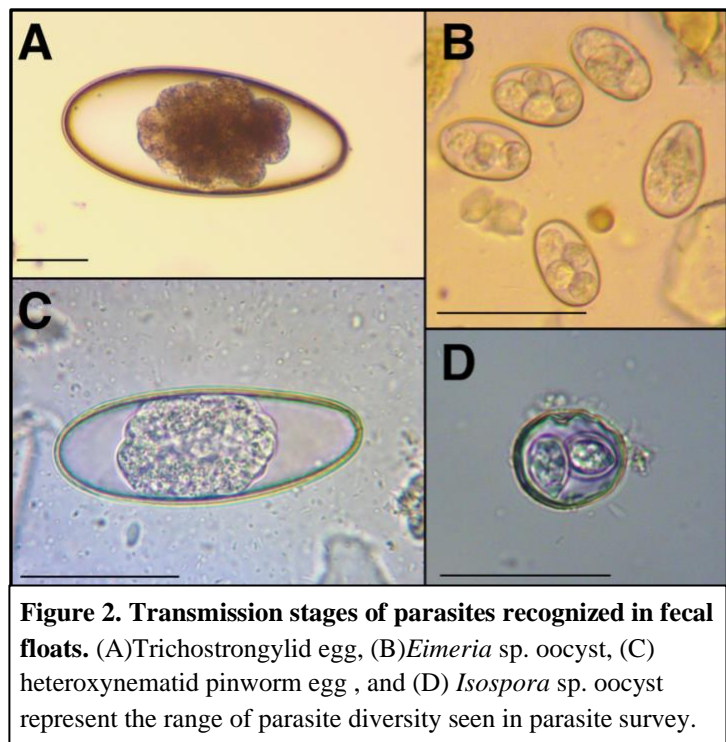
Figure 2. Transmission stages of parasites recognized in fecal floats. (A)Trichostrongylid egg, (B)*Eimeria* sp. oocyst, (C) heteroxynematid pinworm egg , and (D) *Isospora* sp. oocyst represent the range of parasite diversity seen in parasite survey.

previous studies, the types of parasites that we found were similar to common parasites in other comprehensive surveys. For example, the trichostrongylid nematode *Nematodirus* sp. was common in *N. micropus* from Texas (Charles et al., 2012)*,* and Heteroxynematidae pinworms (*Aspicularis* sp.) were common in *N. fuscipes* and *N. macrotis* from California (Betchel et al., 2015). Notably, like Betchel et al. (2015), we also found pinworm and *Eimeria* sp. in *N. macrotis* from California. However, they also found low prevalence of *Giardia*, *Cryptosporidium*, and *Trichuris* (i.e., whipworms). These parasites might also occur in our sampled populations, but at prevalence below our detection limits.

The type of parasite infection is important in considering population health because parasites vary in their effects on host health. For example, *Trichuris* spp. (whipworms) can cause severe illness by damaging host intestinal tissue, while pinworms consume digesta in the gut lumen and often cause few symptoms (Roberts and Janovy, 2009). Low numbers of observed eggs suggest low intensity infections of the helminths recovered in our work. These types of infection would likely not harm hosts due to their minimal interaction with the host gut epithelium. Instead of being a health concern, persistence of low-impact and low-intensity parasite infections in these host populations is a useful indicator of ecosystem function because successful parasite transmission is a proxy for host social interaction and an interconnected food web (Marcogliese, 2005). Although we could not assess infection intensities with our survey, we observed no outward signs of disease in surveyed animals, indicating that parasites were not strongly affecting host health.

This work provides an overview of parasite prevalence in many populations with consistent survey methods. Although our work lacks species-level identifications and infection intensity data that would come with lethal sampling, our method of fecal flotation allowed us to non-invasively sample many wild populations (Riepe et al. 2019). This study will be a resource for future *Neotoma* parasite sampling efforts that target specific helminth or coccidian infections, and future work with targeted lethal sampling could reach species-level identifications and better understand infection dynamics by identifying adult parasite stages with morphological and molecular tools. This would not only be useful in tracking infection rates, but also understanding host specificity. For example, we do not know whether the two Casper's woodrat species host the same species of parasites, but similar prevalences of parasites in the same families indicate that the two species could share parasites and have similar susceptibility to infection. Also, sample size was not equal across populations, and small sample size may have affected our prevalence estimates since no parasites were detected in two populations where fewer than 10 animals surveyed – *N. lepida* from Ocotillo Wells and *N. albigula* from Rio Mesa. Infection prevalence appears to vary across species and sites, but future work with more intensive sampling could elucidate whether these are imperfect estimates or true differences based on host population density and social habits, climate, and other factors govern parasite infection (Combes, 2001).

Table 1. Summary of fecal float data. The proportion infected (i.e., prevalence) is listed after the total number of animals infected for each population. "Average feces" is the average mass of feces used for fecal

Location	Species					
Caspers Wilderness Park Orange County, CA	*N. bryanti*	0.833	6	0 (0)	3 (0.50)	2 (0.33)
	N. macrotis	0.713	4	0 (0)	2 (0.50)	1 (0.25)
Castle Valley Grand County, UT	*N. albigula*	1.421	46	9 (0.20)	2 (0.04)	1 (0.02)
Lytle Ranch Washington County, UT	*N. lepida*	1.587	9	6 (0.67)	0 (0)	1 (0.11)
Ocotillo Wells San Diego County, CA	*N. lepida*	0.736	7	0 (0)	0 (0)	0 (0)
Pioneertown San Bernardino County, CA	*N. bryanti*	0.718	4	3 (0.75)	0 (0)	0 (0)
	N. lepida	0.860	5	0 (0)	2 (0.40)	0 (0)
Redlands, San Bernardino County, CA	*N. bryanti*	1.051	16	2 (0.13)	0 (0)	0 (0)
Rio Mesa Grand County, UT	*N. albigula*	1.020	1	0 (0)	0 (0)	0 (0)
	N. cineria	2.272	3	2 (0.67)	0 (0)	0 (0)
Whitewater, Riverside County, CA	*N. bryanti/ N. lepida*	0.441	32	0 (0)	2 (0.06)	0 (0)
Wupatki Falls, Coconino County, AZ	*N. albigula*	1.085	4	1 (0.25)	1 (0.25)	0 (0)
	N. devia	1.078	4	0 (0)	0 (0)	1 (0.25)

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