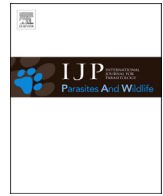




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Endoparasites of American marten (*Martes americana*): Review of the literature and parasite survey of reintroduced American marten in Michigan



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ABSTRACT

The American marten (*Martes americana*) was reintroduced to both the Upper (UP) and northern Lower Peninsula (NLP) of Michigan during the 20th century. This is the first report of endoparasites of American marten from the NLP. Faeces from live-trapped American marten were examined for the presence of parasitic ova, and blood samples were obtained for haematocrit evaluation. The most prevalent parasites were *Capillaria* and *Alaria* species. Helminth parasites reported in American marten for the first time include *Eucoleus boehmi*, hookworm, and *Hymenolepis* and *Strongyloides* species. This is the first report of shedding of *Sarcocystis* species sporocysts in an American marten and identification of 2 coccidian parasites, *Cystoisospora* and *Eimeria* species. The pathologic and zoonotic potential of each parasite species is discussed, and previous reports of endoparasites of the American marten in North America are reviewed.

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1. Introduction

The American marten (*Martes americana*) is an arboreal meso-carnivore that ranges from the boreal forests of northern North America into coniferous and mixed coniferous/deciduous forests of the northern and northeastern United States, including the Great Lakes region (Clark et al., 1987). The American marten was reintroduced to Michigan's Upper Peninsula (UP) and northern Lower Peninsula (NLP) in the mid-20th century after regional extirpation due to habitat loss and over-harvest (Cooley et al., 2004). Over 200 animals were reintroduced to the UP over the course of several reintroductions. Many fewer animals (n = 36) were reintroduced in the Huron-Manistee National Forest of the NLP and 49 martens were reintroduced to the Pigeon River State Forest of the NLP. The UP population has since grown and currently sustains an annual harvest for fur. In contrast, the species is considered a Regional Forester Sensitive Species and there is no harvest in the NLP (USDA

Forest Service, 2012). Factors hypothesized to be contributing to the differences in population sustainability between the UP and NLP include differences in habitat, genetic diversity, health and others. At the time of the original reintroduction, American marten were not examined for parasitic or infectious diseases (Spriggs, unpublished data). Some parasites are of economic or zoonotic importance and may be introduced with animal translocations. Therefore, reintroduction programs should take into account the presence of parasites which are pathogenic or to which the species of concern is not adapted (Kimber and Kollias, 2000).

A collaborative research effort has begun in order to investigate factors that may be contributing to the difference in sustainability between the UP and NLP populations. The aim of this parasite survey was to describe the presence and prevalence of parasites in the Huron-Manistee National Forest of the NLP and to determine whether there are differences in presence or prevalence of parasites between the NLP and UP. This survey uses fecal examination as a non-invasive method for identifying parasites. Should future translocation of animals from the UP into the NLP be considered for management of the species, a non-invasive and inexpensive method for screening animals would be desirable. Also, American marten are not harvested in the NLP and thus adequate numbers of

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carcasses are not available for examination.

While some information exists regarding the prevalence of endoparasitism in American marten in North America, relatively little information is available for the species in Michigan (Poole et al., 1983; Veine-Smith et al., 2011). This study reviews previous parasite prevalence reports from American marten in North America, presents data from the parasitological examination of live-trapped American marten in Michigan, and identifies a possible association between hookworm infection and anaemia in affected American marten.

2. Materials and methods

American marten ($n = 49$) were sampled from the Manistee National Forest in the NLP ($n = 31$), Hiawatha National Forest in the UP ($n = 13$) and Ottawa National Forest in the UP ($n = 5$). American marten were trapped and immobilized from 2011 to 2015 as described by Desmarchelier et al. (2007) for a concurrent habitat study. Faeces were collected either via fecal loop from the rectum or from the trap. Faeces were stored under refrigeration and examined within 4 days of collection. Nine American marten were recaptured and re-sampled, resulting in a total of 60 faecal samples included in analyses.

Blood was collected from the jugular vein and placed into lithium heparin anticoagulant (BD Microtainer Tubes, Becton Dickinson and Company). We determined haematocrit using microhematocrit capillary tubes (SafeCrit) and the StatSpin VT centrifuge (Iris). Individuals were identified as anaemic if the haematocrit was $<42\%$ based on a report of normal haematocrit in captive, fed American martens of $47 \pm 5\%$ (Nieminen et al., 2007). Other health parameters were collected as part of a complete health assessment (Spriggs, unpublished data). Faecal float and sedimentation examinations were performed at Michigan State University's Diagnostic Center for Population and Animal Health using standard methods (Zajac and Conboy, 2012). Faecal flotation was performed using Sheather's sugar solution (specific gravity 1.25–1.27) alone ($n = 30$) from May 2011–May 2012 or with both Sheather's sugar solution and zinc sulfate solution (specific gravity 1.18, $n = 30$) from June 2012–January 2015 and examined by light microscopy. Fifty-nine of the samples, representing 48 individual animals, were sufficient in quantity for faecal sedimentation procedure. Ova were identified based on morphologic characteristics including size and in accordance with parasitologic references and previous reports. Upon consultation with a wildlife veterinary parasitologist (Gerhold), 2 nematode species (*Syphacia muris* and *Aspicularis* sp.) were presumed to be pass-through from rodent prey and excluded from analyses.

Statistical analysis was performed with JMP Pro 10.0.02 (SAS Institute Inc.). Prevalence was calculated as the number of infected hosts divided by the number of hosts examined. Because some American marten were sampled more than once, all parasite species found in an individual were considered together for prevalence calculations. Differences between locations (UP and NLP) and sexes were examined with a Pearson's χ^2 test with $P < 0.05$ considered significant. Significant differences between presence or absence of anaemia and hookworm infection were also examined with a Pearson's χ^2 test. Parasite species richness by host was calculated as the number of parasite species present per host; species richness by sample was calculated as the number of parasite species present per sample. An unidentified capillarid species was not included in the prevalence or host species richness if one or more species of *Capillaria* was identified in other samples from the same host. Thus, an individual American marten found with unidentified capillarid at the initial exam and *Aonchotheca* sp. at a subsequent exam was considered to be infected with *Aonchotheca* sp. alone when

reporting prevalence. If both samples had unidentified *Capillaria*, then the host was included in the calculation of prevalence of unidentified *Capillaria*. Unidentified *Capillaria* were always included in the sample species richness calculations. Differences between sex and location in species richness were examined with a Wilcoxon rank sum test, with $P < 0.05$ considered significant.

The capture and handling protocol was approved by the University of Tennessee Animal Care and Use Committee (protocol #2180), and American marten live-trapping and sample collection was an authorized tribal activity under the 2007 Inland Consent Decree between the State of Michigan and the Little River Band of Ottawa Indians.

3. Results

Sixty samples from 49 individual American marten (28 males, 21 females) were examined, and results are shown in Table 1. Parasite species richness by host is shown in Table 2. Of 49 individual American marten examined, 91.8% were positive for 1 or more parasites and 69.4% were infected with 2 or more parasites. There was no significant difference in mean species richness by host between sexes or locations (NLP and UP).

Trematode eggs were seen in over half (63.3%) of all hosts. *Alaria* species was suspected or confirmed, depending upon examination method. Trematode egg identification was suspected but not confirmed to be *Alaria* sp. during the early part of the study (May 2011–May 2012) when Sheather's sugar solution alone was used for flotation, as *Alaria* species may be distorted due to the osmotic pressure of sugar solution. Later in the study (June 2012–January 2015), trematode ova found on sedimentation were confirmed to be *Alaria* species when the sample was floated with zinc sulfate solution, in which trematode ova will not be distorted. Once the use of zinc sulfate solution was implemented, no trematode other than *Alaria* species was identified, and the authors concluded that trematode eggs identified in the early samples were most likely *Alaria* species, as suspected. In the UP, 3 samples that were positive on sedimentation for trematode ova were suspected to be *Alaria* species and 7 were confirmed via zinc sulfate flotation; in the NLP, 14 samples positive on sedimentation were suspected to be *Alaria* species and 5 were confirmed via zinc sulfate flotation. *Capillaria* eggs were seen in 79% and 78.1% of samples from the UP and NLP, respectively. *Capillaria* eggs were further identified as *Eucoleus aerophila*, *Eucoleus boehmi*, or *Aonchotheca putorii* based on size and morphologic characteristics. A hookworm egg is shown in Fig. 1. There was no significant difference in prevalence of any of the identified parasites between male and female American marten. Of 9 American marten that were sampled more than once, only one had identical results for each time point.

The mean haematocrit was 45.6 ± 8.1 (range 30–68; $n = 49$). Haematocrit was reported to be $47 \pm 5\%$ in the only other report of American marten haematocrit (Nieminen et al., 2007). Using $<42\%$ as a cut-off, 24.5% of blood samples tested in this report were considered anaemic. American marten infected with hookworms were significantly more likely to be anaemic than non-infected American marten ($P = 0.01$) with an odds ratio of 8.75 (95% confidence interval: 1.4–56.4).

4. Discussion

Parasite species richness per host was similar to that reported by Veine-Smith et al. (2011) for American marten in the UP. We identified more parasite species in the NLP than the UP, but this result may be a function of the larger sample size from the NLP, and there was no significant difference in richness between the 2 locations. Foreyt and Langerquist (1993) found 2 or more parasites in

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