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An Analysis of the Parasites of a Mid-winter Population of the Snowshoe Hare, *Lepus americanus,* on Insular Newfoundland During a Cyclical Peak

K. E. Bennett[1], E. M. Baggs[2], J. R. Finney-Crawley, and M. McGrath[3]

Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador A1B 3X9 Canada
[1] P.O. Box 43, St. Paul's Inlet, Newfoundland A0K 4Y0 Canada
[2] Corresponding author
[3] Senior Small Game and Furbearer Biologist, Wildlife Division, Department of Environment and Conservation, Government of Newfoundland and Labrador, P.O. Box 8700, St. John's, Newfoundland and Labrador A1B 4J6 Canada

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A mid-winter sample of 78 Snowshoe Hares *(Lepus americanus)* was collected during their cyclical peak in population from three eco-regions (Western Newfoundland, North Shore and Avalon Forest) on insular Newfoundland and was examined for the presence of enteric parasites. The length of the hares was significantly shorter in the Avalon Forest Region (n = 27) than those of the Western Newfoundland Region (n = 25) and North Shore Region (n = 26) samples ($P \leq 0.001$ and $P \leq 0.003$ respectively); however, no significant differences occurred for other morphological measurements. Four species of parasites, two cestodes (*Mosgovoyia pectinata* and *Taenia pisiformis*) and two nematodes (*Obeliscoides cuniculi* and *Rauschia triangularis*), were recovered. *Taenia pisiformis* was recovered from the North Shore eco-region only. No other significant differences with respect to their prevalence, intensity, mean intensity, relative density and dispersion between eco-regions were found. Within eco-regions, only *R. triangularis* showed a significantly higher value ($P \leq 0.027$) for males and the prevalence of this species was lower than that previously reported. The occurrence of *O. cuniculi* was significantly different between the higher weight classes of hares and the prevalence of this species was higher than that previously reported. No trends for multiple infections were noted. The expansion of a new animal species, the Coyote, *Canis latrans,* to Newfoundland appeared to have had no effect on the diversity of parasites found in the hare.

Key Words: *Lepus americanus,* Snowshoe Hare, parasite diversity, cestodes, *Mosgovoyia pectinata, Taenia pisiformis,* nematodes, *Obeliscoides cuniculi, Rauschia triangularis,* eco-regions, exotics, insular Newfoundland.

Following the Wisconsinian glaciation, the mammalian fauna of insular Newfoundland was impoverished (Dodds 1957 Scruton et al. 1995) and the island had a high predator to prey species ratio. Much of the present biodiversity is a result of accidental or deliberate introductions and colonization. The original small mammal (prey) populations consisted of the Arctic Hare (*Lepus arcticus*) and the Meadow Vole (*Microtus pennsylvanicus*) while the mammalian predator list consisted of the Lynx (*Lynx canadensis*), Black Bear (*Ursus americanus*), Newfoundland Wolf (*Canis lupus beothucus,* now extinct), Red Fox (*Vulpes vulpes*), and a variety of mustelids; i.e., the Pine Marten (*Martes americana*), Short-tailed Weasel (*Mustela erminea*), and River Otter (*Lutra canadensis*). There have also been temporary invasions of the Arctic Fox (*Alopex lagopus*) (Banfield 1987).

Over the last 150 years there have been a number of deliberate introductions that have resulted in successful establishment of populations in insular Newfoundland. These included the Snowshoe Hare (*Lepus americanus*) in 1864 and Moose (*Alces alces*) in 1904 (Banfield 1987), which were introduced as a means of increasing the availability of fresh meat to the resident human population. Small mammal introductions of the Red Squirrel (*Tamiasciurus hudsonicus*) in 1963 (Payne 1976) and Eastern Chipmunk (*Tamias striatus*) in 1962 (Northcott et al. 1973) were made to enhance the small mammal prey base of the island. The Deer Mouse (*Peromyscus maniculatus*), introduced in 1968 (Gould and Pruitt 1969), is thought to have been accidental, imported with cargo shipped through the Maritime provinces of Canada to Newfoundland. The Red-backed Vole (*Clethrionomys gapperi*) (first recorded about 1997 but precise year of introduction unknown) remains an enigma. It has been suggested that it established populations in the Stephenville area and elsewhere on the island and may have originated

from transportation of logs to the liner board mill in Stephenville from Labrador from as far back as the late 1960s. Shipments of these logs were sporadic over that period. The Masked Shrew (*Sorex cinereus*) was introduced in 1958 in an attempt to control outbreaks of the Hemlock Looper (*Lambdina fiscellaria*) (Warren 1970). The carnivore list increased in May 1987 when the Eastern Coyote (*Canis latrans*) became well-established after crossing the Gulf of St. Lawrence on winter ice floes from the Maritimes (Parker 1995).

Introductions of exotic animals have the inherent risk of bringing accompanying parasites and/or pathogens which may subsequently impact on resident species. Dodds and Mackiewicz (1961) examined 630 Snowshoe Hares in an attempt to establish the parasite fauna of these herbivores in Newfoundland and reported the following enteric parasites: trematode: *Dicrocoelium dentriticum;* cestodes: *Mosgovoyia pectinata, Hydatigera taeniaeformis, Multiceps* sp. and *Taenia pisiformis;* nematodes: *Trichostrongylus axei* and *Obeliscoides cuniculi.* Smith and Threlfall (1972) examined three Snowshoe Hares and reported the presence of the cestodes *Multiceps serialis* and *Taenia pisiformes* in the coelomic cavities, the nematode *Rauschia triangularis* in the digestive tract, and an unidentified nematode from the lungs. While there is no information on the parasite burdens of the Snowshoe Hares used in the 1864 introductions, the work of Dodds and Mackiewicz (1961) and Smith and Threlfall (1972) form a basis from which a comparison of the Snowshoe Hare parasites may be made in light of subsequent mammalian introductions. This paper examines the mid-winter enteric parasite standing of *Lepus americanus* from insular Newfoundland collected during the hare cyclical peak (Reynolds et al. 2004*).

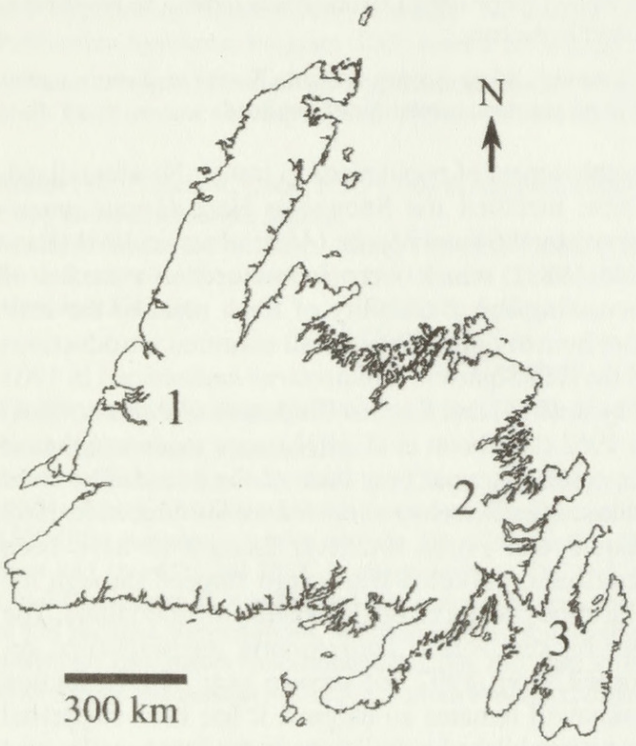

FIGURE 1. Map of insular Newfoundland, Canada. Collection Areas 1, Western Newfoundland, (57°45'W, 49°6'N), 2, North Shore (53°53'W, 48°41'N), 3, Avalon Forest (53°12'W, 47°30'N).

Materials and Methods

A total of 78 adult Snowshoe Hares was collected by shooting and snaring by hunters and trappers from three eco-regions (Figure 1): Western Newfoundland (Eco-region 1), Sub-region 1a – Old Man's Pond (n = 25); North Shore (Eco-region 3) (n = 26) and Avalon Forest (Eco-region 5) (n = 27) of insular Newfoundland (Meades and Moores 1994) and were submitted to the Inland Fish and Wildlife Division of the Government of Newfoundland and Labrador. The three eco-regions have similar populations of plants and animals but differ in physical attributes and land usage. Collections were carried out during January through February 2000 at the cyclical peak for Snowshoe Hares (Reynolds et al. 2004*) in Newfoundland. Morphological criteria were obtained prior to necropsy. Hares were examined for helminth parasites using conventional parasitological techniques. Descriptive statistical analysis of hare morphology, parasite parameters or both was accomplished using the Microsoft Excel 98 statistical package. A comparison of body length-weight relationship was carried out using the general linear model and a comparison of the slopes was made to determine whether the growth curves differed by eco-region. Comparisons of hare population data were carried out using standard paired t-tests and one-way ANOVAs. Comparisons of hare data based on sex were carried out using Mann-Whitney and Kruskall-Wallis non-parametric tests. Parasite parameters (i.e., prevalence, abundance etc.) were determined using the methods of Margolis et al. (1982).

Data for all parasites except *Rauschia triangularis* were based on counts, but, due to the large numbers observed, values for *R. triangularis* were ranked. In all cases this parasite exceeded 50 individuals and a scale of 0 through 3 was used to rank estimated population numbers (i.e., 0 = 0 parasites, 1 = 1 – 50 individuals, 2 = 50 – 100 parasites and 3 = more than100 individuals).

Results

The Snowshoe Hares had an overall sex ratio of 1.1: 1.0 (males: females). Based on weight, there were no significant differences between animals from the three eco-regions (Table 1). There were no differences between the body length of North Shore and Western Newfoundland hares; however, those of the Avalon Forest were significantly shorter ($P \leq 0.001$ and $P \leq 0.003$ from North Shore and Western Newfoundland). There was a trend for the hares to be longer on an east to west basis by eco-region, although no significant differences were noted for any other physical characteristic measured. No significant differences were found in body length-weight relationships ($P = 0.05$) and the subpopulations were considered similar.

TABLE 1. Summary of morphometric data (means) on *Lepus americanus* from three Eco-regions on insular Newfoundland: Western Newfoundland, North Shore and Avalon Forest.

Parameter	Ecoregion		
	Western Newfoundland (57°45'W, 49°6'N)		
	Male (n = 12)	Female (n = 12)	Total (n = 24)
Weight (kg) (± SD)	1.35 ± -0.134	1.46 ± -0.125	1.405 ± -0.138
Length (mm)	442.8 ± -21.70	453.3 ± -11.02	448.05 ± -17.66
L H F L (mm s.u.[1])	127.7 ± -4.73	125.9 ± -4.50	126.8 ± -4.62
Pinnae (mm)	87.2 ± -3.75	85.8 ± -4.43	86.5 ± -4.24
Slot (mm)	70.3 ± -2.53	70.4 ± -4.06	70.35 ± -3.31
	North Shore (53°53'W, 48°41'N)		
	Male (n=13)	Female (n=12)	Total (n=25)
Weight (kg) (± SD)	1.34 ± -0.174	1.44 ± -0.133	1.39 ± -0.161
Length (mm)	440.8 ± -15.77	450.6 ± -14.95	445.70 ± -15.86
L H F L (mm s.u.[1])	122.4 ± -5.88	127.2 ± -16.06	124.80 ± -11.72
Pinnae (mm)	87.5 ± -5.06	89.9 ± -3.29	88.7 ± -4.38
Slot (mm)	71.7 ± -5.41	73.4 ± -3.12	72.55 ± -4.45
	Avalon Forest (53°12'W, 47°30'N)		
	Male (n=14)	Female (n=13)	Total (n=27)
Weight (kg) (± SD)	1.35 ± -0.114	1.41 ± -0.145	1.38 ± -0.130
Length (mm)	426.7 ± -25.92	429.9 ± -21.55	428.30 ± -23.52
L H F L (mm s.u.[1])	124.8 ± -6.86	125.5 ± -9.79	125.15 ± -8.24
Pinnae (mm)	86.8 ± -6.22	88.1 ± -6.28	87.45 ± -6.16
Slot (mm)	72.0 ± -2.33	68.5 ± -4.32	70.25 ± -3.65

[1]L H F L – Left Hind Foot Length; s.u. – *sans ungus*

TABLE 2. Occurrence of the parasites of *Lepus americanus* from three Eco-regions on insular Newfoundland: Western Newfoundland, North Shore and Avalon Forest. + = present; – = not present

Parasite	Ecoregion		
	Western Newfoundland	North Shore	Avalon Forest
Mosgovoyia pectinata	+	+	+
Taenia pisiformis	-	+	-
Obeliscoides cuniculi	+	+	+
Rauschia triangularis	+	+	+

Sixty percent of the hares contained at least one parasite species, 25.6 percent contained two parasite species and 3.8 percent contained three parasite species. No hares contained four parasite species and 10.3 percent of the hares contained no enteric parasites.

Four enteric parasite species were recovered. Two cestodes: adult *Mosgovoyia pectinata* and the cysticercus *Taenia pisiformis* and two nematodes: *Obeliscoides cuniculi* and *Rauschia triangularis* (Table 2). *Taenia pisiformis* occurred in one female hare in the North Shore Eco-region whereas *M. pectinata* and the two nematodes *O. cuniculi* and *R. triangularis* occurred in all three eco-regions. The parasite parameters for *Lepus americanus* from the three eco-regions are shown in Table 3. There were no significant differences ($P = 0.05$) for *M. pectinata* by sex within or between eco-regions. This was also the case for *O. cuniculi. Raushia triangularis* showed significantly higher ($P \leq 0.027$) values for males in the North Shore by sex, however, no differences existed on an eco-regions basis ($P \geq 0.05$).

An evaluation of parasite prevalence etc., for all the hares based on weight categories (Table 4) showed no significant difference ($P = 0.05$) between hare weight classes in infections of *Mosgovoyia pectinata* and *Rauschia triangularis.* Infections with *Obeliscoides cuniculi* showed significant differences between weight class 1.32 to 1.48 kg and 1.64 to 1.80 kg ($P \leq 0.04$) and between weight class 1.48 to 1.64 kg and 1.64 to 1.80 kg

TABLE 3. Parasite parameters for *Lepus americanus* from three Eco-regions on insular Newfoundland: Western Newfoundland, North Shore and Avalon Forest.

Species	W. NF (n=25)	N. Shore (n=26)	Av. For. (n=27)	Total (n=78)
		Prevalence		
M. pectinata	0.040	0.192	0.037	0.090
T. pisiformis	0.000	0.038	0.000	0.013
O. cuniculi	0.350	0.846	0.741	0.654
R. triangularis	0.440	0.423	0.593	0.48
		Intensity		
M. pectinata	1	1-6	2	1 - 6
T. pisiformis	0	1	0	1
O. cuniculi	1 - 189	1-237	1 - 78	1 - 237
R. triangularis	3*	3*	3*	3*
		Mean Intensity		
M. pectinata	1.000	2.500	2.000	2.170
T. pisiformis	0.000	NA	0.000	NA
O. cuniculi	29.78	29.00	32.40	28.82
R. triangularis	NA	NA	NA	NA
		Relative Density		
M. pectinata	0.040	0.480	0.074	0.195
T. pisiformis	0.000	NA	0.000	NA
O. cuniculi	10.72	24.53	24.00	18.84
R. triangularis	NA	NA	NA	NA
		Dispersion		
M. pectinata	1.000	3.970	2.000	
O. cuniculi	134.99	107.38	25.84	

NOTE: In all cases counts for *Rauschia triangularis* exceeded 50 individuals.

W. NF – Western Newfoundland
N. Shore – North Shore
Av. For. – Avalon Forest
3* sample has greater than 100 parasites
NA – not applicable

($P \leq 0.03$), the majority of the parasites occurring in the smaller hares. The largest of the hares (n = 3) had the least number of parasites.

In the smaller hares, there is a tendency for *Rauschia triangularis* to occur at a higher prevalence than *Obeliscoides cuniculi* whereas the reverse is seen for the heavier two weight classes (Table 4).

Discussion

The most extensive study of the parasites of *Lepus americanus* on the island of Newfoundland (Dodds and Mackiewicz 1961) involved collections of hares from 1954 through 1959. Of a total of 630 hares they examined, 483 were collected from the Humber East, White Bay South, St. Barbe and Grand Falls districts. The remaining 147 were collected from Emberly Island in Placentia Bay, Newfoundland, a population that was established in 1954 using hares from the main island. Smith and Threlfall (1972) reviewed the parasites of only three adult hares originating from the Avalon Peninsula of Newfoundland.

Our study differs from Dodds and Mackiewicz (1961). They reported on hares from different seasons and years and for juveniles and adults. Our study used hares captured during mid-winter (January/February) and examined adults only. While containing host specimens from the same area as that evaluated by Dodds and Mackiewicz (1961), it extends the geographic coverage of the island by sampling the eastern portion of the province.

The four parasite species recovered in this study were the same as previous studies in the area. Dodds and Mackiewicz (1961) found that the prevalence of the cestode *Mosgovoyia pectinata* varied over four years starting with 7% prevalence in 1956, rising to a high of 36% in 1958, and dropped to 4% in 1959. The high values found in 1958 occurred during the cyclical

TABLE 4. Parasite parameters for *Lepus americanus* from insular Newfoundland placed in five weight classes.

	Weight Class (kg)				
	1.00-1.15 (n = 5)	1.16-1.32 (n = 18)	1.33-1.48 (n = 33)	1.49-1.64 (n = 17)	1.65-1.80 (n = 3)
Species	Prevalence				
M. pectinata	0.04	0.05	0.03	0.06	0.00
T. pisiformis	0.00	0.00	0.63	0.76	0.00
O. cuniculi	0.60	0.61	0.39	0.53	0.06
R. triangularis	0.80	0.81	0.12	0.00	0.12
	Intensity				
M. pectinata	2	6	1	1	0
T. pisiformis	0	0	0	3*	0
O. cuniculi	17-237	1-58	1-189	1-78	8
R. triangularis	3*	3*	3*	3*	3*
	Mean Intensity				
M. pectinata	2	6	1	1	0
T. pisiformis	0	0	0	NA	0
O. cuniculi	105.67	20.82	28.52	22.46	0.47
R. triangularis	NA	NA	NA	NA	NA
	Relative Density				
M. pectinata	0.80	0.33	0.03	0.12	0.00
T. pisiformis	0.00	0.00	0.00	NA	0.00
O. cuniculi	63.4	12.72	18.15	17.18	0.47
R. triangularis	NA	NA	NA	NA	NA
	Dispersions				
M. pectinata	1.5	6.00	1.00	0.94	NA
T. pisiformis	NA	NA	NA	NA	NA
O. cuniculi	159.02	22.28	90.43	29.08	8.00
R. triangularis	NA	NA	NA	NA	NA

3*– sample contains more than 100 parasites

Note – The sample size (n = 76) for weights is less than the total (n = 78) used for parasites due to heads of the hares being missing in two samples.

decline in hare populations and were from juveniles only; adults did not contain this parasite. Dodds and Mackiewicz (1961) reported that their juveniles often presented distended small intestines which appeared to be occluded, although the hares otherwise appeared to be in good condition. In contrast, the 8% prevalence for *M. pectinata* in our study was for adults taken in mid-winter only and no significant differences in prevalence were found between weight classes (Table 4) of the hares. There were no indications of occlusions or organ damage and the hares appeared to be in excellent condition.

The cysticerci of *Taenia pisiformis* were recovered from only one female hare in the North Shore Ecoregion, however, four out of six specimens of hares snared in the Avalon Forest Eco-region in 2001 contained massive infections of *T. pisiformis* (E.M.B.). Dodds and Mackiewicz (1961) report relatively heavy prevalences for *T. pisiformis* and *Hydatigera taeniaeformis* and lump the data to show prevalences which range from a high of 61% in 1956 to a low of 17% in 1958. We found no indication of *H. taeniaeformis* in this study. The rarity of *T. pisiformis* could be related to the scarcity of canids in the respective eco-regions as the definitive hosts for this parasite are known to be canids (i.e., Red Fox, Coyote and Domestic Dog) (Whitney 2000*). However, the eco-regions utilized in this study are areas where active trapping of furbearers takes place and during peak years of the hare cycle, there may be a dilution effect such that the definitive host populations would be low relative to the intermediate host population. Winter conditions would remove the hares from normally exposed vegetation on which tapeworm eggs would be deposited and coupled with higher mortality of such eggs, a loss in parasites could be expected. These low numbers could also be a result of conferred immunity from earlier infections. Heath (1973) showed immunity to *T. pisiformis* eggs in New Zealand White Rabbits following injections with antigens from various stages of parasite development (i.e., oncospheres, larvae, etc.). Rickard and Coman (1977) further demonstrated that immunity and enhanced development of *T. pisiformis*

in New Zealand White Rabbits depending on which species of *Taenia* was utilized as the antigenic source.

Obeliscoides cuniculi was more prevalent (65%) than any of the values reported by Dodds and Mackiewicz (1961). They reported a prevalence of 44% in 1956 rising to a high of 63% in 1958, subsequently dropping to 54% in 1959. Most of their hares were obtained during the summer of a cyclical peak in population. Erickson (1944) also reports the highest frequency for this parasite at the beginning of a decline in hare numbers. The values for *O. cuniculi* in this study mirror the findings of Erickson (1944). Keith et al. (1985) report significantly higher values ($P = 0.07$ and $P = 0.02$) for this parasite during mid-winter and during repetitive cyclical peaks in 1962 and 1971 respectively. Keith et al. (1985) attribute the higher numbers of the winter populations of *O. cuniculi,* to the rise in the pituitary gonadotrophins and testicular weights prior to the March breeding season. The cyclical increases in *O. cuniculi*, which co-occur with the rise in Snowshoe Hare populations, are probably reinforced through density effects, where large numbers of hares are feeding in restricted habitats.

For all parasites except *Rauschia triangularis* there were no significant ($P \geq 0.05$) differences between eco-regions or between sexes. *Rauschia triangularis* had a significantly higher ($P \leq 0.027$) abundance of parasites in males over females from the North Shore Eco-region. No other differences occurred for this parasite at the other eco-regions. We can offer no explanation for this. Erickson (1944) reports no significant difference between sexes for *R. triangularis* but does indicate that different areas may yield different prevalences for the parasite. He also found a high prevalence during late winter.

An evaluation of the parasite standings based on weight increments for the entire population studied showed no significant differences ($P \geq 0.05$) between weight classes in regards to *Mosgovoyia pectinata* and *Rauschia triangularis* (Table 4).Our results show that a significant majority ($P \leq 0.04$) of *Obeliscoides cuniculi* occur in the smaller hares. This differs from Keith et al. (1986), who report consistently higher values in adult hares during December-April ($P < 0.001$). As in our study, they did not show significant differences between sexes. Results similar to this study and Keith et al. (1986) are shown in Erickson (1944) and Keith et al. (1985). There is a tendency for *R. triangularis* to have a higher prevalence over *O. cuniculi* in the smaller hares, a situation similar to that reported by Keith et al. (1986) who reported a higher prevalences of *R. triangularis* ($P = 0.059$) among juveniles. Conversely, the larger hares contained significantly greater numbers ($P < 0.001$) of *O. cuniculi* over *R. triangularis* as is seen in Keith et al. (1986).

An evaluation of multiple infections showed no apparent trends in the parasite burdens of males or females. Sixty percent of the hares contained at least one species of parasite, 25.6 two, and 3.8 three; 10.3 percent none. Dodds and Mackiewicz (1961) report greater parasite diversities in their study. The trematode *Dicrocoelium dentriticum* and the nematode *Trichostrongylus axei,* which were reported from Emberly Island in Placentia Bay, are normally considered parasites of sheep and other ruminants. This island was used extensively for sheep grazing by residents and it appeared that the hares were paratenic (non specific or reservoir) hosts. Recent studies (in preparation) indicate the presence and spread of new parasites within ungulates and insectivores which are attributed to the Coyote range expansion; however, no new parasites appear to have spread to the Snowshoe Hare from any of the recently (i.e., less than fifteen years) established non-native mammals.

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