First Record of the Southern Red-Backed Vole, *Clethrionomys gapperi,* in Newfoundland: Implications for the Endangered Newfoundland Marten, *Martes americana atrata*

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Hearn, Brian J., John T. Neville, William J. Curran, and Dean P. Snow. 2006. First record of the Southern Red-Backed Vole, *Clethrionomys gapperi,* in Newfoundland: implications for the endangered Newfoundland Marten, *Martes americana atrata*. Canadian Field Naturalist 120(1): 50–56.

We report on the first capture of the Southern Red-backed Vole (*Clethrionomys gapperi),* the eleventh non-native terrestrial mammal established on the island of Newfoundland over the last 150 years. Red-backed Voles may have been accidentally introduced by unknown sources in pulpwood imports or may have been deliberately introduced in an attempt to augment the depauperate small mammal fauna as a vigilante recovery effort for the endangered Newfoundland Marten (*Martes americana atrata)*. We anticipate significant utilization of the Red-backed Vole as prey by both Newfoundland Marten and Red Fox (*Vulpes vulpes*) with associated demographic responses within and between these species. Red-backed Voles will likely change habitat utilization patterns for the endemic subspecies of Meadow Vole, *Microtus pennsylvanicus terraenovae*.

Key Words: Southern Red-backed Vole, *Clethrionomys gapperi,* Marten, *Martes americana atra,* introduced species, Newfoundland.

The island of Newfoundland has only 13 resident native species of terrestrial mammals (Bangs 1913; Cameron 1958; Dodds 1983; Table 1). A fourteenth species, the Newfoundland Wolf (*Canis lupus beothucus*) was extinct by the early 20th century (Allen and Barbour 1937), and one of the three native mustelids, the Newfoundland Marten (*Martes americana atrata*) is currently listed by the Committee on the Status of Endangered Wildlife in Canada as endangered (Lemon 1996*). As well, the indigenous community of terrestrial mammals in Newfoundland has a skewed composition, with a disproportionate number of predators and few prey species; historically, only one microtine, the native subspecies of Meadow Vole (*Microtus pennsylvanicus terraenovae)* occurred on the island (Dodds 1983). Moreover, Cameron (1958) considered 10 of the 14 native species of terrestrial mammals as endemic subspecies; recent genetic analysis has confirmed the subspecies classification of the Newfoundland Marten (Kyle and Strobeck 2003). However, over the last 150 years, an additional nine species of mammals have been either intentionally or accidentally introduced to the island (Dodds 1983; Gould and Pruitt 1969; Northcott 1974*; Northcott et al. 1974; Payne 1976; Table 1). A tenth species, the Eastern Coyote (*Canis latrans*) became established on the island of Newfoundland in 1985, likely after crossing on sea ice from mainland Nova Scotia (Parker 1995). Herein, we report the first record of the eleventh non-native mammal established on the island of Newfoundland, the Southern Red-backed Vole (*Clethrionomys gapperi),* and discuss the circumstances and implications of this recent introduction, particularly with reference to the Newfoundland Marten.

Field Sites and Sampling

Between 2 and 5 November 1999, as part of a larger study investigating the demography and ecology of the Newfoundland Marten, we indexed small mammal populations on four sites inside the Pine Marten Study Area (PMSA) in southwestern Newfoundland (48°37'N, 57°53'W). The PMSA is a 2078-km^2 wildlife reserve, that was created in 1973 by the Newfoundland and Labrador Wildlife Division, for the protection of the Newfoundland Marten (Snyder and Bissonette 1987). Sites 1–3 were overmature (81+ years), Balsam Fir (*Abies balsamea)* stands, whereas Site 4 was a regenerating (10–15 yrs) Balsam Fir stand that regenerated after an outbreak of Spruce Budworm (*Choristoneura fumiferana*) and Hemlock Looper (*Lambdina fiscellaria fiscellaria*) in 1987. Site 4 contained a mix of young Balsam Fir and early successional species, such as White Birch (*Betula papyrifera*) and Pin Cherry (*Prunus pensylvanica*), had a significant number of dead Balsam Fir snags, and had no canopy. Each site was trapped with 100 snap traps on 3 consecutive nights. Traps were baited with peanut butter, and placed in pairs at 50 trapping stations, spaced 15 m apart, yielding a 735-m transect, following the methods previously used by Thompson and Curran (1995). All captures were recorded and collected for further analysis.

Forty small mammals were collected on the four sites over 1200 trap nights: 8 Meadow Voles, three Deer Mice (*Peromyscus maniculatus*), 10 Masked Shrews (*Sorex cinereus*), and 19 Southern Red-backed Voles. How-

TABLE 1. Native and non-native (*) terrestrial mammals on the island of Newfoundland prior to the discovery of the Southern Red-backed Vole[1].

Order	Family	Scientific Name (Authority)	Common Name
Insectivora	Soricidae	*Sorex cinereus acadicus* (Gilpin)	Masked Shrew *
Chiroptera	Vespertilionidae	*Myotis lucifugus lucifugus* (Le Conte)	Little Brown Bat
		Myotis septentrionalis (van Zyll de Jong)	Northern Long-eared Bat
Lagomorpha	Leporidae	*Lepus arcticus bangsii* (Rhoads)	Arctic Hare
		Lepus americanus struthopus (Bangs)	Snowshoe Hare *
Rodentia	Cricetidae	*Microtus pennsylvanicus terraenovae* (Bangs)	Meadow Vole
		Peromyscus maniculatus (Wagner)	Deer Mouse *
		Ondatra zibethicus obscurus (Bangs)	Muskrat
	Scuridae	*Tamiasciurus hudsonicus ungavensis* (Anderson)	Red Squirrel *
		Tamias striatus lysteri (Richardson)	Eastern Chipmunk *
	Castoridae	*Castor canadensis caecator* (Bangs)	Beaver
	Muridae	*Rattus norvegicus norvegicus* (Berkenhout)	Norway Rat *
		Mus musculus domesticus (Rutty)	House Mouse *
Carnivora	Mustelidae	*Mustela erminea richardsonii* (Bonaparte)	Short-tailed Weasel
		Mustela vison (Schreber)	Mink *
		Martes americana atrata (Bangs)	Newfoundland Marten[2]
		Lontra canadensis degener (Bangs)	Otter
	Felidae	*Lynx lynx susolanus* (Bangs)	Canada Lynx
	Canidae	*Vulpes vulpes deletrix* (Bangs)	Red Fox
		Canis lupus beothucus[3] (Allen and Barbour)	Eastern Timber Wolf
		Canis latrans var. (Lawrence and Bossert)	Eastern Coyote *
	Ursidae	*Ursus americanus hamiltoni* (Cameron)	American Black Bear
Arctiodactyla	Cervidae	*Rangifer tarandus terraenovae* (Gmelin)	Woodland Caribou
		Alces alces americana (Clinton)	Moose*

[1]Several other species are either seasonal visitors (e.g., Arctic Fox (*Alopex lagopus*), Polar Bears (*Ursus maritimus*)) or have been introduced to offshore islands (e.g., Bison (*Bison bison*), Bank Vole (*Clethrionomys glareolus suecicus*)). Adapted from Cameron (1958) and Dodds (1983).
[2]Subspecies designation confirmed via recent genetic analysis (Kyle and Strobeck 2003).
[3]Extinct

ever, Red-backed Voles were captured on only two of the four sites (Sites 3 and 4). The two sites where Red-backed Voles were captured were approximately 6 km apart, but on opposite sides of Little Grand Lake. Movement between these two sites would require an overland dispersal of at least 11 km, suggesting that the species is well established in the area. At least one of the collected females had obvious placental implantation scars on the uterine horns, indicating recent breeding. Species identification was confirmed by pelage and dental characteristics (Banfield 1974).

Discussion

Sites 1–3 had previously been snap trapped for small mammals for 4 years, between 1990 and 1993 (Thompson and Curran 1995). Additionally, Site 4, as well as the general area encompassing all four of our sampled sites, was extensively live trapped from 1993 to 1997, as part of a larger study investigating Marten, small mammal communities, and forest structure (Adair 2003). Neither of these two previous trapping efforts captured Red-backed Voles, suggesting that the species had recently become established, most likely sometime during or after 1998. Moreover, a more extensive small mammal survey, conducted two weeks before this survey in the Red Indian Lake area, approximately 35 km east of our four trapping sites, using identical methods but involving 16 sites and >4900 trap-nights, captured 116 small mammals, but no Red-backed Voles. Autumn (October) small-mammal surveys in the Red Indian Lake area, repeated annually since 1999, have subsequently documented the arrival (2001) and eastward dispersal of the Red-backed Vole in southwestern and south-central Newfoundland (B. J. Hearn, unpublished data).

Two explanations for this introduction are possible. Red-backed Voles may have been accidentally introduced in pulpwood or pulp chips imported through the port of Stephenville, (approximately 38 km SW of our sampling sites). Alternatively, the species may have been deliberately introduced by unknown persons to increase prey diversity and abundance for the Newfoundland Marten. Because Red-backed Voles are a common prey item in the diet of American Marten elsewhere (Martin 1994), this management option was debated during preparation of the Newfoundland Marten Recovery Plan (Forsey et al. 1995*), resulting in a divergence of opinions among local stakeholder groups. Although ultimately rejected by the Newfoundland Marten Recovery Team as an ethical recovery action, the limited prey base and the ecological consequences of introducing the Red-backed Vole were publicly discussed in 1998, during a two-day symposium on issues concern-

ing the Newfoundland Marten. Given the coincidence in timing (ca. 1998) and spatial distribution of this discovery (inside the PMSA), we suggest that it is likely that Red-backed Voles were deliberately introduced.

Regardless of the source of this introduction, the direct and indirect effects of this new species on community structure in general, and the Newfoundland Marten in particular, warrant investigation. As an example, Cameron (1958) reported that Newfoundland Meadow Voles are less selective in their habitat requirements than mainland Meadow Voles, and atypically, occupy forested habitats — likely due to the historical absence of Red-backed Voles (Cameron 1958; Clough 1964; Cameron 1965; Morris 1969; Folinsbee et al. 1973). Consequently, the introduction of the Red-backed Vole will probably result in a niche contraction for the endemic Meadow Vole, and we predict that Meadow Voles will be displaced from forested areas and restricted to their preferred habitat (i.e., moist meadow-like areas (Folinsbee et al. 1973)). Preliminary analysis of our 1999–2006 small-mammal trapping data from the RIL area is documenting an irrupting population of Red-backed Voles (>3000 Red-backed Voles captured since 2001), and an essential elimination of Meadow Voles from forested sites where we had previously captured Meadow Voles.

Consequently, the positive effect of increased prey diversity and biomass for the Newfoundland Marten will be offset, to some degree, by a decrease in distribution and densities of Meadow Voles, which have been a historically important prey species (Bateman 1986; Drew 1995; Gosse and Hearn 2005; Tucker 1988). Further, indirect effects of the Red-backed Vole on Newfoundland Marten could occur as a result of the impact of this species on local Red Fox (*Vulpes vulpes*) populations. Given the depauperate prey base in Newfoundland, Red Fox and Marten display considerable dietary overlap, and Red Fox are the most important natural predator of Newfoundland Marten (B. J. Hearn, unpublished data). Consequently, Marten may be negatively affected if the introduction of Red-backed Voles has a positive effect on Red Fox demography, leading to increased intraguild predation on Marten (Lindström et al. 1995) or increased Marten–Fox competition for food (Kurki et al. 1997; Lindström et al. 1994; Marcström et al. 1988). Pine Marten (*Martes martes*) populations in Scandinavia increased in the 1980s, following a decline of Red Fox due to a sarcoptic mange epidemic, as a direct result (hypothesized) of reduced predation by Red Fox (Lindström et al. 1994; Helldin 1998) or reduced competition for *Microtus* prey (Storch et al. 1990). Although counterintuitive to conventional competition theory, increases in food resources (prey availability) can actually increase intraguild predation by supporting increased populations of the superior competitor. Parallel circumstances have been described for other threatened or endangered carnivores elsewhere (e.g., Coyote predation on Swift Foxes (*Vulpes macrotis*) (Sovada et al. 1998), Coyote predation on San Joaquin Kit Foxes (*Vulpes macrotis*) (Ralls and White 1995; White and Garrott 1997; Cypher and Spencer 1998), and Lion (*Panthera leo*) and Spotted Hyena (*Crocuta croenta*) predation on African Wild Dogs (*Lycaon pictus*) (Creel 2001; Creel et al. 2001)). African Wild Dog densities are actually lowest where density of their major prey is highest, due to intraspecific predation (Mills and Gorman 1997). It is noteworthy that Marten live-trapping captures on the Northern Peninsula of Newfoundland increased in 2005 following a recent (2002-2004) rabies outbreak (Whitney 2004*) that virtually eliminated Red Fox from the local landscape (M. McGrath, personal communication).

Changes in prey availability clearly affect densities of carnivores, improving demographic performance (i.e., increased reproductive output and survival (Fuller and Sievert 2001). Furthermore, decreased food resources have been associated with reduced population density or trapper success, enlarged home ranges, and lower reproductive performance of American Marten (Bulmer 1974; Fryxell et al. 1999; Poole and Graf 1986; Simon et al. 1999; Thompson and Colgan 1987). The reduced prey base for Marten in Newfoundland compared with that available on the mainland portion of the province (Labrador) has been suggested as a likely explanation for the difference in the demographic health of these two populations (Bissonette et al. 1988*). By comparison, Labrador has 17 small mammal species, including the Red-backed Vole (Tucker 1988) and Marten populations appear capable of supporting a commercial harvest; 500-800 Marten were harvested annually between 1995 and 1998 (Simon et al. 1999).

However, an increase in vole biomass may not lead to an immediate increase in Marten densities if territory size in Newfoundland is adjusted to the lowest (or historical) level of prey availability. Such appears to be the case for European Badger (*Meles meles*) in Scotland (Kruuk and Parrish 1982), Kit Foxes in California (White and Ralls 1993), and some Coyote populations in the western United States (Mills and Knowlton 1991). Interestingly, Payer (1999) in the largest American Marten study reported to date ($n > 140$ marten ranges), found no difference in mean home-range area for American Marten in Maine between 1995-1998, despite a three-fold decline and recovery in small mammal populations. Thompson and Colgan (1987, 1990) suggested that, based on energetics, Marten in Ontario cannot survive exclusively on small rodents during late winter, and further, take small mammals opportunistically as they hunt for larger prey (i.e., Snowshoe Hare). Moreover, Gosse and Hearn (2005) reported that Snowshoe Hare provide >90% of the caloric intake of Newfoundland Marten in winter, the most energetically stressful period annually (Buskirk et al. 1988). As cautioned by Fuller and Sievert (2001), the correlation between food and density-related demo-

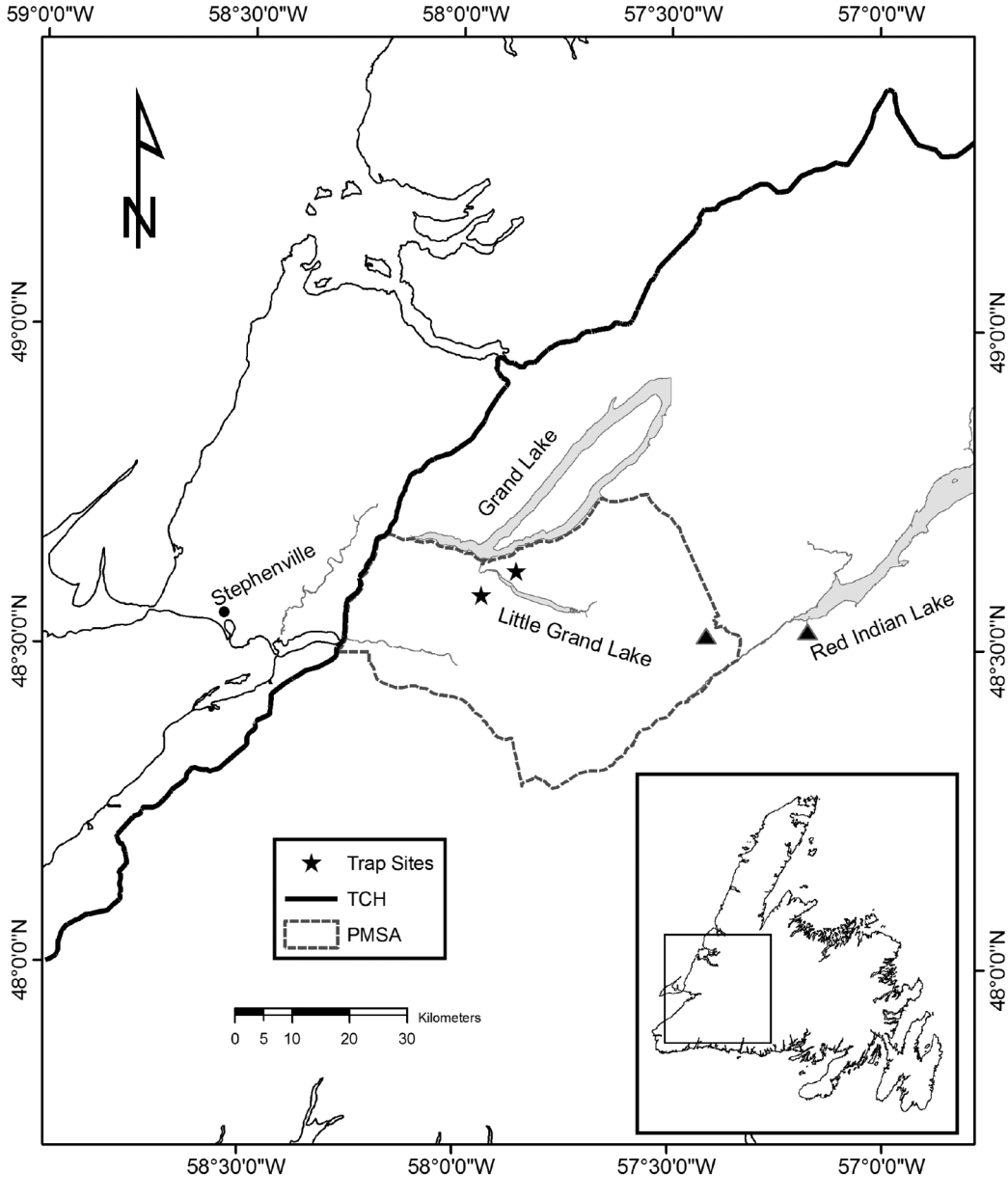

FIGURE 1. Map of southwestern Newfoundland showing location of Southern Red-backed Vole (*Clethrionomys gapperi*) captures in 1999, and capture sites relative to other areas mentioned in text; ▲indicates location of first Southern Red-backed Vole capture in Red Indian Lake area in 2001. Inset map shows the location of areas relative to the island of Newfoundland.

graphic parameters is statistically broad, and many site-specific factors (e.g., prey availability, habitat patchiness, habitat selection under foraging versus predation-risk trade-offs), influence home-range characteristics and carnivore density.

Newfoundland Marten have been geographically and reproductively isolated from mainland Marten populations for the last 7000 years (South 1983), resulting in a genetically distinct subspecies amidst a much more genetically homogenous Canadian main-

land population (Kyle and Strobeck 2003). Additionally, Newfoundland Marten are large (males = 1254 g, n = 122; B. J. Hearn, unpublished data), and have extremely large home-range requirements (males = 30.8 km^2, n = 43; B. J. Hearn, unpublished data) compared with nearby mainland populations in Quebec (males = 937 g, n = 67; 7.4 km^2, n = 40; Potvin and Breton 1997) and Maine (males = 776 g, n = 23, Katnik 1992; 4.04 km^2, n = 96; Payer 1999). Collectively, these population characteristics suggest that the Newfoundland Marten is a product of a unique ecological setting and evolutionary selective factors operating on a geographically and reproductively isolated island population. Thus, it seems unlikely, given the historical ecological setting, that Newfoundland Marten spatial requirements evolved to access or select habitat (Hearn et al. 2005*) based on utilizing small mammals as prey.

We predict that the establishment of the Red-backed Vole on the island of Newfoundland will cause direct and indirect community-level effects in general and for Newfoundland Marten in particular (e.g., increased utilization of the Red-backed Vole as prey by Newfoundland Marten and Red Fox and associated demographic responses and interactions, more restricted habitat utilization by Newfoundland Meadow Voles, and changing utilization and dispersal of seeds by introduced Red-backed Voles and consequently changing plant regeneration patterns). The direct and indirect effects of previous introductions of non-native species to the island of Newfoundland have been previously described for predator–prey interactions (Bergerud 1971, 1983), plant successional patterns (Thompson et al. 1992, Thompson and Curran 1993), and species interactions (Benkman 1993).

Additional small mammal field surveys are being conducted to document the changing distribution of Red-backed Voles on the island and may offer additional information about the mechanism by which this species was introduced. In this regard, genetic analysis may be helpful in determining the source population for this introduction. Future field studies, in areas where Newfoundland Marten spatial characteristics have been well documented (Hearn et al. 2005*) are being considered to assess the effects of this new prey species on Newfoundland Marten population characteristics.

Acknowledgments

Funding for this work was provided by Natural Resources Canada, Canadian Forest Service; the Newfoundland and Labrador Department of Environment and Conservation – Inland Fish and Wildlife Division; Newfoundland and Labrador Department of Forest Resources and Agrifoods – Forestry Division; Corner Brook Pulp and Paper; Abitibi Consolidated; and the Western Newfoundland Model Forest through support of a five-year research project concerning Newfoundland Marten. We thank D. J. Harrison, B. Krohn, J. Loo, and two anonymous reviewers for comments on this manuscript.

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Received 21 February 2005
Accepted 15 March 2006