AN UPDATE ON THE STATUS AND OCCURRENCE OF SMALL MAMMALS ON ST. LAWRENCE ISLAND, ALASKA

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Abstract—St. Lawrence Island's unique biogeographic history as an intermittent landmass and refugium of the Bering Land Bridge during the last glacial interval has resulted in the evolution of several insular endemic small mammal taxa on the island including: the St. Lawrence Island shrew (*Sorex jacksoni*) and subspecies of the northern red-backed vole (*Myodes rutilus albiventer*), root vole (*Microtis oeconomus innuitus*), Nearctic collared lemming (*Dicrostonyx groenlandicus exsul*), and arctic ground squirrel (*Spermophilus parryii lyratus*). Early studies of these mammalian taxa in the 1950s-70s focused on specimen collection efforts to identify the taxa and their general distributions and habitat associations. More up to date information on the basic ecology of these taxa are lacking. Our objective was to update the available information on the distribution, status, habitats, and ecology of small mammals on St. Lawrence Island in the Bering Sea of Alaska. We captured 61 individuals from the 19th to the 27th of July 2012 using Sherman and pitfall traps placed in all major habitat types near the villages of Gambell and Savoonga. We compared out trapping results to earlier studies to determine the current status, distribution, and relative abundance of each taxa in relation to previous years. In 2012, we found that root and northern red-backed voles were most abundant, occurring in mesic and mesic to dry dwarf shrub and herbaceous habitats, respectively. Arctic ground squirrels were observed in mesic to dry habitats, particularly in areas with sandy soil or rocky outcrops. The St. Lawrence Island shrew was the least abundant of the species we captured (n= 2), and was found exclusively in the rocky auklet colonies near Savoonga. Despite targeting trapping effort in habitats where Nearctic collared lemmings were thought to occur, we were unable to capture or observe lemmings in any habitat. Although this survey was limited to a relatively short time period, its finding suggest the need for additional surveys to determine the status of the Nearctic collared lemming and to determine factors that regulate the population size of each of the small mammal species on the island.

Key words

Nearctic collared lemming, northern red-backed vole, root vole, St. Lawrence Island shrew, small mammals**,** conservation status, habitat, survey, western Alaska

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INTRODUCTION

St. Lawrence Island, Alaska, located in the northern Bering Sea, was connected intermittently to mainland Alaska and Russia by the Bering Land Bridge during the last 50 million years of the tertiary and quaternary time periods (Hopkins 1959). The Bering Land Bridge allowed interchange of fauna between Asia and North America (Sempson 1947) and served as a refugium for taxa from advancing ice sheets (Hulten 1937). During the Land Bridge time period, St. Lawrence Island would have been an isolated highland on the temporary landmass. As a result of being connected, then isolated from neighboring continents over time, a unique set of small mammal taxa have evolved on the island that differ from taxa on the mainland of Alaska and Russia. Small mammals endemic to the island include the St. Lawrence Island shrew (*Sorex jacksoni*), and subspecies of the northern red-backed vole (*Myodes rutilus albiventer*), root vole (*Microtis oeconomus innuitus*), Nearctic collared lemming (*Dicrostonyx groenlandicus exsul*), and arctic ground squirrel (*Spermophilus parryii lyratus*). With the exception of *Sorex jacksoni*, the mammals occurring on St. Lawrence Island represent species which are widely distributed in boreal regions, yet they have often been regarded as being distinct from closely related forms occurring on adjacent continents (Rausch 1953).

The Nearctic collared lemming occurs from Alaska through the high arctic of Canada and into northern Greenland (Hall 1981; Nagy and Grower 1999), with St. Lawrence Island at the western edge of its range. In contrast, the northern red-backed vole and root vole occur across northern Eurasia, Alaska, and northwestern Canada (Musser and Carleton 2005). The global range of the arctic ground squirrel is similar to the voles except it is less widely distributed in Eurasia, being restricted to northeastern Siberia (Hall 1981; Thorington and Hoffmann 2005). The St. Lawrence Island shrew is restricted to St. Lawrence Island and its exact relationship to other Beringian shrews is unresolved (Demboski and Cook 2003).

Numerous early studies focused on specimen collections to inventory taxa and determine taxonomic uniqueness and relationships to other small mammal taxa in the Beringian region (Hall and Gilmore 1932; Murie 1936; Rausch 1953; Fay 1973). The majority of these specimens were taken during the 1950s or earlier. More recent collections are lacking. In addition, very little attention has been given to the occurrence, distribution, and habitat preferences of any of these species, and current population status is relatively unknown.

The need to collect and compile information on the endemic small mammals of St. Lawrence Island has been recognized by both international (Hafner and others 1998) and state agencies (ADF&G 2006). The IUCN Rodent Specialist Group (Hafner and others 1998) suggested identifying immediate threats to survival and conducting surveys on St. Lawrence Island to monitor the population of ground

squirrels at regular intervals, to determine the status of Nearctic collared lemmings, and to determine the distribution and population status of root voles. The state of Alaska's Wildlife Action Plan (ADF&G 2006) highlighted the need to collect and archive material to examine taxonomic distinctiveness and to map the spatial distribution of taxa to examine habitat use by insular endemic small mammals in southwestern Alaska and the Bering Sea region.

Objectives of our study were to 1) inventory the current small mammal taxa inhabiting St. Lawrence Island 2) determine species distribution in representative habitat types and describe habitat use by each species, and 3) to collect vouchered specimens and tissue samples to be housed at the University of Alaska Museum of the North (UAM) in Fairbanks, AK. Our goal was to use the information gathered on species composition, distribution, and habitat use to assess the conservation status of the small mammals of St. Lawrence Island, which has not been reviewed for 30 years (Fay and Sease 1985).

METHODS

Study Area

St. Lawrence Island is located in Bering Sea approximately 210 kilometers west of the mainland of western Alaska and 64 km southeast of the Chukchi Peninsula in Russia (Patton and Csejtey 1971). The island is approximately 160 km miles long and 16 to 64 km in width, making up a total of 5,180 square km in area (Young 1971). The climate is characterized by short, cool summers and relatively high precipitation for an arctic region. The growing season is from early June through August with daily highs in the summer rarely above 10° C. From early winter through spring, St. Lawrence Island is surrounded by the polar ice pack, making it relatively cold for its maritime geography (Young 1971).

About half of the island is low lying below 30 meters in elevation and is characterized by wet and moist tundra vegetation intermixed with shallow lakes and ponds. Mountainous regions in the southwestern (Poovookpuk Range), central (Kookooligit Range), and northeastern (Kinipaghulghat Range) portions of St. Lawrence Island reach up to 670 meters and are characterized by drier alpine vegetation and rocky areas dominated by granite rocks on the western and eastern ends of the island and lava flows and cinder cones in the central portion (Young 1971; Fay 1973).

Trapping Effort

We trapped small mammals from 19 to 27 July, 2012, in areas accessible by all-terrain vehicle (ATV) from the villages of Gambell and Savoonga, on the northern coast of St. Lawrence Island. Traps were set in the

5 major terrestrial vegetative cover types on the island. We used Viereck et al. (2002) to classify the major habitat types.

We established transects at sites where previous specimens were collected, as well as in new areas with habitats where target species were expected to occur. Target species included the root vole, northern red-backed vole, Nearctic collared lemming, and St. Lawrence Island shrew. We did not attempt to capture arctic ground squirrels which were not included in our collection permit; however, we recorded the habitats in which ground squirrels were observed. More time was spent trapping in locations where we expected encounters with the more rare taxa (i.e., collared lemming and St. Lawrence Island shrew) than in areas where we repeatedly captured more common species (i.e., root voles, red-backed voles). Transects were placed in a single habitat type when possible and consisted of a series of trapping stations spaced every 5 to 10 meters. At each trapping station, 2 Sherman box traps and/or pitfall traps were placed within 2 meters of each other. Pitfall traps were constructed of 13 cm deep (35.5 ounce) cups buried flush with the ground. When possible, we placed traps in microhabitats that had indications of high animal use, such as along runways, near burrow entrances, and near areas with browsed vegetation. We baited Sherman traps with a mixture of peanut butter and rolled oats and did not bait pitfall traps.

Trapping sessions ranged from 4 to 8 hours and occurred during both day and night. Depending on the species and number of individuals captured, transects were kept open from 4 hours (1 trapping session for pitfall traps) to 2 days (multiple trapping sessions). For each individual captured, we recorded standardized body length measurements, mass, sex, and breeding condition, and then released the individual. For each transect, and within a 5 meter radius of each capture location, we characterized the vegetation to level III of Viereck et al. (1992). All mortalities were collected as specimens, and were immediately frozen and sent to the University of Alaska Museum (UAM) to be archived in the small mammals collection. We calculated capture success as the number of captures per 100 trap hours. Traps that were sprung (e.g., triggered without a capture) were not included in this calculation.

RESULTS

We captured a total of 61 small mammals in 4,948 trap hours. Captures included 37 northern red-backed voles, 22 root voles, and 2 St. Lawrence Island shrews (Table 1). No Nearctic collared lemmings were captured. Captures were along 10 transects that were set within a 2 mile radius of the villages of Gambell and Savoonga in all major habitats (i.e., graminoid, forb, and dwarf shrub plant communities). All captures were made in Sherman traps.

Table 1. Trapping effort and captures for each transect, expressed as trap hours, capture success (captures per 100 trap hours) and number of captures, St. Lawrence Island, July 2012.

Transect No. and Location		No. Stations	Trap Hrs.	Capture Success	No. and Identification of Individuals Captured
Gambell					
1	Lower slope of Sevuokuk Mtn	9	161.9	3.7	4 root voles and 2 red-backed voles
2	Lower slope of Sevuokuk Mtn	10	163.8	1.2	2 root voles
3	West shore of Troutman Lk	29	487.6	2.7	13 root voles
4	Base of Sevoukuk Mtn south of Gambell	14	362.2	0.6	2 red-backed voles
5	Northeast side of Troutman Lk	15	346.5	0.0	0 captures
6	Base of Sevoukuk Mtn near boneyard	10	186.2	0.0	0 captures
7	Wetland south of Troutman Lk	10	81.0	0.0	0 captures
Savoonga					
1	Auklet colony 1 mile east of village	21	1183.4	1.9	1 St. Lawrence Island shrew, 2 root voles, 20 red-backed voles
2	Auklet colony 2 miles east of village	20	853.3	1.2	1 St. Lawrence Island shrew, 1 root vole, 8 red-backed voles
3	3 miles west of village	25	1122.5	0.5	5 red-backed voles

Description of Habitats

Our trapping efforts were focused specifically in herbaceous and dwarf shrub habitats that dominate the vegetation cover of the island (Table 2). We trapped in wet and dry graminoid herbaceous, mesic and dry forb herbaceous, and Dryas and ericaceous dwarf shrub habitats. The wet graminoid herbaceous habitats were in low lying areas with saturated soils. The vegetation in these wettest areas was generally characterized by *Carex aquatilis*, *Dupontia fisheri*, and sphagnum moss mixed with other wet tundra associated species at low abundances. The mesic forb herbaceous habitats we trapped in had better drained soils and were at both low elevations and on hillslopes. The vegetation was co-dominated by a variety of small herbs, graminoids, and dwarf shrubs, often interspersed with boulders. The soils in both the dry forb and dry graminoid herbaceous habitat types were well drained. The dry graminoid herbaceous habitat where we focused our trapping efforts was located along the shoreline of a large inland lake. The habitat was characterized almost exclusively by beach pebbles, *Leymus mollis*, and *Artemisia tilesii.* Similar habitat was also located along much of the coastline, just inland of the shoreline zone. The dry forb herbaceous habitat was more diverse than the dry graminoid and occurred on transects in rocky coastal uplands in active auklet colonies. The auklet colonies were characterized by boulder fields interspersed with vegetation patches containing a diversity of forbs, graminoids, and dwarf shrubs. Dryas

and ericaceous dwarf shrub habitats also occurred on well-drained soil and were at mid to high elevations on upland tundra and in mountainous areas. The Dryas dwarf shrub habitat was characterized by a combination of boulders, mosses, *Dryas* sp., *Cassiope* sp., and lichens. The ericaceous dwarf shrub habitat was characterized by dwarf willow (*Salix polaris*), *Empetrum nigrum*, *Carex* sp., mosses, and lichens interspersed with boulders.

We used the National Land Cover Database (NLCD) to spatially visualize the distribution of plant communities on St. Lawrence Island. Although the NLCD land cover classification does not use the Viereck et al. (1992) classification system that we used to describe survey habitats, it does provide and approximation of the area and distribution of the five major land cover types across the entire island (Figure 1).

Table 2. Classification of the vegetation on survey transects using the Alaska vegetation classification system (Viereck et al. 1992).

Transect	**Viereck Classification**	**Ground Cover**	
		Dominate	**Sub-dominate**
Gambell			
1 and 2	III. B. 2. Mesic forb herbaceous	Mosses and *Wilhelmsia physodes*	*Artemisia tilesii*, *Petasites frigidus*, boulders up to 3.0 m diameter
3	III. A. 1. Dry graminoid herbaceous	*Leymus mollis*	*Artemisia tilesii*, beach pebbles
4	II. D. 2. Ericaceous dwarf shrub	*Salix polaris*, boulders up to 3.0 m diameter, lichens	*Empetrum nigrum*, *Carex sp.*, mosses, lichens
5	III. A. 2. Wet graminoid herbaceous	Mosses, *Rumex arcticus*	*Carex aquatilis*, *Dupontia fisheri*, *Arctagrostis latifolia*, lichens, boulders
6	Mix of: III. B. 2. Mesic forb herbaceous and Non-vegetated	Beach pebbles	*Artemisia tilesii* and mosses
7	III. A. 2. Wet graminoid herbaceous	*Dupontia fisheri*, *Puccinellia langeana*, *Carex glareosa*	-
Savoonga			
1	III. B. 1. Dry forb herbaceous	Boulders up to 0.6 m diameter	Mosses, *Salix arctica*
2	III. B. 1. Dry forb herbaceous	Boulders up to 1 m diameter	Mosses, *Arctagrostis sp.*
3	II. D. 1. Dryas dwarf shrub	Boulders up to 1 m diameter	Mosses, *Dryas sp.*, *Cassiope sp.,* Lichens

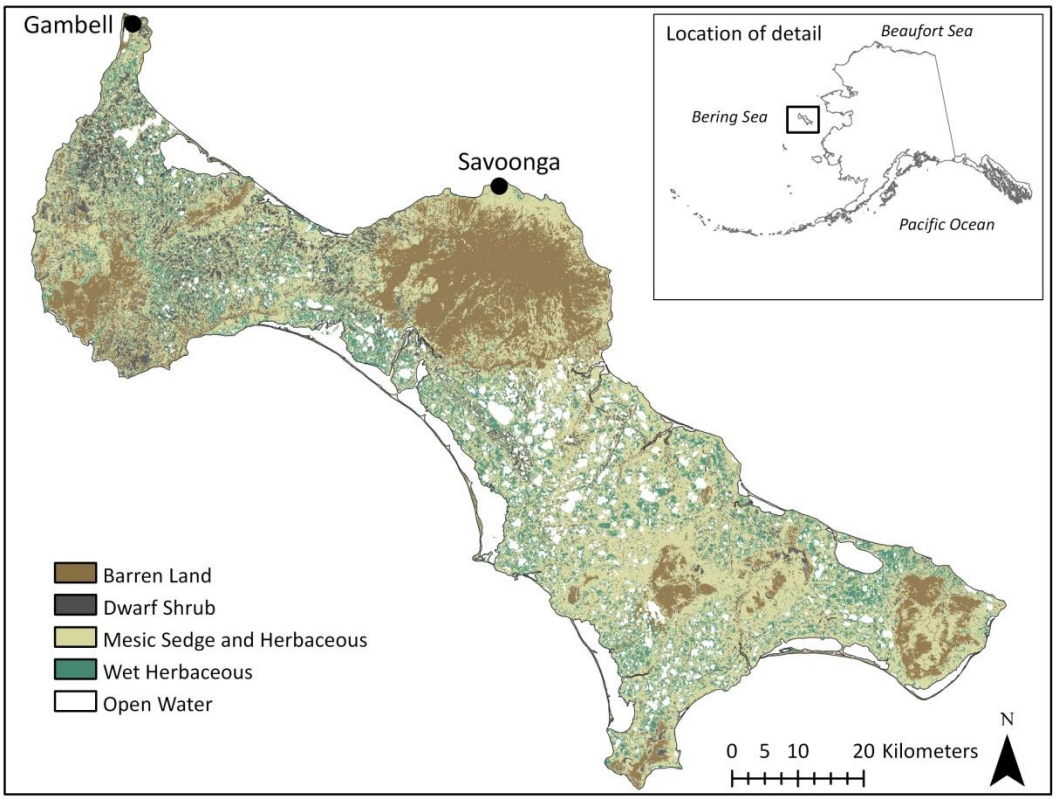

Figure 1. Five major National Land Cover Database (NLCD) classes on St. Lawrence Island. The percent of the island classified as each class is approximately: 18% barren land, 10% dwarf shrub, 45% mesic sedge and herbaceous, 14% wet herbaceous, and 12% open water.

Patterns of Habitat Use

Trapping in dry graminoid and mesic forb herbaceous habitats yielded the greatest number of captures, followed by dry forb herbaceous, Dryas and ericaceous dwarf shrub, and lowest capture success was in the wettest tundra habitats. Root voles were captured and observed in a variety of habitats, primarily at mid to lower elevations. The dry graminoid habitat had the highest overall capture rate of 2.67 individuals per 100 trap hours and was used exclusively by root voles (Figure 2). The high density of root voles in this habitat was evident by the notable number of burrows in the vegetation patches of *Artemisia tilesii* that were connected by extensive systems of runways through the beach pebbles and *Leymus mollis* (beach rye). Two transects in mesic tundra that were characterized by forbs, also had an abundance of root voles. Root voles were also captured in low numbers along the periphery of rocky dry forb habitats that defined the auklet colonies east of Savoonga. Root voles were absent from drier sites characterized by dwarf shrubs and lichens and the wettest graminoid habitats.

Northern red-backed voles were more common in drier sites than root voles, although both species co-occurred along the mesic transects. Northern red-backed voles dominated the captures, with a capture rate of 1.37 captures per 100 trap hours, in dry forb habitats of the auklet colony near Savoonga. At the colony, burrows were typically located adjacent to rocks and runways traversed through vegetation patches and boulder fields. Northern red-backed voles were the only species captured in dwarf shrub habitats, with lower capture success than the other habitat types at 0.47 captures per 100 trap hours (Figure 2). Similar to dry forb habitats, burrows within dwarf shrub habitats were also typically within rocky outcroppings.

Two St. Lawrence Island shrews were captured, both during daytime trapping sessions, in dry forb patches within the auklet colony east of Savoonga. Although ground squirrels were not captured, observations were made in mesic to dry habitats, and squirrels were often observed in areas with some topography to allow a view of the surrounding landscape, such as small hills, banks of riverbeds, and rocky outcroppings. Overall, no small mammals were trapped or observed along transects located in wet graminoid herbaceous habitats (Figure 2). Soils were completely saturated with water and represented the wettest terrestrial habitat on the island. Small burrows and runways were observed in these wet areas; however, it was difficult to determine the intensity, time period, and seasonality of last use.

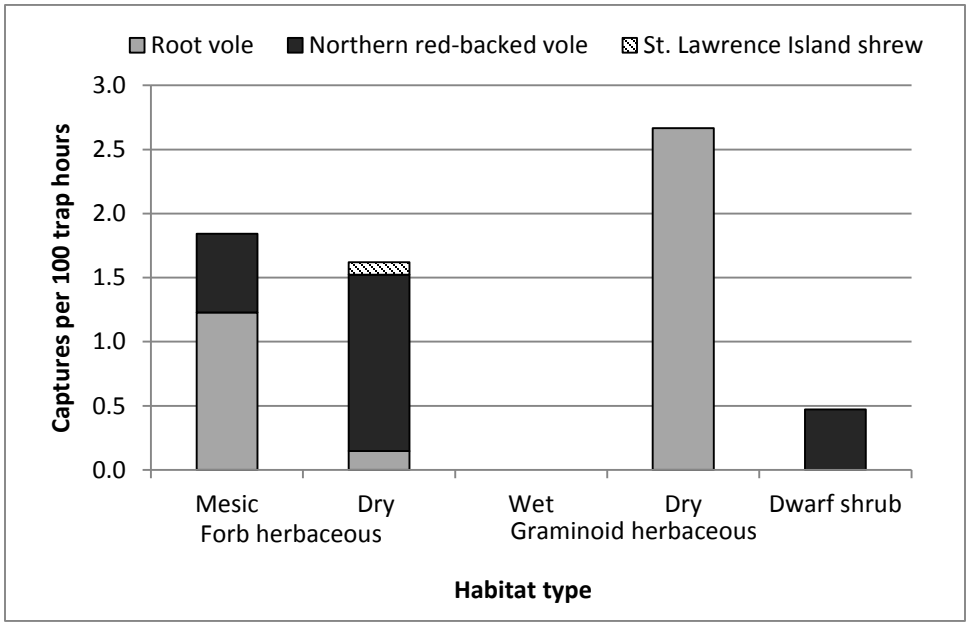

Figure 2. Capture rate (per 100 trap hours) for each taxon by major habitat type, St. Lawrence Island, July 2012.

DISCUSSION

No systematic surveys have been conducted for small mammals on St. Lawrence Island in approximately 40 years (Rausch et al. 1973 being the latest). Although our survey was limited to a single time period within a relatively limited survey area, this survey provides valuable information on occurrence, relative abundance, and habitat utilization by small mammals on St. Lawrence Island. This survey further confirmed the presence of 4 small mammal taxa on the Island and suggests that additional surveys are needed to more thoroughly assess the status of the Nearctic collared lemming, which we did not find, and St. Lawrence Island shrew, for which we had very low trapping success rates.

By accounting for the capture rate of each taxon by habitat type and the relative abundance of each habitat on the island, we qualitatively ranked the relative abundance of each taxon. Species diversity was highest in dry graminoid herbaceous habitats; this habitat type was also where we captured the greatest number of individuals. We found that root voles were the most abundant species occurring in mesic areas that make up a large part of the low lying areas of the island. The second most abundant species was the northern red-backed vole, which was found in mesic to dry areas, often at slightly higher elevations than the root vole. Arctic ground squirrels were moderately abundant and were often observed in mesic to dry habitats, particularly areas with sandy soil or rocky outcrops. The St. Lawrence Island shrew was the least abundant of the small mammals we captured, and was found exclusively in rocky auklet colonies. We were unable to capture Nearctic collared lemmings in any habitat type.

It is possible we captured few shrews and lemmings because they were at a low point in their population cycle or few exist here typically. Our pitfall traps were unsuccessful in capturing any small mammals and may have been too shallow. Elsewhere in southwestern AK, the spring and summer trapping period was the most successful in capturing tundra voles and lemmings.

Patterns of Abundance and Habitat Use

Our survey effort resulted in only 2 St. Lawrence Island shrew captures, which indicates the need for regular survey efforts to better understand their distribution and abundance. Previous surveys on St. Lawrence Island also found this species was scare. In 1931, Hall and Gilmore's (1932) collecting efforts resulted in specimens only from within an auklet colony, although they trapped in wet tundra and offered a reward to local residents for specimens. However, according to Fay (1973) the number of shrews was highly variable from year to year, with periods of abundance. When abundant, shrews were found in old village sites, rocky alpine tundra, and mesic tundra, and when scarce they were only found in rocky, boulder scree habitats, especially in auklet colonies (Fay and Sease 1985). Our captures were both in a rocky boulder field within an auklet colony. The rarity and confinement to the auklet colony suggests that

the St. Lawrence Island shrew was uncommon in the areas we sampled in 2012. The habitat requirements of shrews are often related to invertebrate abundance and physical conditions (Nagorsen 1996). We recommend conducting regular surveys to determine population dynamics and to determine the factors that limit their population size and distribution on St. Lawrence Island.

Our survey effort resulted in no captures of the Nearctic collared lemming. This species seems to have always been uncommon, occurring at low densities on the island, and is considered the rarest of the indigenous mammals on St. Lawrence Island (Murie 1936; Fay 1973; Fay and Sease 1985). In previous surveys on St. Lawrence Island, collared lemmings have been found almost exclusively in high elevation dry habitats, such as rocky areas with heath-lichen vegetation (Rausch and Rausch 1972). An inventory in Alaska's Arctic National Parks found the collared lemming was uncommon and it took thousands of trap nights to collect only 11 specimens (Cook and MacDonald 2006). A survey along the Goodnews River in southwest Alaska also noted the scarcity of lemming specimens collected in the area (Peirce and Peirce 2005). Collared lemmings are known for their cyclic population trends in Alaska (MacDonald and Cook 2009). Elsewhere in the Nearctic, lemmings are key species in tundra ecosystems as their multiannual population fluctuations directly influence the productivity of higher (i.e., predatory birds, carnivorous mammals) and lower (plant communities) trophic levels (See summaries of trophic interactions in Ims and Fuglei 2005; Reid and others 2012). Fay (1985) suggests that on St. Lawrence Island, the root vole fills the so called "lemming niche" as the primary herbivore and principle prey for predatory birds and arctic fox. When found on St. Lawrence Island, the lemming has been in habitats with few or no competitors (Fay 1985), suggesting it may be excluded from habitats by other competing small mammals. We recommend conducting additional surveys to determine if this subspecies is still present on St. Lawrence Island. If present, we suggest monitoring the population to determine if its population is cyclic or simply present at low densities and to determine the lemming's role in the dynamics of the ecosystem, particularly as a food source to predators.

The root vole was the most abundant small mammal in 2012. We captured and observed root voles in a variety of herbaceous habitats, especially in mesic herbaceous vegetation and in a riparian beach area. We quickly found that root voles were easy to capture in Sherman traps and were prevalent in lowland areas; instead focused much of our trapping efforts on the other less common and poorly understood species. Fay and Sease (1985) described the root vole as the most abundant small mammal on the island. This species is reported to be weakly cyclic over a 3 to 4 year period (Rausch 1953; Rausch and Schiller 1956; Fay 1973) and is the primary herbivore on the island and the main prey source for arctic

fox and predatory birds (i.e., jaegers and snowy owls; Fay and Sease 1985). Previous studies have also recorded the root vole in mesic habitats dominated by sedge and moss (Fay and Sease 1985).

Northern red-backed voles were the second most abundant small mammal in 2012; co-inhabited mesic areas with the root vole and were the primary small mammal occupant in dry dwarf shrub and rocky alpine habitats. Northern red-backed voles have a more omnivorous diet (i.e., seeds, fruits, leaves) than root voles (primarily graminoids; Cook and MacDonald 2006) and therefore may be better suited for these shrub and forb dominated habitats. Rausch (1953) found the northern red-backed vole difficult to collect and only 4 specimens were collected in comparison to 600 of the root vole and 2 of the collared lemming. Similarly, Hall and Gilmore (1932) collected only 3 specimens in 1931, compared to 35 for the root vole, 16 for the St. Lawrence Island shrew, and 3 for the collared lemming. These historical accounts indicate this species is not always as abundant as we found in 2012. We recommend monitoring the population to determine if it is cyclic and to determine if competition with the root vole has a large influence on the abundance and distribution of this species.

We observed ground squirrels in a variety of mesic to dry habitats and they were fairly common in abundance in 2012. In the past, ground squirrel have been considered scarce (in 1931; Hall and Gilmore) to common (Murie 1936; Rausch 1953; Fay 1973). We observed ground squirrels in similar habitat types to others, including sandy, rocky, drier tundra (Hall and Gilmore), mesic tundra (Fay 1973), and more barren areas (Fay and Cade 1959).

Overall, our finding suggest that root vole and red-backed vole populations on St. Lawrence Island are apparently secure, with limited threats, and relatively high densities in most habitat types. We point to the need for additional surveys to determine the status of the Nearctic collared lemming and the St. Lawrence Island shrew, and to determine factors that regulate their population size and periodicity, especially if we are to anticipate their response to climate change. Climate change may pose a major threat to these insular taxa in the near future, as arctic islands ecosystems are particularly vulnerable to climate induced changes because they have very little functional redundancy among taxa in comparison to a more speciose systems (Post and others 2009).

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LITERATURE CITED

[ADF&G] Alaska Department of Fish and Game. 2006. Our wealth maintained: a strategy for conserving Alaska's diverse wildlife and fish resources. Juneau, AK: Alaska Department of Fish and Game. xviii + 824 p.

Cook JA, MacDonald SO. 2006. Mammal inventory of Alaska's National Parks and Preserves: Arctic Network: Bering Land Bridge NP, Cape Krusenstern NM, Kobuk Valley NP, Noatak NP, and Gates of the Arctic NP&P. National Park Service Alaska Region, Inventory and Monitoring Program Final Report 2006. 204 p. Available from 4175 Geist Road, Fairbanks, AK 99709.

Demboski JR, Cook JA. 2003. Phylogenetic diversification within the *Sorex cinereus* group (Soricidae). Journal of Mammalogy 84: 144-158.

Faber-Langendoen D, Nichols J, Master L, Snow K, Tomaino A, Bittman R, Hammerson G, Heidel B, Ramsay L, Teucher A, Young B. 2012. NatureServe conservation status assessments: methodology for assigning ranks. Arlington, VA: NatureServe. 44 p. Available from NatureServe, 4600 N. Fairfax Drive, 7th Floor, Arlington, VA 22203.

Fay FH. 1973. The ecology of *Echinococcus multilocaris* Leuckart, 1863, (Cestoda; Taeniidae) on St. Lawrence Island, Alaska. Annales de Parasitologie 48: 523-542.

Fay FH, Sease JL. 1985. Preliminary status of selected small mammals. Final Report to U.S. Fish and Wildlife Service. University of Alaska Fairbanks, Institute of Marine Science. 52 p.

Galbreath KE, Cook JA. 2004. Genetic consequences of Pleistocene glaciations for the tundra vole (*Microtus oeconomus*) in Beringia. Molecular Ecology 13: 135-148.

Hafner DJ, Yensen E, Kirkland Jr LG. (compilers and editors). 1998. North American rodents. Status survey and conservation action plan. Gland, Switerland and Cambridge, UK: IUCN/SCC Rodent Specialist Group. 166 p. Available from IUCN Publications Services Unit, 219c Huntingdon Road, Cambridge CB3 0DL, UK.

Hall ER. 1981. The mammals of North America. New York, New York: Wiley-Interscience. 1181 p.

Hall ER, Gilmore RM. 1932. New mammals from St. Lawrence Island, Bering Sea, Alaska. University of California Publication in Zoology 38: 391- 404.

Hoffman RS, Peterson RS. 1967. Systematics and zoogeography of Sorex in the Bering Strait area. Systematic Zoology 16: 127-136.

Hopkins DM. 1959. Cenozoic history of the Bering land bridge. Science 129: 1519-1528.

Hulten E. 1937. Outline of the history of arctic and boreal biotia during the quaternary period: their evolution during and after the glacial period as indicated by the equiformal progressive areas of present plant species. [dissertation]. Stockholm, Thule: Lund University. 168 p.

Ims RA, Fuglei E. 2005. Trophic interaction cycles in tundra ecosystems and the impact of climate change. BioScience 55: 311-322.

MacDonald SO, Cook JA. 2009. Recent mammals of Alaska. Fairbanks, AK: University of Alaska Press. 387 p.

Murie OJ. 1936. Notes on the mammals of St. Lawrence Island, Alaska. In: Geist OW, Rainey FG, editors. Archaeological excavations at Kukulik, St. Lawrence Island, Alaska. Vol. II. Fairbanks, AK: Misc. Publ. Univ. Alaska, Fairbanks. p 337-346.

Musser GG, Carleton MD. 2005. Superfamily Muroidea. In: Wilson DE, Reeder DM, editors. Mammal species of the world: a taxonomic and geographic reference. Third Edition. Baltimore, MD: Johns Hopkins University Press. p 894-1531.

Nagy TR, Grower BA. 1999. Northern collared lemming, Dicrostonyx groenlandicus. In: Wilson DE, Ruff S, editors. The Smithsonian book of North American mammals. Smithsonian Institution Press, Washington, D.C., in association with the American Society of Mammalogists. p 659-660.

Nagorsen DW. 1996. Opossums, shrews, and moles of British Columbia. Royal British Columbia Museum Handbook. Volume 2. Vancouver, BC: UBC Press. 169 p.

Patton Jr WW, Csejtey Jr B. 1971. Preliminary geologic investigations of western St. Lawrence Island, Alaska. Geological Survey Professional Paper 684- C. Washington DC: United States Government Printing Office. 15 p.

Peirce KN, Peirce JM. 2005. Occurrence and distribution of small mammals on the Goodnews River, southwestern Alaska. Northwestern Naturalist 86: 20-24.

Post E, Forchhammer MC, Bret-Harte MS, Callaghan TV, Christensen TR, Elberling B, Fax AD, Gilg O, Hik DS, Høye TT, Ims RA, Jeppesen E, Klein DR, Madsen J, McGuire AD, Rysgaard S, Schindler DE, Stirling I, Tamstorf MP, Tyler NJC, van der Wal R, Welker J, Wookey PA, Schmidt NM, Asstrup P. 2009. Ecological dynamics across the arctic associated with recent climate change. Science 11: 1355-13358.

Prost S, Smirnov N, Fedorov VB, Sommer RS, Stiller M, Nagel D, Knapp M, Hofreiter M. 2010. Influence of climate warming on arctic mammals? New insights from ancient DNA studies of the collared lemming *Dicrostonyx torquatus*. PLoS ONE 5: e10447.

Rausch RL. 1953. On the status of some arctic mammals. Arctic 6: 91-148.

Rausch RL, Schiller EL. 1956. Studies on the helminth fauna of Alaska. XXV. The ecology and public health significance of *Echinococcus sibiricensis* Rausch and Schiller, 1954, on St. Lawrence Island. Parasitology 46: 395-419.

Rausch RL, Rausch VR. 1972. Observation on chromosomes of *Dicrostonyx torquatus stevensoni* Nelson and chromosomal diversity on varying lemmings. Z. F. Saugetierk 37: 372-384.

Reid DG, Ims RA, Schmidt NM, Gauthier G, and Ehrich D. 2012. Lemmings (*Lemmus* and *Dicrostonyx* spp.). In arctic report card 2012. Available from http://www.arctic.noaa.gov/reportcard.

Sempson GG. 1947. Holarctic mammalian faunas and continental relationships during the Cenozoic. Geological Society of America Bulletin 58: 613-688.

Thorington RW, Hoffmann RS. 2005. Family Sciuridae. In: Wilson DE, Reeder DM, editors. Mammal species of the world: a taxonomic and geographic reference. Third Edition. Baltimore, MD: Johns Hopkins University Press. p 754-818.

Young SB. 1971. The vascular flora of St. Lawrence Island with special reference to floristic zonation in the arctic regions. Contrib. Gray Herbarium 201: 11-115.

Viereck LA, Dyrness CT, Battern AR, and Wenzlick KJ. 1992. The Alaska vegetation classification. Gen. Tech. Rep. PNW-GTR-286. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 278 p.