

## ABSTRACT

### ECOLOGY OF THE MASKED SHREW, *SOREX CINEREUS*, ON THE ISLAND OF NEWFOUNDLAND, CANADA

by

JOHN DAVID FOLINSBEE

The masked shrew, *Sorex cinereus* Kerr, a widely distributed North American insectivore, was introduced into Newfoundland in 1958. This study describes the biology of the species on the island of Newfoundland, including data on dispersal of the population, habitat preference, reproduction, longevity, predation, and morphology.

Trapping revealed that the population had dispersed at a rate of over 33 km per year since the introduction, and that by 1970 the species was present over most of the island. There was little evidence that dispersal was seriously affected by topographic barriers. Shrews were found to have dispersed to at least two islands in Notre Dame Bay. Shrews were collected in all habitats trapped; populations were highest in areas of deciduous scrub, and lowest in open bogs and fens.

A mark-recapture study revealed no evidence of home ranges. Shrews were seldom recaptured in the pitfall traps, and no individual was taken more than four times.

Breeding started in early spring (mid-May) and continued at least until September, but the number of females actively reproducing declined sharply in July. Sexual maturity in young-of-the-year was very rare; only two young individuals showing signs of sexual activity were collected.

The sex ratio for adults was strongly in favour of males (over two to one); the sex ratio in juveniles was equal.

Tooth wear was found to be the most satisfactory means of aging

shrews. Absolute ages could not be determined, but year classes could be separated accurately. No shrew was found to have survived longer than about 18 months.

Mature shrews were larger and heavier than juveniles. There were marked changes in the skull with age; old shrews had narrower, flatter skulls than juveniles.

A series of measurements suggested a difference between the Newfoundland and the mainland (parent) populations, with the Newfoundland shrews having smaller skulls. This difference may be genetic, caused in part by the limited gene pool of the introduction stock (the founder effect).

Two specimens with abnormal dentition were collected. One specimen had two supernumerary unicuspid, the other lacked a fifth unicuspid. Several examples of healed fractures were encountered, including fractures of the tibia-fibula and the innominate bone. Injuries to the feet (missing toes) were common in adult males.

It is suggested from largely circumstantial evidence that weasels and foxes are the most important predators of shrews in Newfoundland.

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by

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## INTRODUCTION

The masked shrew, *Sorex cinereus* Kerr, is a common and widely distributed North American insectivore; it was, however, absent from the Island of Newfoundland until its introduction there in 1958. There is little geographic variation in the species, and *S. cinereus cinereus* Kerr, the most widely distributed subspecies, ranges from eastern Canada to northwestern Alaska and south to the southern limit of the species (Jackson, 1928). The form occurring in eastern Canada south of the St. Lawrence River has been described as *S. cinereus acadicus* Gilpin (Hall and Kelson, 1959) but Jackson (1928) provisionally referred this form to *S. cinereus cinereus*.

The masked shrew is found in virtually all habitats throughout its range, but moist sites are preferred (Jackson, 1928; Getz, 1961).

*S. cinereus* is one of the smallest American mammals, averaging 110 mm in length and weighing about 4 grams (Peterson, 1966). The fur is soft, dark brown in colour above, pale grey below; the tail is bicoloured, brown above and buffy below. The ears are inconspicuous, nearly hidden in the relatively long fur. The highly mobile snout is well supplied with vibrissae. Shrews have a pair of side glands which give off a musky odour.

Shrews are voracious eaters, often consuming as much as their own weight in a single day (Peterson, 1966). They are largely insectivorous, but will eat carrion and occasionally vegetable material (Jackson, 1928).

Permanent dentition is present at birth, and tooth wear is not

compensated by growth. The tooth wear pattern, emphasized by the reddish pigment on the tips of the teeth, provides a good means of aging the animal. Shrews rarely survive two years in the wild--most individuals die by the end of their second summer (Peterson, 1966).

Northern species of *Sorex* undergo a peculiar reduction in body size during the winter months; there are associated changes in organ weights and general metabolism. This is known as Dehnel's phenomenon (Mezhzherin, 1964).

The breeding season begins in early spring (Brambell, 1935; Brambell and Hall, 1936) and continues for several months; fall breeding sometimes occurs (Jackson, 1928; Short, 1960; Buckner, 1966a). A litter of about eight young is born after a gestation of 18 days; the young are weaned at three weeks (Peterson, 1966).

Shrews have an interesting activity rhythm consisting of a short term (2 to 4 hour) cycle superimposed on a 24-hour cycle (Crowcroft, 1954; Mann and Stinson, 1957; Ingles, 1960). Activity is strongly affected by weather (Bider, 1968, Mystkowska and Sidorowicz, 1961). Shrews may be active at any hour, but activity (at least on the ground surface) is greatest at night.

The Island of Newfoundland had an impoverished mammalian fauna, and as early as 1942 Dr. R. E. Balch suggested the introduction of an insectivorous mammal to strengthen control of forest insects on the island (Balch, 1942--not seen, cited by Warren, in press). Officials of the Federal and Provincial Governments in Newfoundland became interested in the suggestion, and in 1955 the Provincial Government approved the introduction of the masked shrew. *Sorex cinereus* was chosen because, as Warren (in press) states, "it has a wide habitat range, is almost

entirely insectivorous, is common in similar forest and climatic conditions in the adjacent mainland provinces, and has been shown ... to be an effective predator of the larch sawfly". Unsuccessful attempts to introduce shrews were made in 1956 and 1957, and in 1958 shrews were successfully released at St. Georges on the west coast of the island (Buckner, 1966b).

The history of the introduction has been reported regularly in the Annual Report of the Newfoundland Forest Protection Association and the Annual and District reports of the Forest Insect and Disease Survey (Warren, Haines and Pardy, 1967). Other reports include MacLeod (1960), Carroll (1964), Buckner and Ray (1964), Haines (1965), Warren and Haines (1966), and Warren et al. (1967).

Most of the studies by Forestry personnel have been directed towards the effect of shrews on forest insects, while the basic biology of shrews was neglected. This was unfortunate, as the introduction of the shrew has resulted in a unique opportunity to study a small mammal population expanding into a previously unoccupied area. The situation is unique in that shrews cannot be properly considered alien to Newfoundland, they are absent only because of a combination of geographical factors, including the recent glaciation of the island and the major topographic barrier of the Strait of Belle Isle.

The purpose of this study is to outline the basic biology of *Sorex cinereus* on the Island of Newfoundland and to document the various aspects of this major range extension.



## STUDY AREA

The study area included, technically, the entire Island of Newfoundland (Figure 1), but because of the large size of the island, I concentrated my research in the more accessible central and eastern regions. I spent a total of 11 months in the field, mainly in the summers of 1968 and 1969, but collected some data in the summer of 1967, the winter of 1968-69, and the summer of 1970.

In August 1968 I established a permanent camp at Northern Arm Brook, 18 km north-northeast of Grand Falls, and used this camp until 3 September 1968, and from 28 April to 15 September 1969. The live trap plot was located here, and considerable work was done in nearby areas (Figure 2).

I visited other areas of the island primarily to locate the maximum dispersal of the *Sorex* population. Figure 3 shows the localities trapped.

### Topography

The Island of Newfoundland is situated off the east coast of North America, and lies across the mouth of the Gulf of St. Lawrence. It is approximately 111,000 square kilometres<sup>1</sup> in area, and is separated

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<sup>1</sup>All figures in this thesis are cited in the metric system. Where the figures were originally in another system, they have been transposed and rounded off to the nearest suitable metric unit.

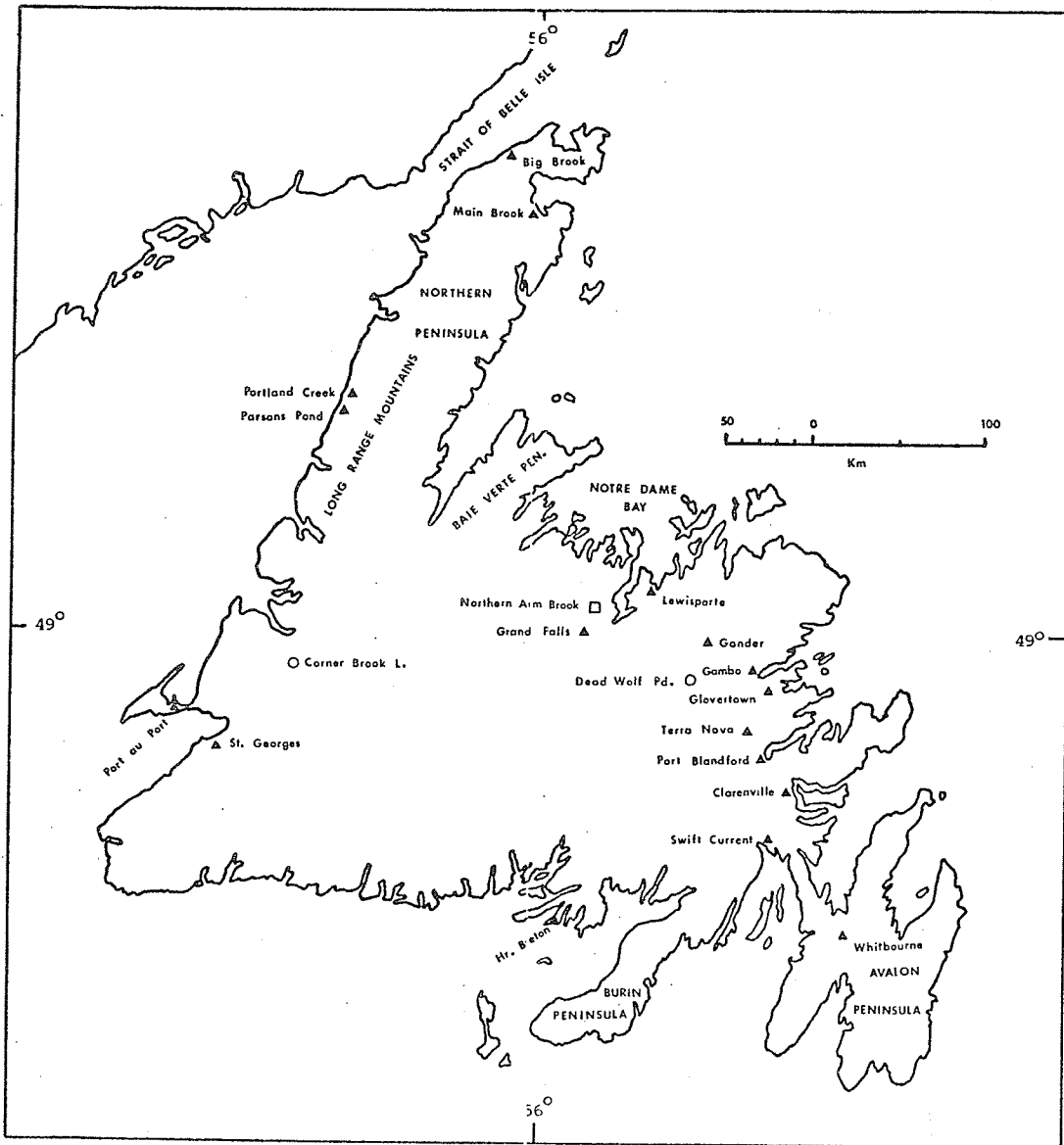


Figure 1. A map of the Island of Newfoundland showing the localities and geographic features to which reference is made.

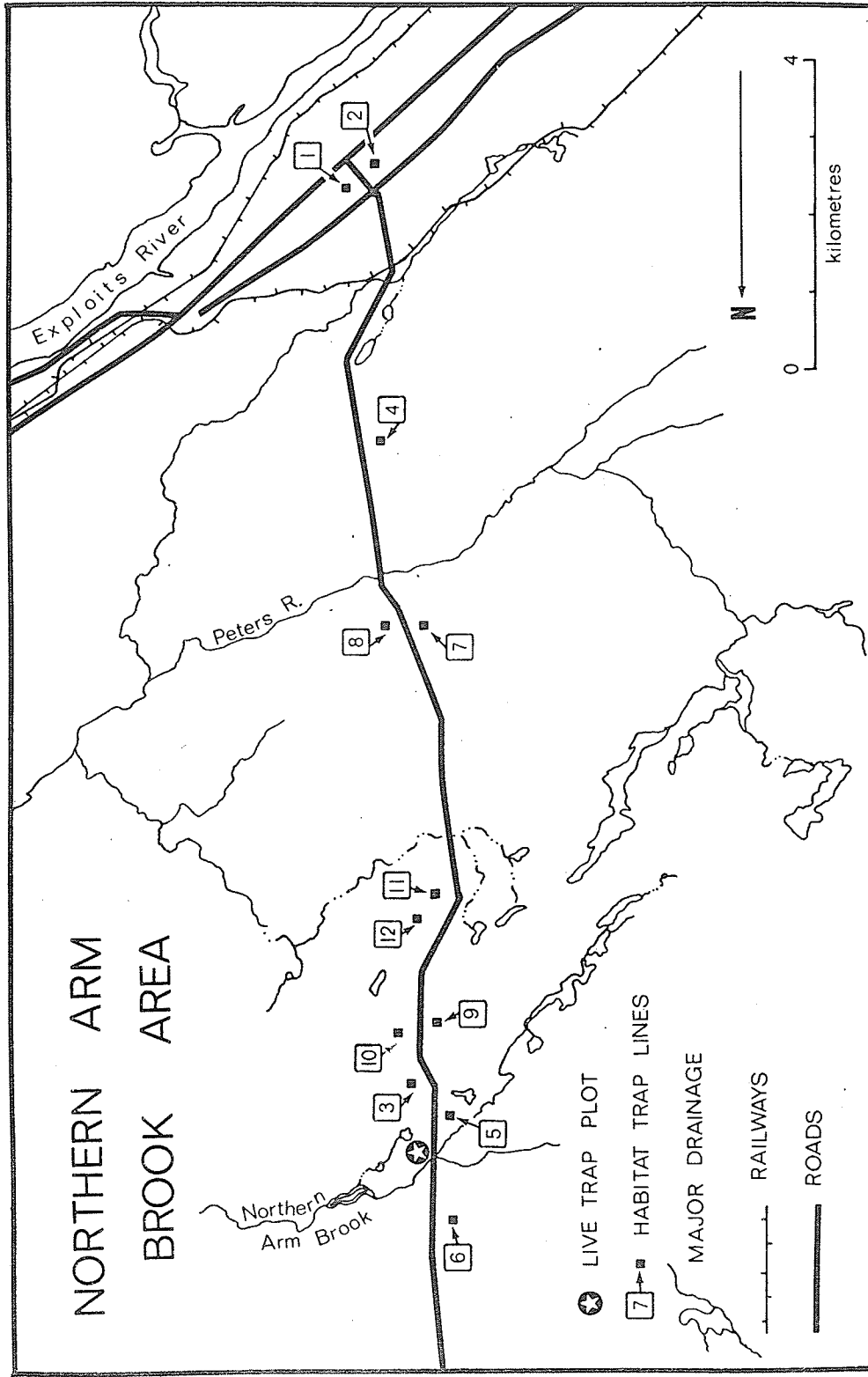


Figure 2. The Northern Arm Brook study area showing the location of the live trap plot and habitat trap lines.

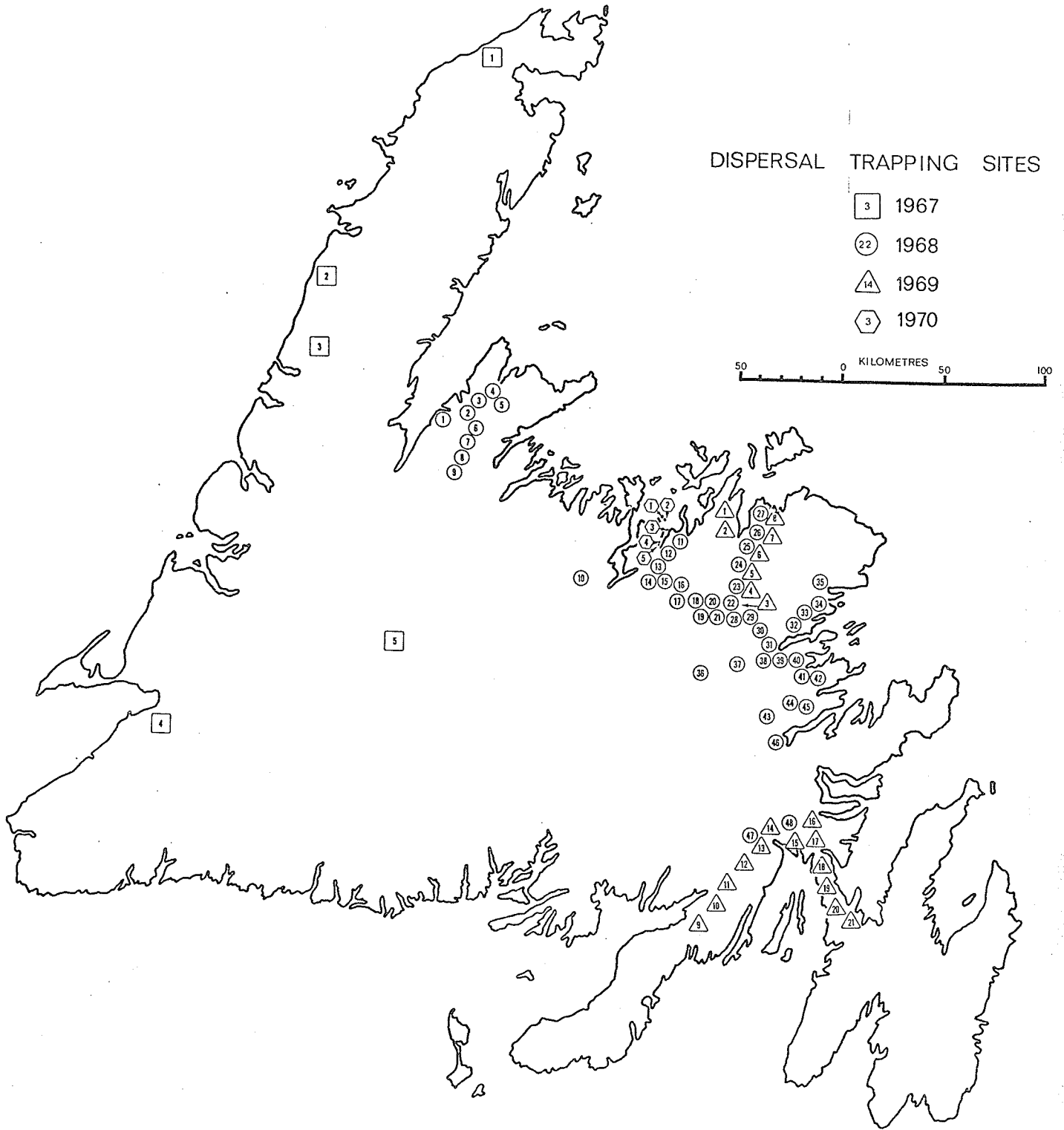


Figure 3. Localities trapped between 1967 and 1970 in insular Newfoundland.

from continental Labrador by the 18-km wide Strait of Belle Isle, and from Cape Breton Island by the 110-km wide Cabot Strait.

The island consists of a plateau rising in a westerly direction, reaching its highest elevations (over 800 m) only a few kilometres from the west coast. The coastline is dissected by numerous bays, inlets, and fjords, with many offshore islands and long, narrow peninsulas. There are some areas of high relief, such as the Long Range Mountains of the west coast, but most of the interior is gently rolling at an altitude of 250 to 450 m. Occasionally monadnocks of more resistant rock rise above the general level. Bogs and lakes, some of considerable size, are common.

The Northern Arm Brook area (Figures 2 and 4) is characterized by rolling, forested hills, with numerous small streams, ponds, and bogs. Elevations range from 40 to 170 m above sea level, with the average about 80 m. Rivers and streams drain to the northeast; the major ones are the Exploits River, Peters River, and Northern Arm Brook.

The entire island was apparently glaciated during the Wisconsin ice advance (MacClintock and Twenhofel, 1940), but there is some possibility of refugia having existed on the adjacent continental shelf (Youngman, 1967) or in the mountain areas of the west coast (Lindroth, 1963).

### Climate

The following data are compiled from Hare (1952), and publications of the Department of Transport (1967a, 1967b).

Winter temperatures are cool in the interior and mild on the coasts, with January means ranging from  $-10^{\circ}\text{C}$  to  $-7^{\circ}\text{C}$  in central regions, and as



Figure 4. Northern Arm Brook; a view looking east, showing the general nature of the topography. The live trap plot extends downstream from about the middle of the picture, and the approximate boundary is indicated by the white line. The arrow gives direction of stream flow. This photograph was taken in July when the stream was quite low.

high as  $-4^{\circ}\text{C}$  on the east coast. Spring is retarded by the presence of the cold Labrador current and pack ice. In March the sea ice reaches a maximum, usually surrounding the north, east and west coasts of the island; scattered bergs may persist until July. Summers are warm, with July means for the interior reaching  $17^{\circ}\text{C}$  and for the coasts, about  $12^{\circ}\text{C}$ .

Precipitation is abundant, well distributed throughout the year, with a slight peak in late fall (November) and a minimum in April. Annual precipitation ranges from 75 cm in the north to 140 cm in the south and west. Snowfall is over 250 cm in all areas except the south coast, and may be even higher in the mountain region of the west coast; short term records for Corner Brook Lake (elevation 275 m) indicate an average of over 550 cm of snow.

Snow cover does not become permanent until early December and melts in April or May. Some areas, especially along the coasts, receive significant snow in May and June. Snow cover is rarely permanent along the coasts. At high elevations snow banks may remain until August or occasionally throughout the year.

### Vegetation

Newfoundland lies within the boreal forest region (Rowe, 1959), but the island is by no means completely forested. Large areas of alpine and coastal barren occur in the west and south, and bogs are common throughout the island.

Balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*) are the most abundant trees, with fir dominating on the more favourable sites, and

black spruce being most common on very wet, very dry, and less fertile areas. White spruce (*P. glauca*), uncommon in the interior, is common or even dominant along the coasts. Larch (*Larix laricina*), white birch (*Betula papyrifera*), and aspen (*Populus tremuloides*) are fairly common. White pine (*Pinus strobus*), once common, has been largely destroyed by disease and logging. Trees with restricted distributions or which are uncommon include balsam poplar (*Populus balsamifera*), yellow birch (*Betula lutea*), red maple (*Acer rubrum*), and red pine (*Pinus resinosa*).

The "barrens," a term applied locally to non-forested areas of the island, are characterized by ericaceous shrubs such as *Kalmia*, *Vaccinium*, and *Ledum*. Mosses and lichens are common in the ground cover. Some barren areas are of climatic origin, caused by exposure, elevation, or high precipitation. Other areas are barren due to a combination of climatic and human factors such as fire and logging (Rowe, 1959).

Bogs and fens cover much of the island. These areas usually do not support trees, although a few black spruce or larch may be present. *Sphagnum*, *Carex*, *Scirpus*, and *Eriophorum* compose the ground cover, and shrubs such as *Kalmia*, *Ledum*, *Chamaedaphne*, and *Vaccinium* usually occur.

#### Fauna

The terrestrial mammalian fauna of the island is poor, consisting of only 14 native species:

<i>Myotis lucifugus</i>	Little brown bat
<i>Myotis keenii</i>	Keen's bat
<i>Ursus americanus</i>	Black bear
<i>Martes americana</i>	Marten
<i>Mustela erminea</i>	Weasel
<i>Lutra canadensis</i>	Otter
<i>Vulpes fulva</i>	Red fox
<i>Canis lupus</i>	Timber wolf
<i>Lynx canadensis</i>	Lynx



<i>Castor canadensis</i>	Beaver
<i>Microtus pennsylvanicus</i>	Meadow vole
<i>Ondatra zibethicus</i>	Muskrat
<i>Lepus arcticus</i>	Arctic hare
<i>Rangifer tarandus</i>	Caribou

Two northern species occasionally wander south to the island;

<i>Thalarctos maritimus</i>	Polar bear
<i>Alopex lagopus</i>	Arctic fox

(above data from Cameron, 1958)

Eleven species have been accidentally or intentionally introduced to the island:

<i>Sores cinereus</i>	Masked shrew <sup>1</sup>
<i>Mustela vison</i>	Mink <sup>2</sup>
<i>Mus musculus</i>	House mouse <sup>2</sup>
<i>Rattus norvegicus</i>	Norway rat <sup>2</sup>
<i>Tamias striatus</i>	Eastern chipmunk <sup>1</sup>
<i>Tamiasciurus hudsonicus</i>	Red squirrel <sup>1</sup>
<i>Clethrionomys glareolus</i>	Bank vole <sup>1</sup>
<i>Clethrionomys gapperi</i>	Red-backed vole <sup>1</sup>
<i>Lepus americanus</i>	Snowshoe hare <sup>1</sup>
<i>Alces alces</i>	Moose <sup>1</sup>
<i>Bison bison</i>	American bison <sup>1</sup>

(data from Cameron, 1958; Bergerud, 1963; and personal observations)

*Canis lupus* has been extirpated from the island, and *Lepus arcticus* and *Martes americana* are extremely rare (Cameron, 1958). *Tamiasciurus hudsonicus*, *Clethrionomys glareolus*, *Clethrionomys gapperi*, and *Bison bison* were introduced for scientific study to offshore islands, and are hence restricted in distribution. The red squirrel has been transported to the mainland<sup>3</sup> and may spread over the rest of Newfoundland. Red squirrels are also found in the Main Brook area of the Northern

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<sup>1</sup>Intentional introduction.

<sup>2</sup>Accidental introduction.

<sup>3</sup>This term is used to differentiate between the main island of Newfoundland and its offshore islands.

Peninsula (O. Forsey, pers. comm.), but I have been unable to determine the reason for, or date of, this introduction. The eastern chipmunk was liberated in three provincial parks, but apparently has not increased its distribution to any extent (Bergerud, 1963). The other introduced mammals are common and found throughout the island. There is one record of *Peromyscus maniculatus* for the island (Gould and Pruitt, 1969), but the species is apparently not established.

Reptiles and amphibians, with the exception of the introduced Green frog, *Rana clamitans*, are absent (Cameron and Tomlinson, 1962).

## METHODS AND MATERIALS

### Trapping techniques

Snap traps (Victor 4-way, Schuyler No. 3 Folding Animal Killer, Museum Special), small folding aluminum Sherman live traps, and two sizes of pitfalls were tested. Pitfalls were made by removing the tops of tin cans 175 mm deep by 160 mm wide (large pitfall), and 175 mm deep by 105 mm wide (small pitfall). A number of workers (Clarke, 1938; Prince, 1941; Moore, 1949; Edwards, 1952) have found pitfalls more effective for *Sorex* than either box-type live traps or snap traps. MacLeod and Lethiecq (1963) found pitfalls to be much more effective for shrews on the island of Newfoundland. Buckner (1957) used pitfalls on a live trap plot to reduce mortality.

A small amount of comparative trapping showed pitfalls to be much more effective than snap traps, and in spite of the greater difficulty in setting pitfalls, they were used almost exclusively for the rest of the study. Pitfalls were set in the usual manner, with the top of the trap at or slightly below the ground surface. In very wet or rock areas this was not always possible, so stones, soil, or moss were used to build the ground surface up to the level of the trap. This was especially necessary in wet areas, where traps either filled with water or else floated out of the hole. For kill trapping a small amount of water was allowed to accumulate in the traps which drowned the animals, and

prevented escapes and cannibalism. Snap traps were baited with a mixture of peanut butter, rolled oats and raisins, while pitfalls were left unbaited.

#### Dispersal trapping

In both 1968 and 1969 I trapped in an effort to locate the boundary of the shrew population. The usual trap site consisted of five or ten pitfalls, set a short distance apart in an area which appeared favourable for *Sorex*. Trap sites were spaced ten to thirty kilometres apart along roads, and were visited at irregular intervals. If a shrew was captured, the traps were usually relocated in an area farther from the known range. Data were also collected by questioning local residents about shrews, and by observing sign in snow. Only those specimens which were in a good state of preservation or which represented a new locality record were saved. Figure 3 shows the approximate location of all dispersal sites.

#### Habitat preference studies

In 1969 I selected 12 areas for a habitat preference study. A trap line consisting of five large pitfalls spaced ten metres apart was set in each area. All lines were at least 100 metres from roads, and if possible, in a large area of uniform habitat. The habitat lines were trapped for three-day periods at approximately fifteen day intervals throughout the summer. All *Sorex* taken were preserved.

When not in use, I filled traps with sticks, stones, or moss. A small amount of water was allowed to accumulate in the traps. Figure 2 shows the location of the habitat trap lines with respect to the Northern

Arm Brook camp.

The habitat trap lines were of four general types: deciduous shrub forest (alder-maple swamp), conifer forest (usually with a few deciduous trees), cutover (formerly spruce-fir forest), and bog or fen. A complete description of each line is given in Appendix I. A brief description is given below. The nomenclature of the vascular plants follows Rouleau (1956).

Line 1. Alder-maple-willow forest. This habitat was a dense shrub forest (*Alnus*, *Acer*, *Salix*), with extensive shrub (*Viburnum*, *Vaccinium*) and herb (*Rubus*, *Cornus*, *Dryopteris*) cover, considerable leaf and twig litter, and very little moss, on a level, moderately well drained site.

Line 2. Alder-birch-mountain ash forest. Similar to Line 1, this site supported a dense shrub forest of alder (*Alnus*), birch (*Betula*), and mountain ash (*Pyrus*), but the herb layer (*Cornus*, *Maianthemum*, *Trientalis*) was sparse, and there was considerable exposed rock and soil. The area was poorly drained.

Line 3. Balsam fir forest. This site consisted of a dense, even-aged stand of balsam fir (*Abies balsamea*), with a few birch (*Betula*) and poplar (*Populus*). The ground cover was a nearly complete layer of feather mosses (*Pleurozium*, *Hypnum*), with some leaf litter. The herb layer was very sparse, consisting of *Cornus*, *Linnaea* and *Clintonia*. The site was well drained.

Line 4. Spruce-balsam fir forest. This site supported a mixed stand of black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*), with a poorly developed understory, some leaf and needle litter, and some feather mosses. The site was level and well drained.

Line 5. Spruce-birch forest. This area was a mature stand of spruce (*Picea mariana*), birch (*Betula papyrifera*), and fir (*Abies balsamea*), with a few shrubs, but a well developed herb layer of *Cornus canadensis*, *Clintonia borealis*, and *Lycopodium* sp. About half the ground was carpeted with feather mosses, the rest with leaf and needle litter. The area was well drained.

Line 6. Fir-spruce-birch forest. This site was a mature fir-spruce-birch forest with few shrubs, but a very well developed herb and moss layer. *Gaultheria hispidula*, *Cornus canadensis*, *Linnaea borealis*, *Trientalis borealis*, and *Dryopteris* sp. were the principle herbs. The site was well drained.

Line 7. Spruce-ericaceous shrub forest. This site supported an open stand of black spruce (*Picea mariana*) with numerous ericaceous shrubs (*Kalmia*, *Rhododendron*, *Vaccinium*). Feather mosses and lichens formed a nearly complete ground cover.

Line 8. Spruce-ericaceous shrub forest. This site was very similar to Line 7--a black spruce forest with ericaceous shrubs. A few birch and fir also occurred. *Clintonia borealis*, *Cornus canadensis*, and *Gaultheria hispidula* were the common herbs. Feather mosses (*Pleurozium*, *Hypnum*) covered about half the area, with needle and leaf litter covering the rest.

Line 9. Cutover. This site was a clear-cut area with a good regeneration of poplar (about one to two metres tall). Part of the area

supported a relatively undisturbed stand of deciduous forest (*Populus tremuloides*, *Betula papyrifera*), with an abundant shrub and herb layer. The rest of the area had leaf and twig litter, with very few herbs.

Line 10. Cutover. This site was similar to Line 9, but had been cut more recently, and there was no regeneration. Most of the area consisted of logging slash, with tops, branches and needle litter. Herb cover was sparse in the heavily disturbed area, and more abundant where a few birch and alders had been untouched. The area was well drained.

Line 11. Fen. This site was a small, isolated area of fen, dominated by sedges (*Carex* and *Scirpus*). Some *Sphagnum* was present, forming small hummocks on which occurred shrubs such as *Juniperus*, *Potentilla*, and *Myrica*. Standing water was present throughout the summer.

Line 12. Dwarf shrub bog. This site was a relatively dry, raised sphagnum bog, supporting a good cover of ericaceous shrubs, with some herbs and lichens. *Picea mariana*, *Ledum*, *Chamaedaphne*, *Kalmia*, *Empetrum*, and *Cladonia* were common, occurring mainly on the drier hummocks.

### Live trapping

In August 1968 a live trap plot was established on the south side of Northern Arm Brook (Figure 2). The plot consisted of a 100 x 100 m grid, with a 10-m grid interval.

In 1969 the plot was extended northward to the edge of the stream and southward to the edge of a small fen, for a total area of 1.63 hectares. The spacing of the traps was changed, with additional traps being placed in the central area, resulting in a 5 x 10-m trap spacing (Figure 10).

Both large and small pitfalls were used on the plot. Masonite trap covers were used in 1969.

I trapped at night, as attempts at daylight trapping were unsuccessful. Traps were usually opened at dusk and closed at dawn. Traps covers were removed completely on warm, dry nights; however, on wet or rainy nights the covers were left a few centimetres above the trap, supported on small sticks. Traps were checked at one hour intervals.

When a shrew was captured, it was examined for ectoparasites, aged, sexed if possible, toe clipped, and released. I made no attempt to sex immature animals, because of the difficulty of the procedure and the possibility of injuring the animal.

Between 11 and 14 September 1969, I opened all traps on the plot in an effort to secure as many specimens as possible. The traps were checked two to four times daily during this period. The few live specimens taken were toe clipped and released; all others were preserved as specimens.

I mapped the major types of vegetation occurring on the plot, and listed the species of vascular plants present.

#### Handling of specimens

All specimens were examined for ectoparasites, weighed, and the standard measurements (total length, tail length, hind foot length) taken. Some specimens were preserved as study skins; a moult diagram of the pigmented areas on the inner side of the skin was drawn before the skin was prepared. The viscera were preserved in AFA<sup>1</sup> or formalin.

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<sup>1</sup>90 parts 70% ethyl alcohol, 5 parts 40% formaldehyde, 5 parts glacial acetic acid.



The skeletons were air dried, cleaned by means of a dermestid colony (Hall and Russell, 1933), then washed in strong ammonia water (14%  $\text{NH}_4\text{OH}$ ). Some specimens were preserved entire in formalin or ethyl alcohol.

I examined all specimens to determine their reproductive condition. Testes of males were measured and noted were made on the condition of accessory reproductive structures. I examined females for the presence of embryos or placental scars and noted the condition of the mammary glands. By observing the condition of the uterus and attached mesenteries it is possible to distinguish parous from non-parous females (Tupikova, 1964). Parous females show increased vascularization and an increase in the length of the uterine horns. Regression of mammary glands is very rapid (Brambell, 1935), and hence visible mammary tissue is a good indication of functional lactation. All females with easily visible mammary tissue were considered to be lactating.

#### Age determination

Specimens were classified according to the amount of tooth wear, and grouped into two broad age classes, young-of-the-year, or young, and overwintered, or old animals. Other characters such as the shape of the skull, the length of the femur, shape of the pelvis, and sexual maturity were also used to age specimens.

For a more accurate determination of age, a series of 12 skulls was selected, showing the range of tooth wear from unworn to heavily worn, and all other skulls were compared with this standard series.

This method is essentially similar to those of Pearson (1945) and Rudd (1955).

Live specimens were somewhat more difficult to age, but by using a combination of tooth wear (visible on the anterior teeth), size, sexual maturity, amount of hair on the tail, and colour of the feet, I was able to separate young from old animals. The details of the methods of age determination are discussed under AGE DETERMINATION AND POPULATION AGE STRUCTURE, pages 60 to 71.

#### Measurements

I made a series of measurements on all suitable skeletal material, using a binocular microscope and a craniometer as described by Anderson (1968).

I measured 261 specimens from the Island of Newfoundland, and 62 specimens from New Brunswick. The mainland specimens were all collected near the source of the introduction stock in northwestern New Brunswick (See Appendix III).

The orientation of the specimen for each series of measurements is described below.

#### Skull--dorsal surface

The skull was placed on the craniometer stage, resting on the tips of the upper incisors and the tympanic rings or mastoid region. Broken

skulls were supported in this position with a bit of clay.

Condylbasal length: length of the skull from the most anterior point of the premaxillae to the most posterior point of the occipital condyles, measured parallel to the long axis of the skull (Jackson, 1928).

Cranial breadth: greatest lateral diameter of the skull, measured at right angles to the long axis (Jackson, 1928).

Least interorbital breadth: lateral diameter of the interorbital region, measured directly above (in vertical view) the point where the posterior edges of the maxillary processes appear to disappear beneath the rostrum (probably identical to least interorbital breadth of Jackson, 1928).

#### Skull--ventral surface

For these measurements, the skull was secured ventral side uppermost with the plane joining the tips of the incisors and the ventral side of the occipital condyles parallel to the surface of the stage.

Palatal length: maximum length of the bony palate in the midline (Jackson, 1928).

Maxillary tooth row: length of the upper tooth-row, from the anterior side of the first apicusp (I2), to the posterior side of the last molar (M3), measured at the cingulum and parallel to the midline of the skull (Findley, 1955).

#### Skull--lateral view

For these measurements, the skull was rotated  $90^{\circ}$  from the above

position, so its sagittal plane was parallel to the stage.

Frontal depression: the distance between a line tangential to the frontal and nasal bulges of the skull and a parallel line tangential to the deepest point of the frontal depression (Anderson, 1968).

Depth of cranium: the distance between a line tangential to the occipital condyles and the pterygoid bulge of the skull, and a parallel line tangential to the highest point of the cranium, including the sagittal crest.

#### Mandible

The halves of the mandible were separated, and the left half placed on the stage, labial side up.

Mandibular tooth row (excluding incisor): length of the tooth-row from the anterior side of the canine to the posterior border of the last molar, measured at the cingulum and parallel to the ventral ramus of the mandible.

#### Femur

For this measurement, the left femur was placed anterior side up on the stage.

Femur length: maximum length of the femur from the dorsal side of the head to the end of the median condyle, measured parallel to the long axis of the shaft.

#### Predator food habits

I collected all predator scats encountered during the study. These

were examined in the laboratory for the presence of *Sorex* remains.

No special attempt was made to identify other materials or to determine their relative abundance. I kept note of the various species of potential predators seen in the field.

## THE INTRODUCTION AND DISPERSAL OF *SOREX CINEREUS* IN NEWFOUNDLAND

### The introduction and the dispersal prior to 1968

*Sorex cinereus* was introduced into Newfoundland in September 1958, at a site near St. Georges on the west coast of the island. The introduction stock came from the Green River watershed in northwestern New Brunswick and 22 individuals (10 males, 12 females) were eventually released in Newfoundland (Peterson, 1966, Buckner, 1966b). In 1961 shrews were captured at the St. Georges release site, and liberated at two localities in central Newfoundland; Halls Bay and Exploits Dam (Figure 5). Populations from the three introduction sites had merged by 1966 (Warren, in press).

By 1967 shrews had dispersed over more than half the island. Figure 5, compiled from unpublished data of the Canada Department of Fisheries and Forestry, shows the known range in the fall of 1967. Shrews were still absent from the Northern Peninsula; I caught none in several days of trapping near Portland Creek and W. O. Pruitt, Jr., took none in regular trapping of plots near Big Brook (Pruitt, pers. comm.).

Warren (in press) points out the ability of shrews to cross physical barriers. He cites two instances where the population crossed relatively long narrow land bridges, one natural (the Port au Port isthmus), and one man-made (the Pilley's Island causeway--400×20 metres).

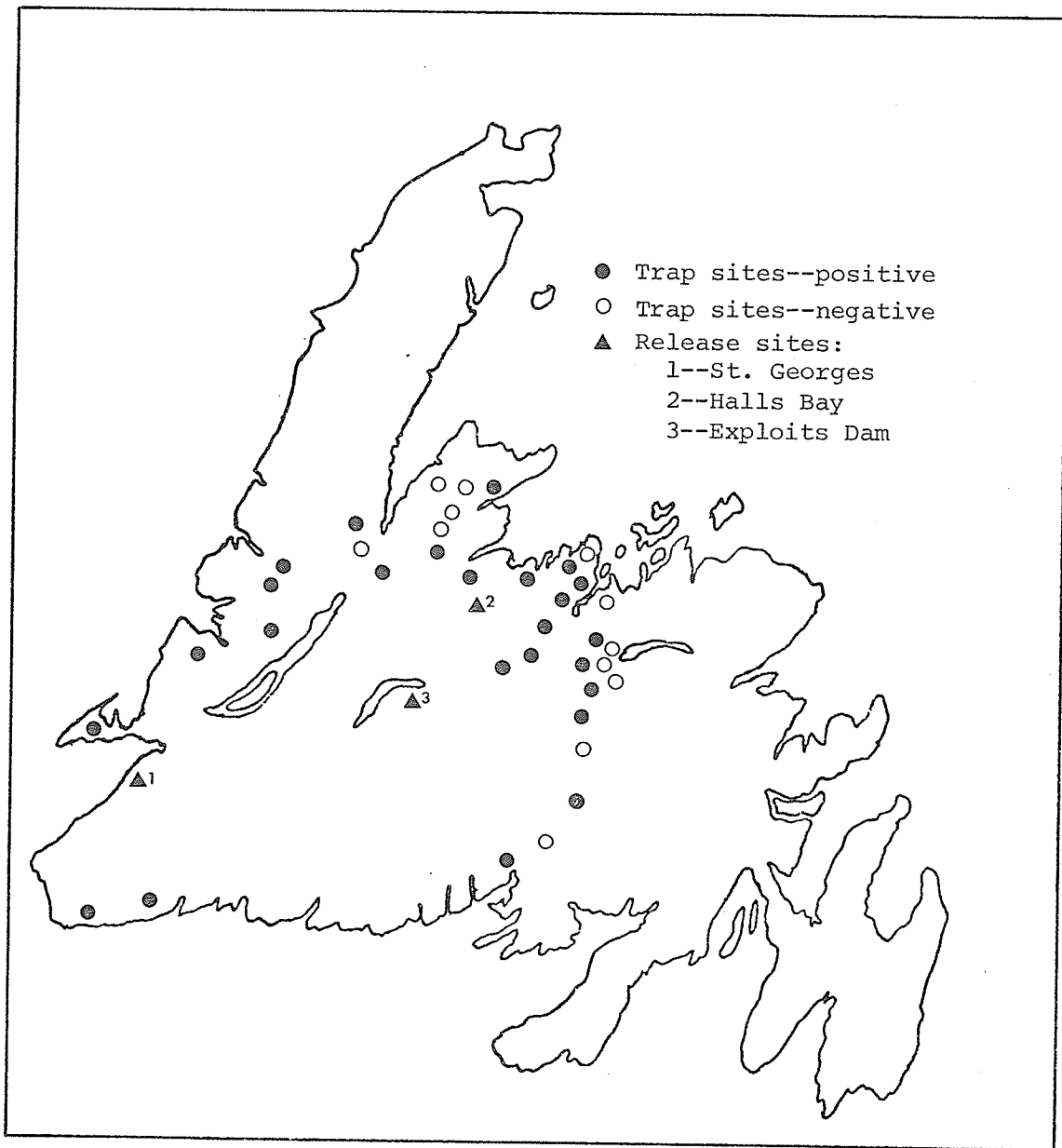


Figure 5. Known distribution of *Sorex cinereus* in Newfoundland in the fall of 1967 (compiled from unpublished data of the Canada Department of Fisheries and Forestry with the permission of G. L. Warren).

### Distribution in 1968

During 1968 I trapped a number of areas with the objective of defining more accurately the population boundary. The results of this trapping are shown in Figure 6. Not all trap sites are shown, but enough are included to show the general distribution. A complete list of trap sites, with the location, habitat, types of traps, and results is presented in Appendix II.

*Sorex* had dispersed north on the Northern Peninsula as far as Portland Creek. I obtained specimens collected from Portland Creek and Parsons Pond by M. Luther and A. Wentzell, respectively. The population apparently had not reached the end of the peninsula since W. O. Pruitt, Jr. failed to collect shrews in 1200 trap nights near Big Brook. All the sites I trapped on the Baie Verte Peninsula were positive, and it is probable that shrews had reached the extremities of this peninsula.

There was, however, one major anomaly in the distribution. Between Gander and Carmanville I set six trap lines on 5 September and checked these as late as 10 November (65 days) with negative results. I caught only one shrew between Gander and the Gander River (at site 19) and other sites in this area (18, 20, 21) were negative. The indication was that was of the fall of 1968 the population was low and discontinuous west of Gander and north of Gander Lake, in the triangle of land east of the Gander River. The details of this distribution are shown in Figure 7.

South and east of Gander Lake I found *Sorex* in all areas. Shrews were common at Dead Wolf Pond, and were taken as far south as Port Blandford. I also took shrews in the vicinity of Terra Nova (sites 43-45) and at Glovertown (sites 40-42). A resident of Clarenville informed me that shrews were present in that area. This report of *Sorex* at



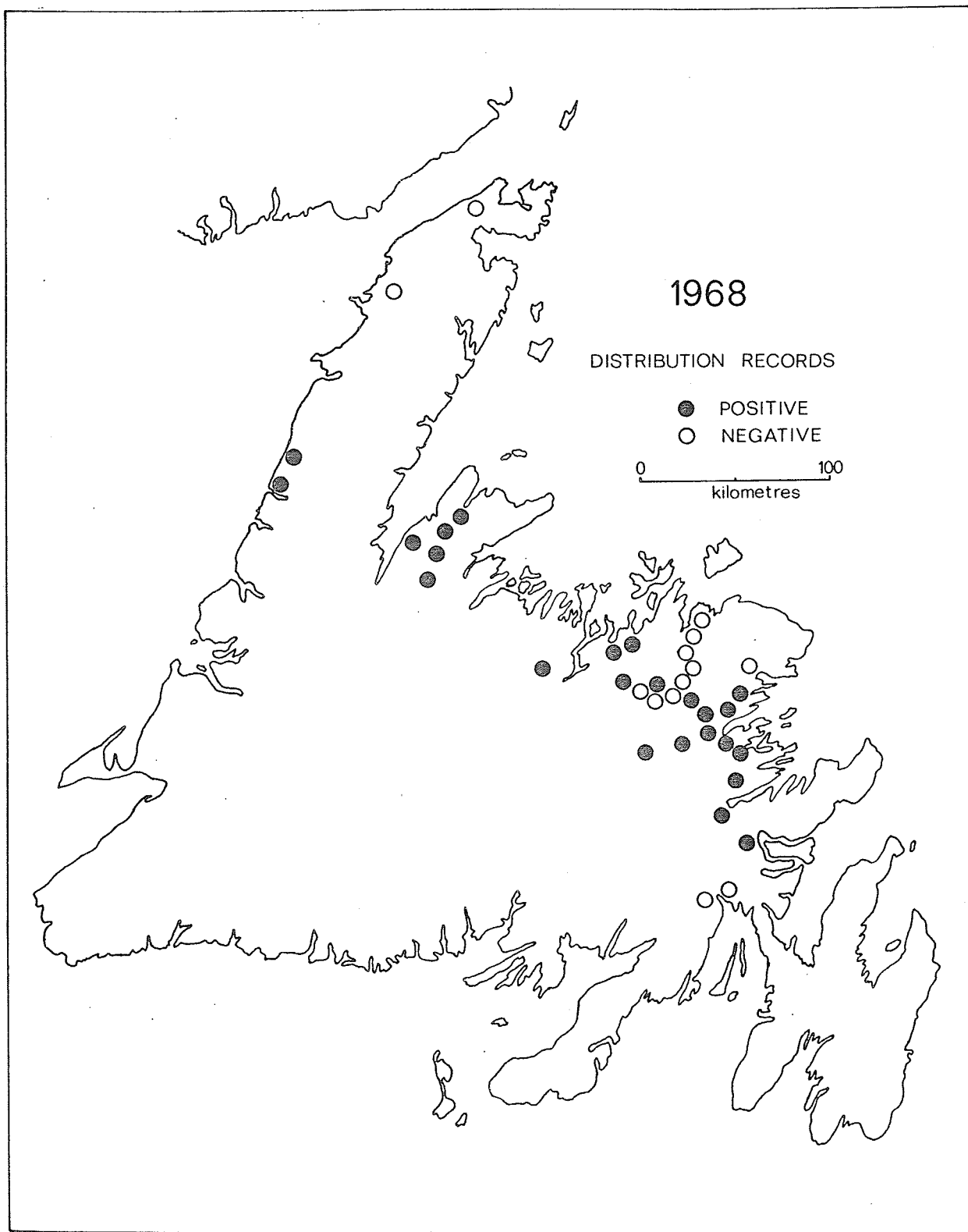


Figure 6. Results of the 1968 dispersal trapping.

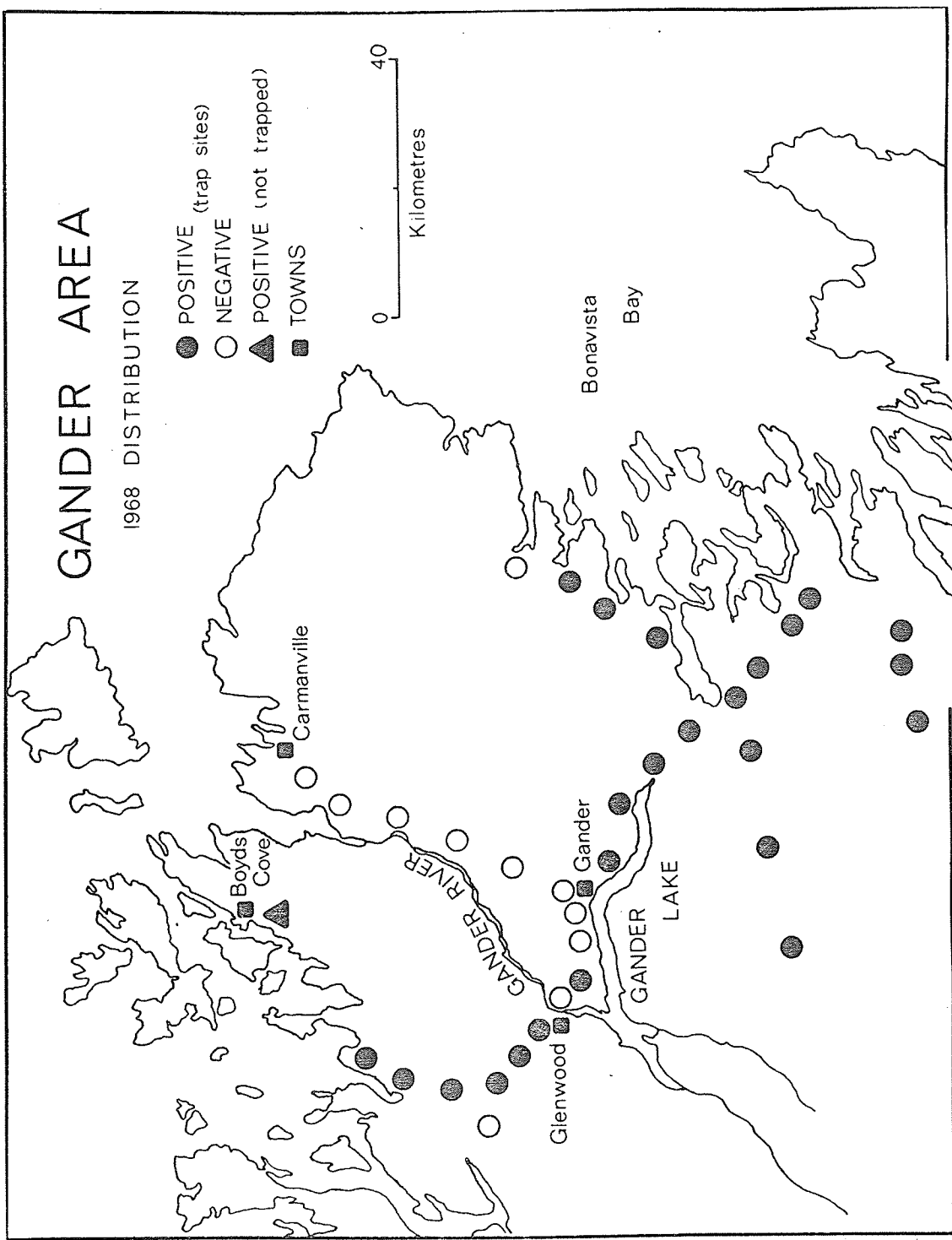


Figure 7. Distribution of *Sorex cinereus* in the Gander area in 1968.

Clareville was the farthest from the release sites that I was able to locate shrews.

I failed to take shrews in a small amount of trapping near Swift Current (sites 47, 48). However, because of the small number of trap days it is possible that shrews were present and not captured. Mr. Philip Patey, a biology graduate student at Memorial University, informed me that residents of Swift Current did not see shrews in 1968, but that shrews were common by 1969. Reports from local residents are usually based on dead shrews left near homes by pet cats, and people readily distinguish a shrew from a mouse or vole, so reports of this nature are generally reliable.

To sum up, by the fall on 1968 shrews were present over most of the island, with the exception of the northern part of the Northern Peninsula, and the area immediately north and west of Gander. I did not trap either the Burin or Avalon Peninsulas, so it is impossible to be certain of the status of shrews there. They were probably not present however, as none were taken at Swift Current, which lies at the base of both peninsulas.

#### Distribution in 1969

In 1969 I retrapped the sites north and west of Gander, opening these traps on 28 July (the traps in these sites had been left in place over the winter). Shrews were taken in all sites by 7 August. The anomaly of distribution had thus disappeared, with shrews being present in all areas north and west of Gander (Figure 8).

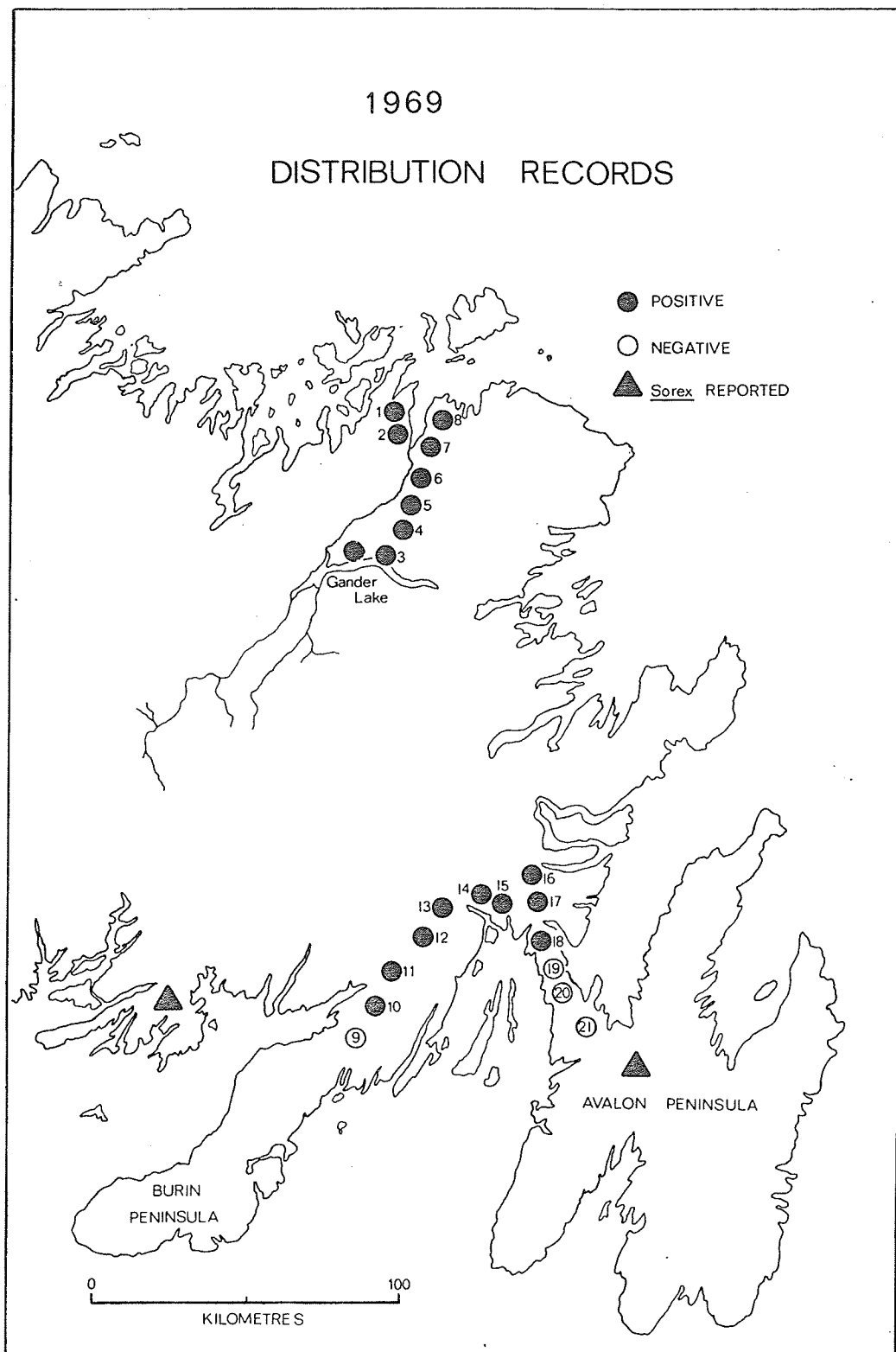


Figure 8. Results of the 1969 dispersal trapping. Note the presence of shrews north of Gander Lake.

A number of sites on the Burin Peninsula also produced shrews (sites 10-14) with only one site (9) being negative. This was the first year that residents of the Swift Current area saw shrews, and in view of the negative results here in 1968, it seems likely that 1969 was the first year *Sorex* was present in any numbers. I also trapped the base of the Avalon Peninsula, and found shrews in the more northerly sites (15-18) while the more southerly sites (19-21) were negative. Shrews were present even farther east; Mr. G. L. Warren of the Canada Department of Fisheries and Forestry, St. John's, informed me his department took shrews as far as Whitbourne on the Avalon. It is possible that the distribution was discontinuous in this area.

Shrews were reported for the first time from south coast towns in the vicinity of Harbour Breton (Anonymous, 1969). Again this is a report of dead *Sorex*, probably killed and abandoned by house cats. Shrews were still absent from the Big Brook area of the Northern Peninsula (Pruitt, pers. comm.).

In summary, by the fall of 1969 shrews were present throughout the main part of the island, and only absent on the northern part of the Northern Peninsula, and possibly absent on the Burin and eastern part of the Avalon Peninsulas.

#### Distribution in 1970

I set traps on five islands in the Lewisporte area during the summer of 1969, but these traps were not visited until June 1970, when C. H. and L. E. Payne kindly checked them for me. At this time shrews were present

on two of the five islands; Mussel Island ( $49^{\circ}16'15''$  N.,  $58^{\circ}1'30''$  W.), and an unnamed island ( $48^{\circ}18'00''$  N.,  $54^{\circ}59'15''$  W.). Both these islands are less than 20 hectares in area, and both are forested. Mussel Island is separated from the mainland by a shallow tickle which is nearly dry at low tide. The unnamed island is separated by a deep, 200-m wide tickle. In all probability both these tickles would become frozen in a severe winter (in 1969-70 Lewisporte Harbour was frozen for three to four months; C. H. Payne, pers. comm.).

Traps set on the other three islands (Birchy, Sivier, Rice) were negative. Birchy Island is separated from the mainland by a moderately shallow tickle which, due to a strong tidal current, seldom freezes. This tickle is about 100 m wide. Sivier Island is about two kilometres off the mainland and less than 200 m from the south shore of Birchy Island. Rice Island is close to shore, and is separated from Mussel Island by very shallow water. It is unusual that shrews were taken on Mussel and not on adjoining Rice Island.

C. H. and L. E. Payne also trapped Pruitt's plots on the Northern Peninsula using the same methods as Pruitt. *Sorex* were taken on these plots for the first time in 1970, although the plots had been trapped regularly since 1965.

Thus by 1970 *S. cinereus* had populated nearly the entire island, with the possible exception of the eastern part of the Avalon Peninsula, and the southern part of the Burin Peninsula. Shrews had also dispersed to at least two islands in Notre Dame Bay.

The exact population boundary cannot be determined from the data, partly because of the rapid expansion of the population, partly because of the difficulty of interpreting negative trapping evidence

and partly because little trapping was done in areas which were definitely beyond the extreme boundary of the population. For these reasons I have made no attempt to draw a boundary on any of the distribution maps.

#### Rate and method of dispersal

The rates of dispersal of mammal populations moving into new areas are not well known. Many introductions occurred in the last century and often animals were introduced into sparsely settled areas. In some cases mammals were introduced independantly at a number of points. This is especially true of such associates of man as rats, mice and domestic animals. As a result there are few published rates of dispersal. De Vos, Manville, and Van Gelder (1956) and Elton (1958) give good reviews of animal introductions.

The dispersal of *S. cinereus* in Newfoundland has been very rapid. By 1967 the maximum known distance of dispersal was 138 km; a rate of 18 km per year. By 1968 the maximum known distance (Exploits Dam to Clarendville) was 201 km (28 km per year) and by 1969 the maximum (Exploits Dam to Whitbourne) was 268 km, a rate of over 33 km per year. The increasing rate may be an artefact of the trapping, indicating that distances were underestimated for the first few years.

This rate of dispersal is roughly comparable to that of other species introduced into new areas. Buckner (1966b) calculated a series of dispersal rates based on data from Elton (1958); these ranged from a low of about four miles (6.4 km) per year for Japanese Beetle in the United States and Canada to a high of 30 miles (48 km) per year for European Spruce Sawfly in Canada. Mohr (1933) reviewed the introduction

of muskrat in Europe and gave a maximum dispersal rate of 50 to 70 km per year (in 1923-24 in Bavaria), and a rate of 30 to 40 km per year in Finland. The average was somewhat less. Buckner (1966b) gave a rate of 10 miles (16 km) per year for the muskrat in Czechoslovakia.

Shrews have a considerable ability to cross topographic barriers such as water. I trapped shrews on two of five islands in Notre Dame Bay, one of which was over 200 m from the nearest mainland. The only possible evidence for a dispersal barrier that I found was in the distribution of shrews in the Gander area in 1968. It appeared as if the Gander River and Gander Lake had acted as a barrier to the expanding population, forcing it to go around the south side of the lake and approach Gander from the east. I should emphasize that this is highly speculative, and that other causes may have been responsible for the apparent absence of shrews between Gander and the Gander River (Figure 7).

Shrews are capable of long distance travel on ice; Nelson (1887) on several occasions saw shrew tracks and tunnels in snow crossing the Yukon River from bank to bank, and once followed a shrew trail for over a mile on the ice. He also reported shrews sometimes wander far out on the sea ice.

*Sorex* swims well, hence dispersal across water may also occur in summer. Cade (1953) reported seeing a shrew (*Sorex vagrans*) swim halfway across the Yukon River near Eagle Alaska. He felt it was possible for a shrew to swim the river at this point, but unfortunately did not give the width of the river. Cade also found that shrews would not hesitate to enter the water if chased. Shrews are commonly found in the stomachs of fish. Teplóv (1943--not seen, cited by Crowcroft, 1957) found about ten per cent of grayling contained small mammal remains



and of 275 individuals identified, 270 were common shrews (*S. araneus*). Hildebrand (1949) and Peterson (1966) also report shrews in the stomachs of fish. There is one report (Anonymous, 1969) of shrews in sea trout in southern Newfoundland.

I discovered in my pitfall trapping that shrews will remain afloat even after they have died of shock or exhaustion. The entire upper body is out of the water, and only the feet, tail, nose and belly are wetted.

I observed swimming on three occasions. Twice, shrews live trapped adjacent to Northern Arm Brook entered the water when released. One swam about a metre out into the stream and returned to shore. The other swam across the brook, a distance of about five metres, and was then captured by hand after a short chase among the rocks. The shrew was completely dry. On the third occasion a shrew was released on a small rock about two metres from shore. The shrew entered the water and with no apparent difficulty swam upstream for about a metre, investigated my boots, and unable to climb up, turned and swam across the current to shore without losing any headway. Johnston (1957) noted that *S. vagrans* swam well and its fur did not get as wet as that of several other small mammals. Crowcroft (1957) reported that shrews swim with the entire body submerged and only the tip of the nose out of the water. My observations agree with those of Johnston. *S. cinereus* swims with its back out of the water, and only the feet, tail, and belly are wetted. The first impression is that the body has not penetrated the surface film, but this is probably not the case. The fur is quite resistant to wetting.

It is impossible to make any definite statements about the method of dispersal. However, several points should be mentioned. A dispersal of over 30 km per year is unlikely to occur solely because of population

pressure. It is probably that some sort of innate dispersal mechanism is involved. Howard (1960) reviewed the phenomenon of innate dispersal, and concluded it was one of the ways in which populations invade new areas.

I found almost no breeding by young-of-the-year. However, breeding by young females can occur. Buckner (1966a) found that most female *S. cinereus* on his plots in Manitoba matured by the time they were four months old. If this occurred in Newfoundland it would be possible to have two or perhaps three generations per year. However, even assuming three generations, shrews from each would have to move a minimum of 11 km before breeding to produce the observed dispersal rate. Two generations is a more realistic figure, and this would mean an individual movement of over 16 km per year.

*S. cinereus* is non-specific in its habitat preferences (Jackson, 1928; Cameron, 1958; Brown, 1967). Most of Newfoundland is suitable shrew habitat and it is unlikely that the dispersal rate was greatly affected by adverse habitat conditions. There are no native insectivores which might compete with the masked shrew. Predators are relatively uncommon. Given these conditions it is possible that the observed rate of dispersal represents a maximum or near maximum for the species.

## HABITAT PREFERENCE

*Sorex cinereus* is the most widely distributed of the North American long-tailed shrews and is found throughout the arctic mainland and south to the southern United States (New Mexico, North Carolina, Tennessee), and from the Atlantic to the Pacific Coasts (Hall and Kelson, 1959).

As well as being widely distributed, *S. cinereus* is catholic in its habitat preferences. Jackson (1928) states it "may be expected in the normal shrew habitat of damp woods, mossy banks of streams, coniferous swamps, and sphagnum bogs; yet there are numerous records of specimens of this species taken in houses and other buildings . . . and of other individuals in dry woods and meadows . . .". Moore (1949) reported that near the southern limit of distribution (Virginia) *S. cinereus* was found in a variety of habitat types, although it was restricted to higher elevations. Cameron (1958) found *S. cinereus* to occur in "a wide variety of habitats ranging from the damp borders of streams to dry upland woods" on Prince Edward Island and that it was "among the most abundant of the small mammals in the areas in which collections were made". Spencer and Pettus (1966) found approximately equal numbers of *S. cinereus* in several different habitats ranging from a marshy meadow to forest. Brown (1967) stated *S. cinereus* was "cosmopolitan in distribution, being represented in all habitats sampled except short-grass prairie".

These observations agree with the results of the habitat line trapping summarized in Table 1. Shrews were taken in all habitats trapped, although not in equal numbers. It is evident that the largest deviations from the

Table 1. Numbers of *Sorex cinereus* captured on the habitat lines for each three-day trapping period.

Habitat line	May		June		July		August		September 9-11	Total	Number/100 trap days	
	26-28	3-5	12-14	26-28	2-4	12-14	26-28	1-3				29-31
1. Alder-maple-willow	0	0	17	4	-	4	-	2	1	5	33	27.5
2. Alder-birch-mountain ash	1	0	14	-	2	-	2	-	4	4	27	22.5
3. Balsam fir forest	-	1	1	1	-	1	-	4	3	2	13	12.4
4. Spruce-fir forest	2	0	0	-	4	-	5	-	4	4	19	18.1
5. Spruce-birch forest	-	-	-	-	1	-	2	-	0	0	3	5.0
6. Fir-spruce-birch forest	3	0	2	1	-	3	-	0	1	0	10	8.3
7. Spruce-ericaceous shrubs	-	0	2	4	-	4	-	1	4	0	15	14.3
8. Spruce forest	-	-	-	-	3	-	3	-	1	2	9	15.0
9. Cutover	0	1	4	-	6	-	0	-	1	2	14	13.3
10. Cutover	5	1	0	3	-	3	-	3	4	5	24	20.0
11. Fen	0	0	0	1	-	0	-	0	0	0	1	0.8
12. Dwarf shrub bog	0	0	0	0	-	3	-	1	-	0	4	3.8

KEY: a dash (-) indicates the line was not trapped during a given trapping period; a zero (0) indicates the line was trapped, but no shrews were caught.

average occur in the alder swamps (Lines 1-2) and the peatlands (Lines 11-12). The alder swamps had the highest population of any habitat sampled; much of this difference was, however, the result of a very high catch for the nights of June 15-18. The reason for this abnormally high catch is not known. The areas with the lowest populations were the bog and fen (Lines 11-12). The fen, which was the wetter of these sites, had slightly lower numbers of shrews.

I tested the data in Table 1 against a null hypothesis of no difference between the numbers of shrews captured in each habitat. The difference was highly significant ( $\chi^2 = 59.9$ ,  $P < 0.01$ ), indicating that shrews were not equally distributed throughout all habitats. It is evident from Table 1 that the greatest part of the  $\chi^2$  value comes from the extreme values for Lines 1, 2, 11, and 12. If these lines are omitted from the calculation there is no significant difference in the utilization of the remaining areas ( $\chi^2 = 11.0$ ,  $P > 0.10$ ).

These data show that *Sorex* has a wide habitat tolerance and that it is found, although in varying numbers, in all major habitat types. The species apparently avoids the wet, boggy areas, and is found in greatest abundance in areas of deciduous shrubs.

There are many possible factors which may affect the local distribution of shrews. Getz (1961), working in southern Michigan, concluded that moisture was the single most important factor, and shrews were restricted to moist sites. Pruitt (1959) found *Blarina brevicauda* was limited to areas with sufficient soil moisture to saturate the air in burrows. The absence of *S. cinereus* in the bog and fen habitats cannot be explained by a lack of soil moisture. Pruitt (1959) has

shown that air in an artificial burrow remained saturated until the available soil moisture dropped to zero, and even for some time afterward. Thus even a small amount of soil moisture is probably sufficient to saturate the air in a small mammal burrow. Both the bog and fen had a very high water table, and free water could be squeezed out of a handful of peat taken from the surface of a dry hummock in both these areas.

Pruitt (1959) found that *B. brevicauda* was restricted to areas where the soil was suitable for underground tunnelling. Both the bog and fen were ideal in this respect, with dry hummocks having natural cavities and tunnels around the roots of shrubs. The high water table in these areas might, however, prevent deep tunneling and dry nest sites might be unavailable.

The soil temperature regime might be more severe in the bog and fen habitat than in the other areas sampled. Pruitt (1959) found that *Blarina* required a stable, moderate temperature, and excessively high or low temperatures appeared to be limiting. However, on this basis I would have expected the cutover areas (Lines 9-10) to have had a low shrew population, as these areas are as exposed as the bog and fen, and lack the stabilizing effect of a high water table. In the absence of microclimate data I can only speculate on the importance of soil temperature, but it would seem that in summer at least, it should not be limiting.

Pruitt (1953) noted that *Blarina* could not inhabit areas where the ground froze hard during the winter. Riewe (1971) found *Microtus pennsylvanicus* on an island in Notre Dame Bay avoided the bogs and meadows during the winter. Open areas in north-central Newfoundland (such as bogs and fens) usually have a shallow or intermittant snow cover, due to the frequent mid-winter thaws. It is possible that during periods of colder

weather the relatively shallow snow cover on the bogs and fens is too thin to allow small mammals to overwinter.

Getz (1961) concluded that food was not a limiting factor for *S. cinereus*. His observations are not necessarily applicable to Newfoundland. Invertebrate populations might be lower in the bog and fen than in the other habitats, or the species present might be less preferred by shrews.

The results of the live trapping also indicate no specific habitat preferences. Figure 9 is an air photo of the plot area showing the general distribution of the habitat types. Figure 10 is a map of the plot showing the vegetation types, 1969 trap locations and captures for 1969 (including kill trapping). There is no obvious restriction to any habitat types; the captures are more or less randomly distributed.

The conifer forest consists of black spruce and balsam fir and occupies the drier portions of the plot. A few birch, poplar, alder and service berry (*Amelanchier*) occur scattered throughout, and other shrubs such as *Ledum*, *Kalmia* and *Rhododendron* are locally common. *Larix* (larch) is common in the strip of conifer forest on the flood plain at the north end of the plot. Feather mosses (*Pleurozium*, *Hylacomium*, *Hypnum*) are common in most areas. Figure 11 shows a typical area of conifer forest.

The alder swamp-poplar forest (Figure 12) includes the wet alder swamps and the somewhat drier alder-poplar forest along the edges of the alder swamps. The transition between alders and conifer forest was sometimes quite abrupt, especially if there was a sharp change in relief. In areas where there was a noticeable intermingling of the alder swamp or poplar forest with the conifer forest, this gradual transition or ecotone is shown in Figure 10 as mixed forest.



Figure 9. An air photo of the Northern Arm Brook plot. The boundary of the plot is indicated by the white line.



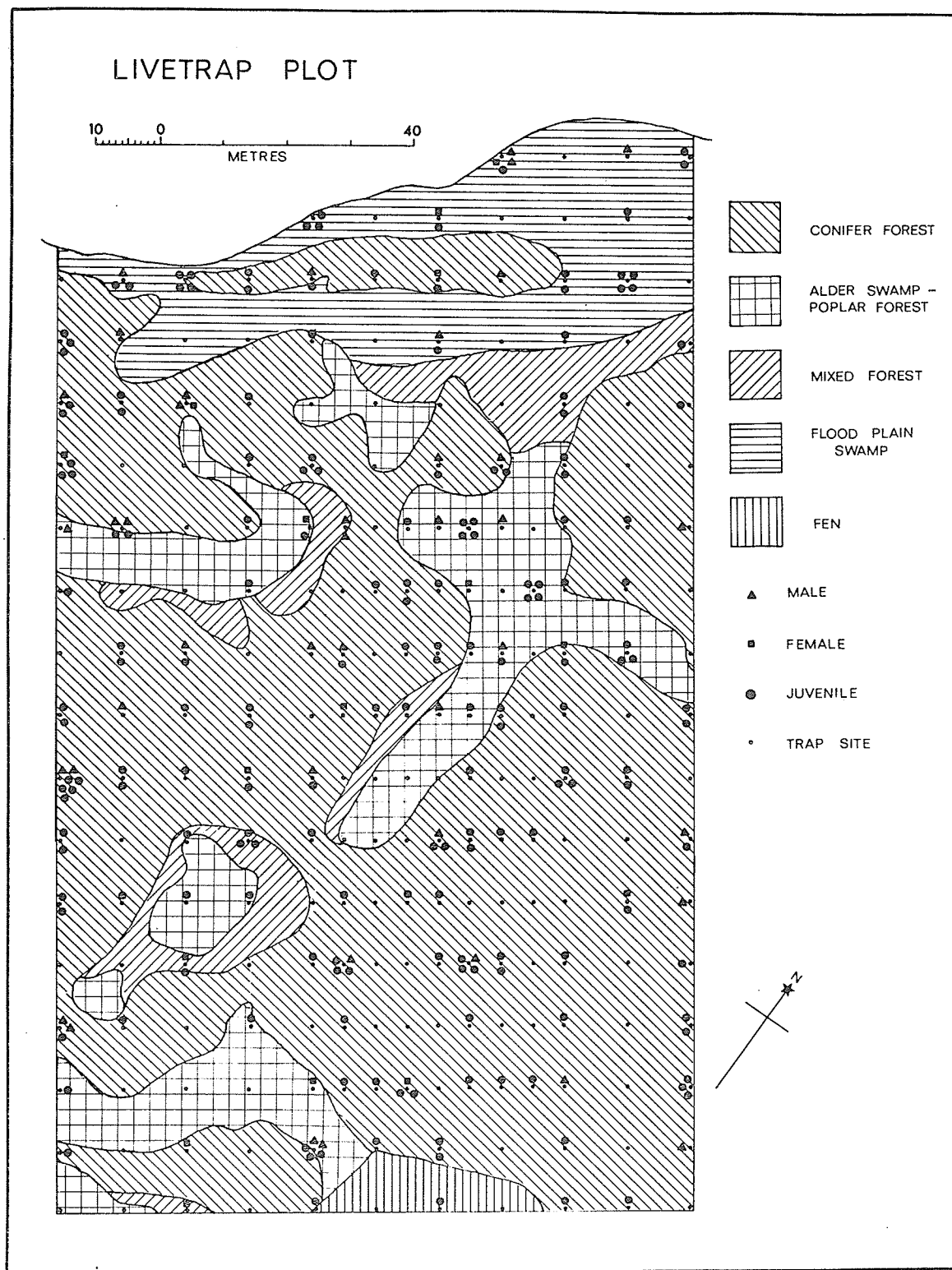


Figure 10. A map of the live trap plot showing vegetation types and all captures of shrews in 1969.

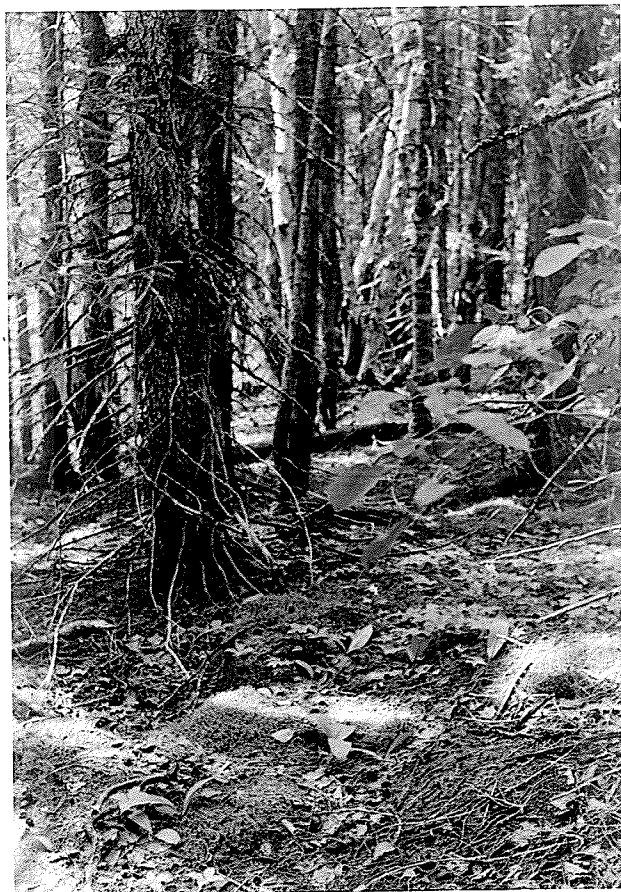


Figure 11. Conifer forest (black spruce-balsam fir) on the Northern Arm Brook plot. The ground cover is mainly *Pleurozium*. Note the alder in the right foreground and the birches in the background.



Figure 12. Two views of an alder swamp on the Northern Arm Brook plot. Left, a general view; right, a close-up of ground cover.

The flood plain swamp (Figure 13) is a flat, low-lying area bordering the brook. It is not a true flood plain, but is less than one metre above the stream level and is partially inundated with standing water when the stream is high. The vegetation is largely alder and sweet gale (*Myrica Gale*) with a few small spruce and larch. Grasses, *Carex*, *Eriophorum*, *Thalictrum*, *Rosa*, *Potentilla fruticosa*, *Aster* and *Solidago* are common and more or less restricted to this habitat.

The fen (Figure 14) is a very small area of *Scirpus* and *Carex* along the borders of a very small stream. Standing water is present throughout the summer.

The activity of shrews with respect to vegetation type is shown in Table 2. There is no significant difference in the numbers of *Sorex* taken in any of the five habitat types represented on the plot ( $\chi^2 = 4.06, P > 0.25$ ). This is similar to the data from the habitat lines where there was no significant difference in the trap success in the forested habitats. The fen on the plot had the lowest average catch of any area, but with only four traps it is impossible to tell if there is a real difference. However, the live trap data does support the conclusions drawn from the habitat lines, that is, shrews are found in all habitats with the exception of the very wet, open bogs and fens.

It is clear that without a detailed study of the response of *Sorex cinereus* to various environmental conditions and factors such as microclimate (soil moisture, temperature, light, radiation), availability of food, nesting sites, vegetation, and cover, it is impossible to pinpoint the reasons for the habitat preferences of the species. Shrews are, however, found in virtually every habitat in Newfoundland



Figure 13. Two views of the flood plain swamp at the north end of the Northern Arm Brook plot. Above, a view toward the stream from the east side of the plot; below, a view northeast from the west side of the plot.



Figure 14. The fen at the south end of the Northern Arm Brook plot. The scale in the left foreground is divided into 5-cm sections.

Table 2. Activity of *S. cinereus* on the Northern Arm Brook plot in 1969 grouped according to vegetation type.

Vegetation type	Number of traps	Number of shrews captured	Number captured per 100 traps
Conifer forest	150	176	117
Alder swamp-poplar	39	36	92
Mixed forest	12	12	100
Flood plain swamp	22	29	132
Fen	4	2	50

and it is unlikely that habitat restrictions have seriously limited the rate of dispersal.



## MARK-RECAPTURE STUDY

I trapped the live trap plot for 16 nights between 5 August and 2 September 1968, and for 32 nights between 24 May and 30 August 1969. The results are summarized in Table 3.

The majority of shrews were taken only one time, and no individual was captured more than four times. Mortality in the traps was low, (six individuals, 2.5% of the shrews successfully marked) and probably was not a factor in the low recapture rate.

There was a difference in the movements of adult and juvenile shrews. The average distance between successive captures of juveniles (28 measurements) was 30 m, the average for adult males (16 measurements) was 52 m, and the average for adult females (6 measurements) was 55 m. The maximum observed range length for an adult male, and adult female, and a juvenile were 115 m, 100 m, and 71 m respectively<sup>1</sup>.

Only four individuals were captured in both summers. Three were caught once in 1968, and one, two, and three times respectively in 1969. One was taken twice in 1968 and once in 1969. The average distance from the last 1968 capture to the first 1969 capture was 39 m. All were

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<sup>1</sup>Observed range length is the distance between the most widely separated capture sites for any individual (Stickel, 1954).

Table 3. Mark-recapture of *Sorex cinereus* in 1968 and 1969.

Number of captures per individual		Number of individuals captured	Distance moved between successive captures (metres) range	Distance moved between successive captures average*	Longest observed range length† (metres)
1968		51	-	-	-
1					
2		10	7-58	28	58
3		3	14-100	51	100
4		2	11-83	47	96
1969		147	-	-	-
1					
2		19	5-95	34	95
3		5	23-70	50	115

\*Average distance between successive captures of all individuals.

†Distance between the most widely separated captures of a single individual.

sexually immature (young) in 1968, and sexually mature (three males, one female) in 1969. These results are in general agreement with those of other workers. Shillito (1963) found that the range of male *Sorex araneus* was greater than that of females, and that adults (sexually mature shrews) ranged farther than juveniles. Adult males ranged up to 144 m, adult females up to 112 m, and juveniles up to 54 m. Michielsen (1966) obtained similar results with *S. araneus* and *S. minutus*. Ingles (1961) found a range length of from 5 to 78 m for *S. vagrans*.

Some authors (Buckner, 1957, 1966a; Ingles, 1961; Shillito, 1963; Michielsen, 1966) have found shrews to have a definite home range, or even to be territorial. I was unable to detect territorial behavior or even much evidence of a home range. It is possible that shrews in Newfoundland do not have home ranges, but this would be contrary to most of the records in the literature. It is more likely that the shrews learned to avoid the traps. Taber and Cowan (1969) reported that shrews learn to avoid pitfall type traps after an initial capture. The use of bait as suggested by Michielsen (1966) would probably have improved trapping results.

The dispersal of the population in Newfoundland has been rapid, and the rate would suggest some sort of innate dispersal mechanism. It is possible that some of the shrews taken were in the process of dispersal and so were never recaptured. Such dispersal is, however, usually limited to juveniles (Howard, 1960) and could not explain the failure to recapture adults.

## REPRODUCTION

Males

All overwintered or old males become sexually mature in the early spring, and sexual maturity in young-of-the-year males is very rare. Brambell (1935) found all old males of *S. araneus* to be sexually active by April, and that young males did not achieve sexual maturity in the summer of their birth. Pucek (1960) concluded that sexual maturity in young males shrews was theoretically possible (in *S. araneus*, *S. minutus*). He did find some young males with enlarged testes, but none of these were producing sperm. Other workers who have obtained similar results (all old males reproductively active, all young males inactive) include Pearson (1945), Conaway (1952) and Clothier (1955).

All overwintered males examined during this study (102 individuals) had enlarged testes and accessory reproductive organs (seminal vesicles, prostate glands), and all were considered to be reproductively active. I did not take epididymal smears or do any histological examination of the reproductive organs. Brambell (1935) has shown that testis size is correlated with the presence of sperm, so enlargement of the testes and other reproductive organs is a good indication of reproductive activity.

The earliest date I collected specimens was 28 April 1969, and even at this time all old males showed signs of reproductive activity. No regression of the reproductive organs was apparent by 11 September,

the latest that old males were collected.

There is evidence that some males become sexually active in their first year of life. Rood (1965) reported several examples of apparent sexual activity in young male Scilly Shrews (*Crocidura suaveolens*). Buckner (1966a) found breeding by young *S. cinereus* but he failed to specify if he found such activity in both males and females.

I collected one young males *S. cinereus* which showed signs of reproductive activity. This specimen, collected near Gambo in August 1968, had testes measuring 4x3 mm and enlarged seminal vesicles. The femur was of young size, 5.59 mm long. Cranial measurements could not be made as the skull was distorted by preservation in alcohol. This specimen was the only example of reproductive activity in a young-of-the-year male. All other young males had testes less than 1.5 mm in length, and showed no enlargement of accessory reproductive organs.

#### Females

The onset of sexual activity in females is typically later than it is in males. Brambell (1935) found that female *S. araneus* became sexually active a month to six weeks later than the males; Conaway (1952) found about the same delay in *S. palustris*.

I obtained similar results, with a number of reproductively inactive females being taken in early May, although by this time all old males were sexually active. By the first week of June all old females were sexually active. Figure 15 shows the reproductive activity in 1969. The first pregnant female was taken 7 May, the first lactating female on 29 May and the first juvenile on 16 June. Assuming a synchronous

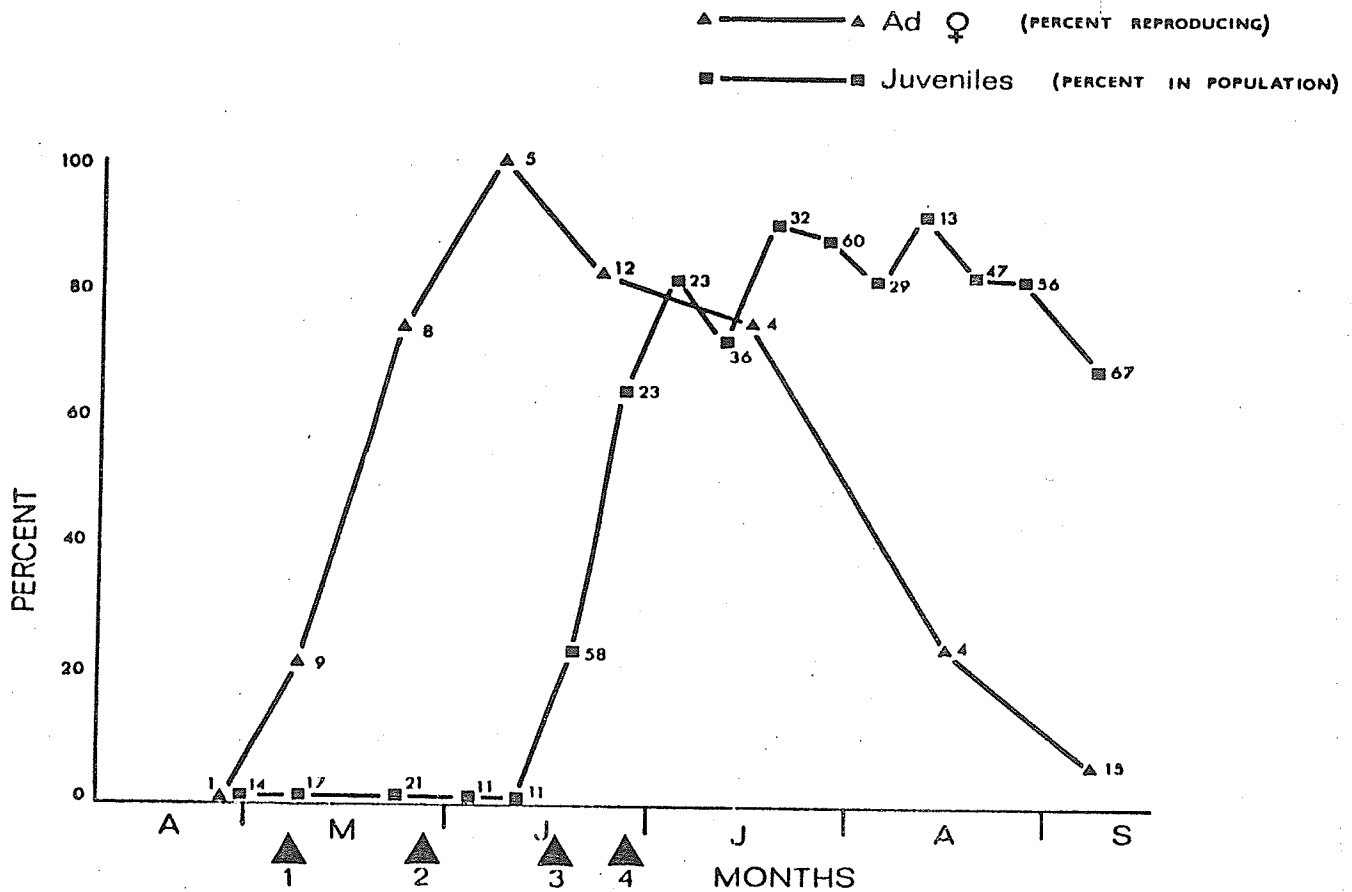


Figure 15. Reproductive activity of adult females and per cent of juveniles in the population at Northern Arm Brook (1969). The curve for females shows the per cent of adult females actively reproducing (either pregnant or lactating); the curve for juveniles is expressed as the per cent of juveniles in the total population. Numbers beside points on the curves are the sample sizes. The large triangles indicate the dates of the following events: 1, first pregnancy; 2, first lactating female; 3, first appearance of juveniles; 4, last pregnancy.

onset of breeding, these dates give a very rough indication of the gestation and lactation periods. Twenty-two days elapsed between the first pregnancy and the first lactation and 18 days between the first lactation and the first appearance of juveniles.

Unlike the situation in males, where sexually maturity in the first summer of life is very rare, females sometimes mature at an early age (Pearson, 1945; Conaway, 1952; Pucek, 1960; Rood, 1965; Buckner, 1966a).

I collected only one young female which was sexually mature. This specimen, taken in early July, had prominent nipples and large, apparently functional mammae. It was definitely young (tooth wear class 2) and had juvenile body size (femur length 6.19 mm). Unfortunately the skull was damaged so cranial measurements were not possible.

*Sorex* which mature in the first year of life apparently do not show the growth spurt associated with the spring onset of breeding (Pucek, 1960). This growth spurt is well documented and has been observed by a number of workers (Brambell, 1935; Conaway, 1952; Crowcroft, 1957; Hyvärinen, 1969). Both the mature young shrews I collected had juvenile body size, and the femur, which is a very good indication of size, was within the range of young animals. This indicates that the growth spurt had not occurred.

There are a number of records of fall breeding in various species of *Sorex* (Jackson, 1928; Moore, 1949; Rudd, 1955; Short, 1961; Buckner, 1966a). I collected a lactating female as late as the second week of September, which is by no means unusual. Breeding does, however, decline sharply after the middle of July (Figure 15).

The average number of embryos, based on nine pregnant individuals,

was 7.88, ranging from six to nine. The number was remarkably constant; five of the nine specimens had eight embryos.

A post-partum oestrus and pregnancy are apparently normal in some species of *Sorex*, for example *S. araneus* and *S. minutus* (Brambell, 1935; Brambell and Hall, 1936). Conaway (1952) found that *S. palustris* apparently underwent a post-partum ovulation, although a successful pregnancy did not necessarily follow, perhaps due to resorption of the embryos. I found only one possible example of a post-partum oestrus in the nine pregnant individuals collected. One of these specimens was lactating and pregnant (eight embryos, 3-mm long).

There is a rapid initial increase in the proportion of young animals in the population, but by the middle of July the ratio is relatively stable (Figure 15). This coincides with the decline in reproductive activity of the females. The breeding season is about three months, although a few individuals continue to breed until September.



## AGE DETERMINATION AND POPULATION AGE STRUCTURE

It was important to determine the ages of the shrews captured during this study, and to be able to separate accurately young-of-the-year from old, overwintered animals, because of the rather unusual life history of the masked shrew. Virtually the entire breeding population is made up of old animals, and young-of-the-year rarely breed (See Reproduction, pp. 55-59). In the following discussion "old" refers to overwintered animals, and "young" to young-of-the-year. Several criteria were used to separate these age classes.

A number of workers (Brambell, 1935; Conaway, 1952; Pruitt, 1954a) have noted the difference in size and weight of young versus old shrews. Old animals are generally larger, heavier and more robust than young ones. This is the result of a growth spurt in the spring coinciding with the onset of sexual maturity (Conaway, 1952; Pucek, 1960; Hyvärinen, 1969). However, there is evidence to suggest that the growth spurt is not a result of sexual maturity, but is only coincident with it. That is, a young shrew may become sexually active in the first summer of life, but retain juvenile dimensions until the following spring, when it shows a normal growth spurt coinciding with the onset of the breeding season (Pucek, 1960). I found this was apparently the case in the two young sexually mature shrews I collected. Both were of juvenile size.

All overwintered animals matured by early spring, and virtually all young animals remained immature. Thus all shrews fall into one of two categories which are easily distinguished from one another--large,

sexually mature, overwintered adults, or small, sexually immature (with rare exceptions), young-of-the-year.

Tooth wear is another character useful for aging live shrews. A detailed examination of the teeth is, of course, impossible, but the amount of wear can be judged roughly by the amount of red pigment on the anterior teeth. With experience it is easy to separate old and young animals in this manner.

Hamilton (1940) used the appearance of the tail to aid in distinguishing young from old shrews. Old shrews had less hair, especially at the tip of the tail, and often had scars on the tail. This character was found to be unreliable for *S. cinereus*, especially females, and was used only as a double check of other aging criteria.

The colour of the feet is a fairly reliable indicator of age. In young *S. cinereus* the feet, particularly the dorsal surfaces, are quite dark greyish brown. This contrasts with the pale pinkish or whitish feet of old shrews.

Table 4 presents these age criteria in summarized form, listed from the most to the least reliable. All live shrews were aged using these characters.

The relative ages of study specimens can be determined more accurately. Tooth wear is probably the best means of determining relative age. Rudd (1955) and Pearson (1945) described tooth wear progression in two species of soricids. Conaway (1952) described a method of measuring teeth to determine tooth wear. He also concluded that tooth wear was relatively constant throughout the life of the animal.

As previously mentioned, specimens were compared against a standard tooth wear series and assigned a number from 1 to 12 depending on the

Table 4. Age determination in live *Sorex cinereus*.

Age criteria	Age		Remarks
	Young	Old	
Tooth wear	unworn to slightly worn	moderately to heavily worn	easily observed, very reliable
Size and maturity	small, immature	large, sexually mature	easily observed, reliable
Foot colour	dark, brownish	pale, pinkish	fairly easy to see, probably reliable
Tail	hairy, unscarred	hairless, scarred	not reliable; but a useful double check

degree of wear. Only the upper tooth rows were used in the age determination. I made no attempt to correlate tooth wear with absolute age due to a lack of known-age specimens and to having only a partial wear series. As I was unable to trap any *Sorex* in the winter there was a gap in the series which probably represented specimens from five to eight months in age. Rudd (1955) with a complete wear series, was able to assign absolute ages to his specimens with a probable accuracy within one month. I found it difficult to correlate accurately my wear series with Rudd's, although I have indicated my interpretation of Rudd's age classes with the following tooth wear description. This description is not complete, but is rather a "key" by which the various wear classes may be distinguished from one another. Some cusps are better indicators of age than others, showing characteristic patterns which change rapidly with age. Probably the best indicators of age are the protocones of M1, M2, and M3. Other useful indicators are the parastyle of Pm3 and the W-shaped ridges of the first and second molars.

The terminology for the following description is that of Jackson (1928).

#### Tooth wear description

Class 1. No visible tooth wear. (1-)<sup>1</sup>

Class 2. Wear visible on protocones of Pm3, M1, M2, M3; slight wear visible on parastyle of Pm3, no wear on metacone of Pm3, slight wear on posterior half of metacone-metastyle ridge of Pm3; other cusps usually without visible wear. (1-, 1).

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<sup>1</sup>Numbers in parentheses are the approximate age class(es) of Rudd (1955) to which the wear pattern corresponds.

Class 3. Wear easily visible as a linear groove on protocones of molars; parastyle and metacone of Pm3 blunted, but wear not progressing posteriorly along parastyle-metacone ridge, metacone-metastyle ridge worn along its entire length, pigment slightly divided at tip of metacone of Pm3; a narrow line of wear on ridges of molars; slight wear on posterior surfaces of unicuspid. (1, 1+).

Class 4. Wear on protocones similar to Class 3, a linear groove immediately adjacent to the pigmented cusp; parastyle of Pm3 blunt, with wear progressing posteriorly along parastyle-metacone ridge, not yet reaching the anterior ridge of the metacone; ridges of molariform teeth worn slightly down the labial side of the cusps. (1+).

Class 5. Wear on the protocones similar to Class 4, but a wider, somewhat triangular groove, the pigmented cusp still projecting above the level of the inner non-pigmented area; parastyle-metacone ridge of Pm3 worn posteriorly to the anterior ridge of the metacone, but not progressing up the anterior side; wear on ridges now continuous except for part of the anterior face of the metacone of Pm3; wear on unicuspid generally reaching the pigmented tip, resulting in a notched appearance. (2-).

Class 6. Wear on protocones a wide, triangular groove, with pigment sometimes lacking on the anterior side of protocone of M2 and M3; wear progressing up the anterior face of metacone of Pm3; wear on ridges of molars a wide, slightly hollowed groove, pigment may be divided at the mesostyle of M2 and M3. (2).

Class 7. Wear on protocones a wide, triangular groove, sometimes with the cusp worn level with the non-pigmented portion of the teeth, giving a flat, shelf-like appearance, especially on M1 and M2; pigment worn from anterior edge of cusp of protocones of molars; parastyle of

Pm3 worn nearly to base level of pigment, resulting in a tear-drop shaped wear surface in ventral view, wear progressing about halfway up the anterior face of metacone of Pm3; wear on ridges heavy, showing a definite groove, wear reaching base level of pigment on mesostyles of M2 and M3, but otherwise pigment on the molar ridges is continuous. (2+).

Class 8. Similar to Class 7, but wear on protocones of M1 and M2 below the level of the surrounding area (so that the cusp is lower than the inner portion of the protocone), with a narrow linear groove next to the pigmented cusp; wear on the anterior face of the metacone of Pm3 reaching of nearly reaching tip; pigment on ridges of M2 and M3 divided at the mesostyle; metacone and protocone of of M3 still with some pigment. (3-).

Class 9. Wear on protocones of molars below surrounding level as in Class 8, but with wear pattern on M1 usually a triangular groove; wear on the anterior face of metacone of Pm3 reaching tip, but a very narrow line at the tip; ridges of molars worn to a wide, continuous groove; metacone and protocone of M3 usually lacking pigment. (3).

Class 10. Wear on protocones of both M1 and M2 a distinctly triangular groove, with the lingual side lower than the labial side; parastyle-metacone-metastyle ridge of Pm3 worn to a continuous groove; protocone of Pm3 may lack pigment. (3+).

Class 11. Protocones of M1 and M2 heavily worn, lingual side of triangular groove lower than labial side, pigment worn off except for the extreme posterior portion of the cusps; ridges of M2 and M3 may lack pigment; M3 worn to a flat, slightly hollowed surface; wear sometimes progressing over tips onto anterior surfaces of unicuspid. (4-).

Class 12. Very heavily worn, little or no pigment on molariform teeth;

wear may be continuous in a line from parastyle to protocone of PM3 along anterior edge of tooth; M3 hollowed, pigmentless; wear progressing over tips onto anterior surfaces of unicuspid; this class is distinguished from Class 11 primarily by the degree of wear and the nearly complete absence of pigment. (4-,4).

Table 5 shows tooth wear classes with the date of capture. Note the complete separation of young and old specimens. There is a slight increase in the average wear of both young and old animals throughout the summer, but this is less than might be expected. Several factors are acting to obscure the increase in individual tooth wear which must occur.

Firstly, there is probably individual variation in the rate of tooth wear. Without a series of known-age specimens it is impossible to estimate the importance of this factor. Secondly, while breeding is concentrated in May and June, some young are born much later in the summer. For example, a lactating female was taken 14 September at Northern Arm Brook and a young juvenile with unworn teeth (Class 1) was captured 26 October at Glovertown. Thus shrews taken at any given time may vary considerably in age, perhaps as much as four months. Thirdly, there may be differential mortality of the older age classes, especially old adults, tending to remove old animals from the population, and so keep the average tooth wear from increasing. These factors make it difficult to use tooth wear as a means of estimating the absolute age of a shrew. The clear separation of young and old does, however, allow the accurate determination of year classes.

I caught no old specimens after the middle of September and found

Table 5. Tooth wear of *S. cinereus* in Newfoundland grouped by date of capture (by weeks).

Tooth wear class	Date of capture (by weeks)																	
	April			May			June			July			August			September		
1	4	1	2	3	4	1	2	3	4	1	1	1	2	3	4	1	1	2
2							4			10	2	6	10	11	14	2	10	2
3							10	2	2	3	3	5				2	4	5
4												1				2	3	5
5																		1
6										1								
7										1	1	1						
8													3	5	3	2	1	5
9													2	6	2	9	2	1
10													4	1	1	2	2	1
11																2	1	1
12																1		

Monthly average

Juv/Ads      -/8.62      -/8.85      2.08/9.14      2.17/8.90      2.88/10.35      2.93/10.43



no evidence of survival through a second winter. This observation is supported by a number of authors (Rudd, 1955; Conaway, 1952; Clothier, 1955; Michielsen, 1966). Brambell (1935) reported a parous female in March, presumably an overwintered adult which had lived through a second winter. However, Brambell classified his shrews as adult on the basis of sexual maturity alone, and it is well known that *S. araneus* can breed in the first year of life (Pucek, 1960). Thus there is a possibility that this adult female was, in fact, a juvenile which had bred the previous summer, and was less than a year old. Pearson (1945) pointed out this source of error in Brambell's (1935) data. Pearson also reported two specimens of *Blarina brevicauda* which survived two winters. The smaller shrews rarely if ever survive through two winters; Buckner (1966a) reported one *S. cinereus* which survived 23 months, but this is exceptional.

The data in Table 5 cannot be used to make an estimate of the age ratios in the population as the specimens were selected to some degree, especially in favour of adults. As well, there is no assurance that each tooth wear class corresponds to the same time interval. This is certainly true for Class 1, which occurs very infrequently. This is due to the fact that once a shrew leaves the nest and is liable to be caught, its teeth also start to wear. Wear may become visible a very short time after weaning resulting in the scarcity of specimens with unworn teeth.

Table 6 shows the age and sex ratios for shrews in the Northern Arm Brook area in 1969. The data are limited to 1969 because this is the only year for which I have a large series of accurately aged and sexed specimens.

Table 6. Age and sex ratios of *Sorex cinereus* from the Northern Arm Brook area in 1969, expressed as a per cent of the total population.

Dates	Adults			Immatures			Sample size
	M	F	total	M	F	? total	
28 April-15 May	56.5	43.5	100	-	-	-	23
16-31 May	71.4	28.6	100	-	-	-	21
1-15 June	77.3	22.7	100	-	-	-	22
16-30 June	50.6	14.8	65.4	19.8	11.1	3.7	81
1-15 July	20.3	1.7	22.0	28.8	22.0	27.1	59
16-31 July	7.6	3.3	10.9	5.4	5.4	78.3	92
1-15 August	9.5	4.8	14.3	21.4	26.2	38.1	42
16-31 August	15.5	1.9	17.4	11.7	17.5	53.4	103
1-15 September	9.0	22.4	31.4	31.3	35.8	1.5	67
Total numbers	131	56	187	80	80	163	510
						323	

First consider the sex ratio among the adult (overwintered) specimens. In the early spring males and females are about equally represented in the samples, with a slight excess of males. As the summer progresses, however, there is a decline in the numbers of adult females. This decline continues until August, coinciding with the breeding season. It is possible that during this time males are more active and wide ranging than females, and thus have a greater probability of encountering a trap. Michielsen (1966) found this to occur in *S. araneus* and *S. minutus*. The only month when the ratio was in favour of females was September. By this time reproductive activity had all but ceased (Figure 15). It is also possible that males, due to higher activity or some other factor, are more vulnerable to predation or death through other causes and so are removed from the population. This would cause an apparent increase in the ratio of old females in the late summer.

The sex ratios for juveniles remained nearly constant throughout the summer. Over the entire period the ratio was exactly equal. The large numbers of unsexed shrews shown in Table 6 are the result of using live trap data, where juveniles could not be sexed. All dead specimens were carefully sexed and the sex ratios for juveniles are therefore unbiased.

The ratio of adults to immatures had stabilized by early July. This was the result of a decline in reproduction (Figure 15). There appears to be a slight increase in the numbers of adults in the fall, with the ratio of juveniles dropping from a high of 89 per cent in July to 68 per cent in September. This is not the result of juveniles attaining sexual maturity; a careful examination of teeth showed all sexually mature specimens were overwintered individuals. The increase in adults is due mainly to a large number of adult females, and may be the result of increased activity in females at the end of the breeding season.

There are conflicting reports of sex ratios in shrews. Brambell (1935), in over a thousand specimens, found a ratio of 54 per cent males. Rudd (1955) found about the same ratio for *Sorex vagrans*. Conaway (1952) and Clothier (1955) also found nearly equal sex ratios in shrews. Middleton (1931) found about 61 per cent males in *S. araneus*, and the ratio was higher in older animals. Rood (1955) found a ratio of 1.3 males to 1.0 females in *Crocidura sauveolens*. Pruitt (1954b) discusses the causes of the disproportionate sex ratio in *Blarina brevicauda*, where males outnumber females about two to one. Pruitt considered this to be due to males invading sub-optimum habitats, while females remain in the better areas. Small mammal collectors trap in a variety of habitats, and so their collections contain more males than females. In optimum habitats (virgin forest) Pruitt found the sex ratio was about two females to each male. Howard (1960) also found males tended to disperse more than females; about 63 per cent of rodents caught along a drift fence were males. This tendency of males to move into marginal habitats and to disperse more readily than females could partly explain the apparent abundance of males. My results show a sex ratio of over 70 per cent males for the adult age class.

I found an apparent correlation of the breeding season and the sex ratios of adults. I would speculate that at least two factors contributed to the greater numbers of males: greater activity and range of males, correlated with the onset of the breeding season (similar to the results of Shillito, 1961; Michielsen, 1966), and decreased activity of females as a result of remaining closer to a nest site during pregnancy and care of the young. There is some evidence for this in the increase in adult females at the end of the breeding season.

## WEIGHTS AND MEASUREMENTS

Body size of Newfoundland *Sorex cinereus*

Age differences in the body size of shrews are well known (Brambell, 1935; Conaway, 1952, Clough, 1963) with adults being larger than young animals. Sexual differences in the body size of adults occasionally occur (Conaway, 1952; Rudd, 1955).

Measurements of a large series of Newfoundland specimens showed that there were marked differences in the size of adults and juveniles. These differences are shown in a number of measurements, including total length (Figure 16) and femur length (Figure 17). The larger size of adults is probably due to a growth spurt in the spring following the animals birth (Conaway, 1952; Pucek, 1960). Hyvärinen (1969) describes the physiology of this growth spurt.

In *S. cinereus* there is no overlap in the lengths of adult and juvenile femurs (Figure 17), and femur length is thus an excellent age criterion. Pruitt (1966) found femur lengths of a microtine rodent, *Microtus oeconomus*, to be closely correlated with age. Although I have no winter data, I would speculate that the increase in femur length occurs during the spring growth spurt. This period of growth is two to three weeks in duration (Pucek, 1960). Evidence suggests that shrews which mature sexually in their first summer do not undergo a simultaneous growth spurt; the two sexually mature young shrews taken in this study were both in the juvenile size range (femur length 5.59 mm, 6.19 mm). This observation is in agreement with those of Pucek (1960).

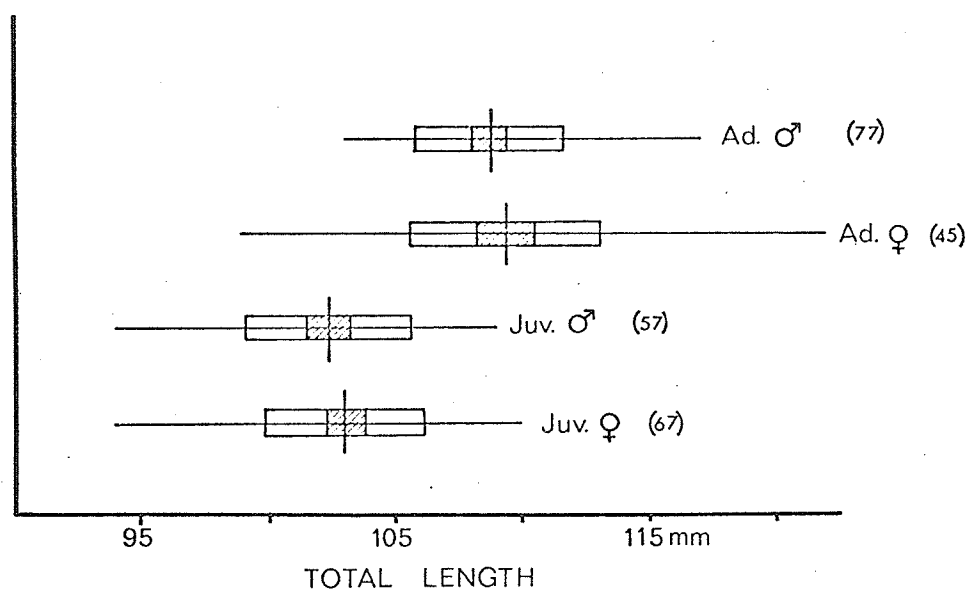


Figure 16. Total length of Newfoundland *Sorex cinereus*. The horizontal lines indicate the range of the sample; the vertical lines indicate the sample mean. The hollow rectangles outline one standard deviation on each side of the mean; the shaded rectangles indicate two standard errors of the mean on each side of the mean. Figures in parentheses are the sample sizes.

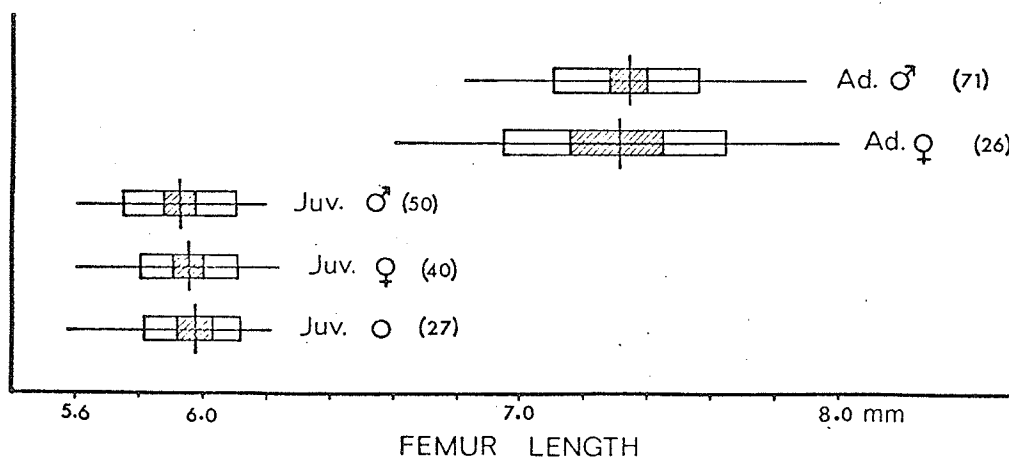


Figure 17. Femur length of Newfoundland *Sorex cinereus*. See Figure 16 for an explanation of symbols. The class "Juv. O" includes all juveniles of unknown or doubtful sex.

Table 7 gives the mean and range of body weight for various sex and age classes throughout the summer. It is probable that there is some loss of weight in the pitfall traps and the weights are not identical to those of live shrews. The weight differences between adults and juveniles are marked and there is no overlap of weights before September. Conaway (1952) and Clough (1963) both noted similar weight differences between adult and immature *Sorex*.

Adult males appear to be slightly heavier than non-reproducing adult females, but pregnant or lactating females average heavier than males.

There is a decline in the weights of adults in the fall, and a slight increase in the weights of juveniles, resulting in an overlap of weights for the first time.

#### Cranial measurements of Newfoundland *Sorex cinereus*

The following data are based on a series of cranial measurements taken on a large number of skulls. The data for each measurement are separated into five classes, adult (old) males, adult (old) females, juvenile (young) males, juvenile females, and juveniles of unknown or doubtful sex. All adults included in these data were carefully sexed.

In the following comparisons most data have been subjected to a *t*-test. The levels of significance are indicated as follows: "significant" means significant at the five per cent level; "highly significant" means significant at the one per cent level or better. Some data were compared graphically using the method of Hubbs and Perlmutter (1942) and in these cases the words "apparently significant" or "apparently not significant" are used. Graphical comparison involves determining the degree of overlap of the shaded rectangles indicating two standard errors of the mean

Table 7. Weights in grams of *Sorex cinereus* in the Northern Arm Brook area in the summer of 1969.

Months	Sex and age classes	Weight range	Mean weight	Standard deviation	Sample size
April	Ad. male	4.1-6.4	4.92	1.00	5
	Ad. female (N)*	3.1-4.3	3.70	0.85	2
May	Ad. male	4.3-5.6	4.95	0.40	22
	Ad. female (N)	3.1-4.3	3.72	0.47	7
	Ad. female (R)†	4.2-8.0	6.19	1.20	7
June	Ad. male	4.0-5.7	4.98	0.42	39
	Ad. female (N)	-	5.0	-	1
	Ad. female (R)	4.2-6.8	5.69	0.88	9
	Im. male	2.5-3.8	3.21	0.30	26
July	Im. female	2.7-3.8	3.20	0.29	12
	Ad. male	4.3-5.1	4.83	0.25	9
	Ad. female (R)	-	4.6	-	1
	Im. male	2.6-3.9	3.31	0.34	21
	Im. female	2.5-3.9	3.27	0.34	22
August	Ad. male	4.2-5.7	4.81	0.47	8
	Ad. female (N)	4.3-5.8	4.97	0.76	3
	Im. male	2.4-3.7	3.03	0.36	19
September	Im. female	2.5-3.8	3.20	0.32	31
	Ad. male	3.6-5.3	4.38	0.65	6
	Ad. female (N)	3.2-4.9	3.84	0.51	14
	Ad. female (R)	-	4.4	-	1
	Im. male	2.7-4.4	3.48	0.50	19
	Im. female	2.4-4.0	3.06	0.43	23

\* (N) indicates non-reproducing females

† (R) indicates reproducing females (either pregnant or lactating)



(see Figure 16 for symbols); when the standard errors do not overlap the means are usually significantly different.

Some measurements showed no age or sex differences. These were condylobasal length (Figure 18), maxillary and mandibular tooth row length (Figures 19, 20). It is interesting that there is no change in the condylobasal length with age. There are obvious changes in the shape and size of the cranium associated with age, but this apparently does not affect the length of the skull. Pruitt (1954a) found a difference in the condylobasal length of young and old *S. cinereus* in Michigan. Findley (1955) also noted that old shrews (*S. vagrans*) had shorter skulls than young shrews. Clothier (1955) found no difference in the condylobasal length of young and old *S. vagrans*. Dehnel (1949) found the condylobasal lengths of young and old *S. araneus* were similar.

As might be expected, there is no change in the length of the tooth rows with age. Shrews have a fully developed set of permanent teeth at weaning and it would seem logical that the length of the tooth row would remain constant throughout life. The end points for this measurement are on tooth surfaces which do not wear so this would not affect the measurement.

As previously mentioned, there is a change in the shape of the cranium with age. This has been well documented by other authors (Jackson, 1928; Pruitt, 1954a; Pucek, 1963). These changes (associated with other physical and physiological changes such as reduction in weight, reduction in brain size, changes in the activity of endocrine organs) are apparently an adaptation to reduce the food requirements of the shrew during the winter period; this phenomenon is known as Dehnel's Phenomenon (Mezhzherin, 1964). These changes are most apparent during the winter; little change occurs during the summer months (Pucek, 1963). The purpose of this analysis

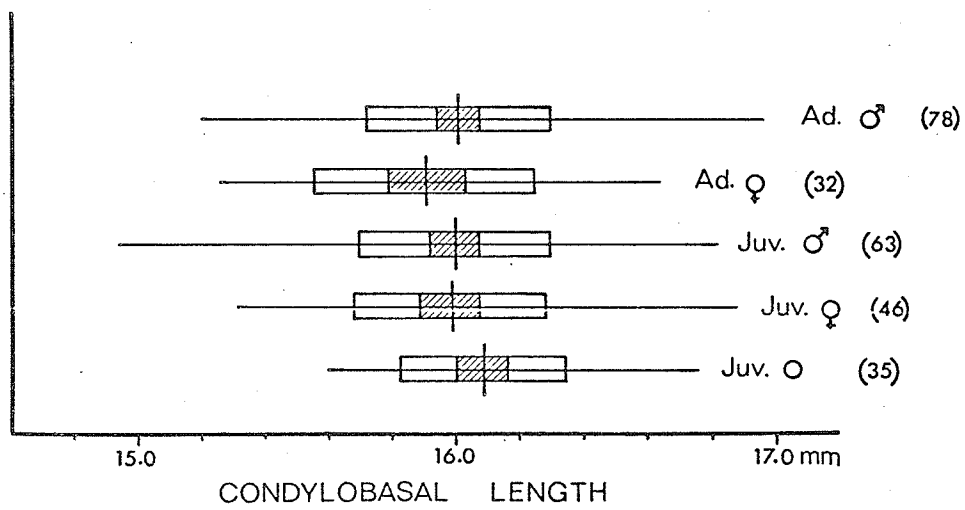


Figure 18. Condylobasal length of Newfoundland *Sorex cinereus*. For an explanation of the symbols see Figures 16 and 17.

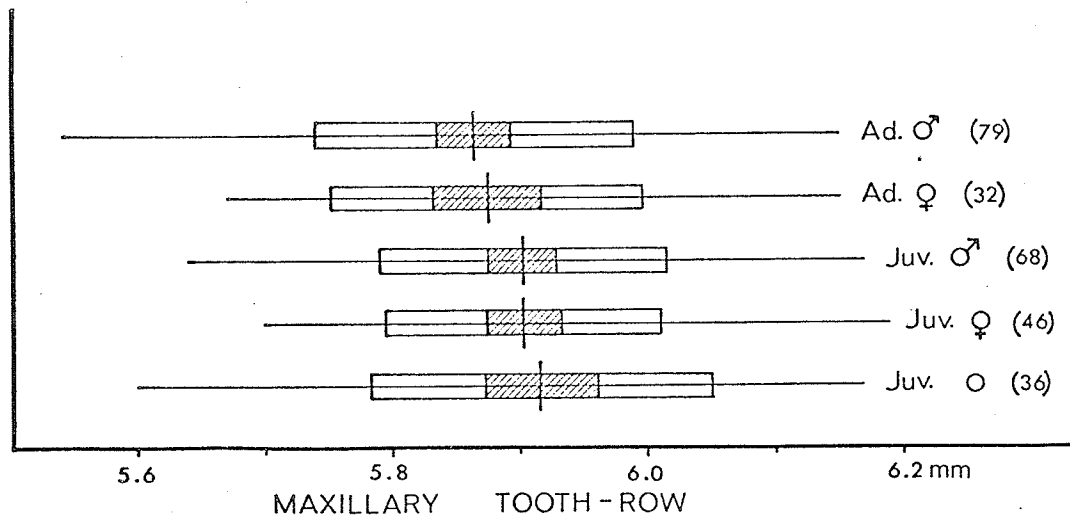


Figure 19. Length of the maxillary tooth row of Newfoundland *Sorex cinereus*. See Figures 16 and 17 for an explanation of the symbols.

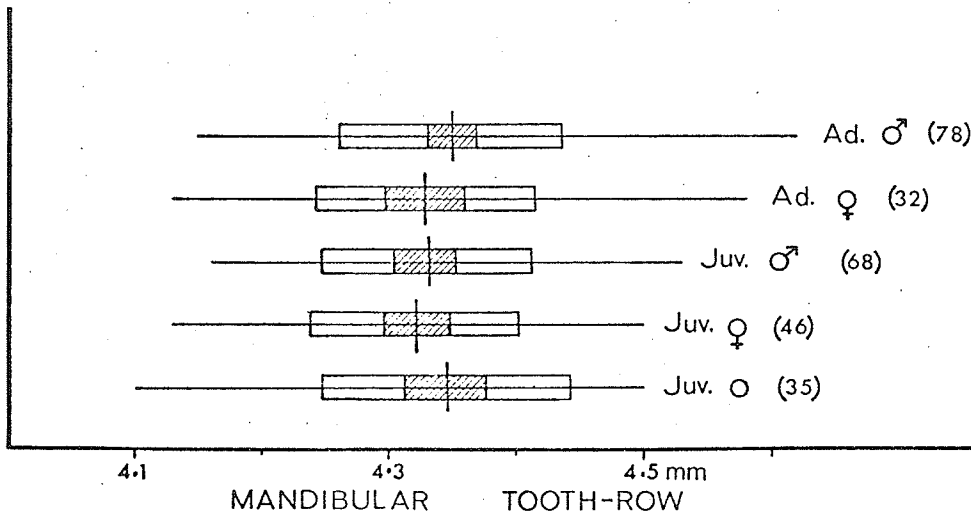


Figure 20. Length of the mandibular tooth row of Newfoundland *Sorex cinereus*. Symbols as in Figures 16 and 17.

of various measurements is to compare the Newfoundland population with the parent mainland population; a long discussion of Dehnel's phenomenon would be out of place here. The reader is referred to the following authors for more information: Dehnel (1949), Schubarth (1958) Crowcroft and Ingles (1959), Mezhzherin (1964), Pucek (1965), Gebczynski (1965), Mezhzherin and Melnikova (1966) and Röben (1969).

The cranial breadth is shown in Figure 21. The skull is significantly broader in all classed of juveniles. Females tend to have narrower skulls than males. There are conflicting reports of the age changes in cranial breadth. Pruitt (1954a) found the skulls of old *Sorex cinereus* were narrower than the skulls of young shrews, an observation which agrees with my results (Figure 21). Other authors (for example, Findley, 1955; Schubarth, 1958; Pucek, 1963; Mezhzherin, 1964) have found old shrews to have broader skulls than juveniles. It is possible that different species of soricids differ in this character. The method of preparation of the material could also affect the results. I found, for example, that the crania of skulls which had been preserved in alcohol or which had been boiled to remove the flesh were usually distorted.

Coupled with the decrease in width of adult skulls, there is a large decrease in the cranial depth (Figure 22). Immature males are a fairly variable class, but this is due to a small number of extreme specimens. Only three immature males had cranial depths of less than 5.0 mm, and only two had cranial depths greater than 5.5 mm. There is a highly significant difference between the skulls of adults and juveniles; this is so great that there are only four juvenile skulls which overlap the range of adult skulls. There is also a highly significant difference

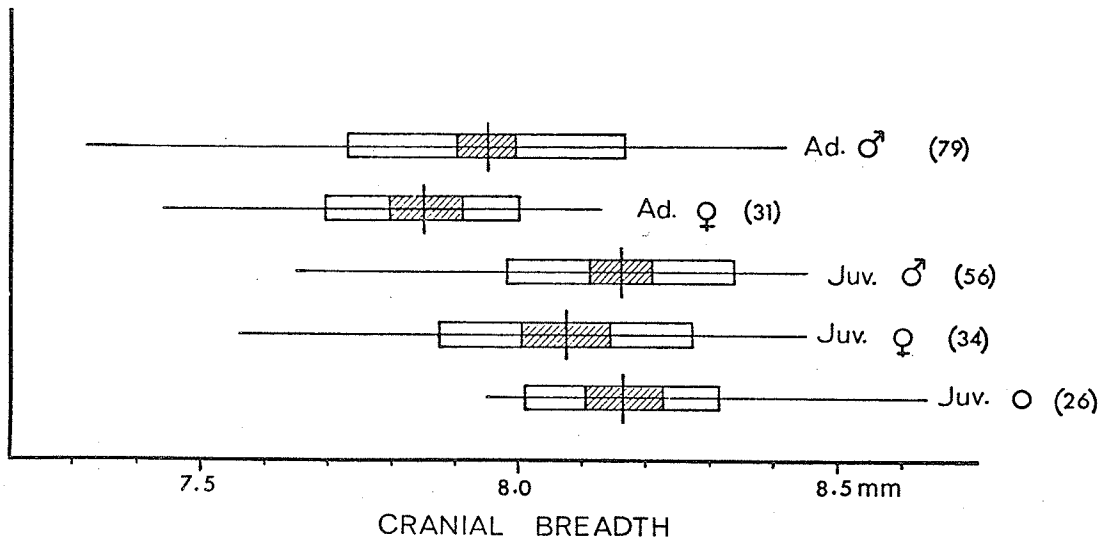


Figure 21. Cranial breadth of Newfoundland *Sorex cinereus*. Symbols as in Figures 16 and 17.

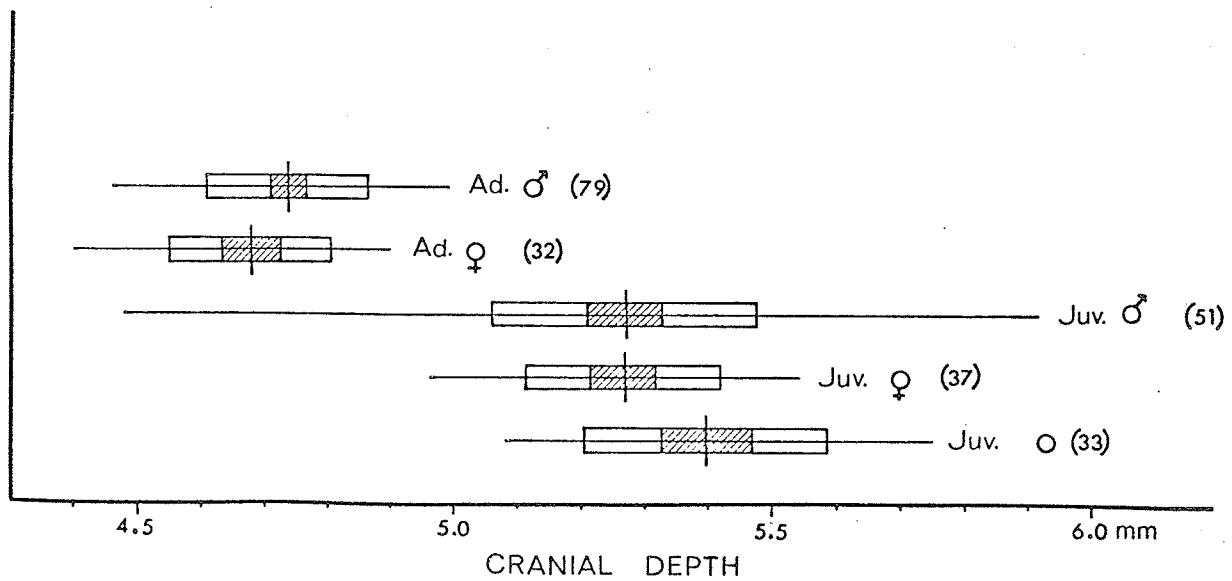


Figure 22. Cranial depth of Newfoundland *Sorex cinereus*. Symbols as in Figures 16 and 17.

between the cranial depth of the unsexed juveniles and the other juvenile classes. The reason for this is not known; it is possible that very young shrews have deeper crania, and are also harder to sex, thus biasing the results.

The frontal depression (Figure 23) shows age changes similar to those in cranial depth. This is to be expected as the depth of the frontal depression is partly dependant on the shape and height of the cranium.

Interorbital breadth is significantly larger in adults than in immatures (Figure 24). The difference, however, is slight.

Palatal length also varies with adults having slightly longer palates than juveniles, but the differences are apparently not significant in all cases (Figure 25).

In summary, there are a number of measurements which show age or sexual differences. Age differences can be detected in total length, femur length, weight, and probably in other measurements related to body size. There are marked differences in the size and shape of the cranium, with adults having flatter, narrower skulls than juveniles. Some other skull measurements (interorbital breadth, palatal length) show slight age differences. Sexual differences can be detected only in adults. Females are lighter in weight than males, but increase in weight during pregnancy and lactation and average somewhat heavier than males at this time. Females tend to have smaller skulls.

#### Variation between Mainland and Newfoundland *Sorex cinereus*

The introduction stock of *S. cinereus* was collected in September 1958 in the Green River watershed of northwestern New Brunswick, Canada

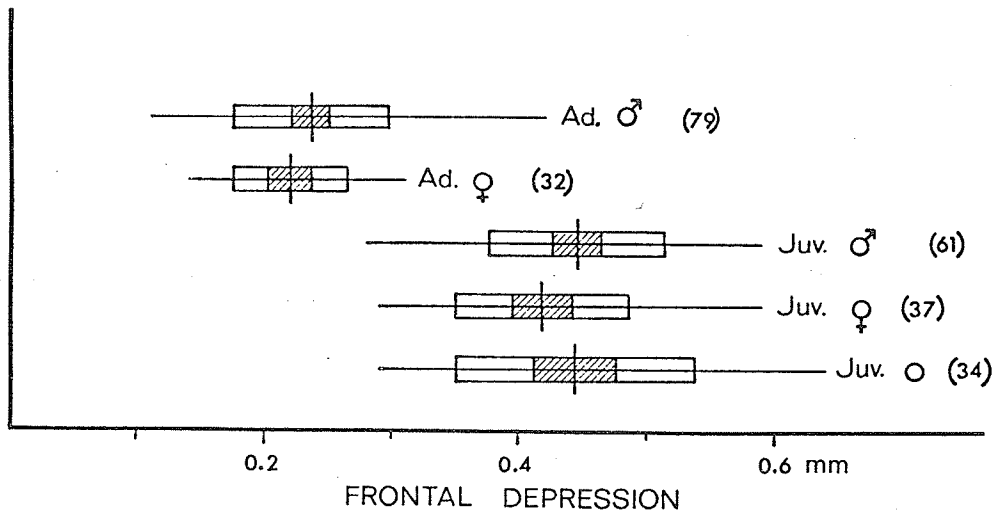


Figure 23. Frontal depression of Newfoundland *Sorex cinereus*. Symbols as in Figures 16 and 17.

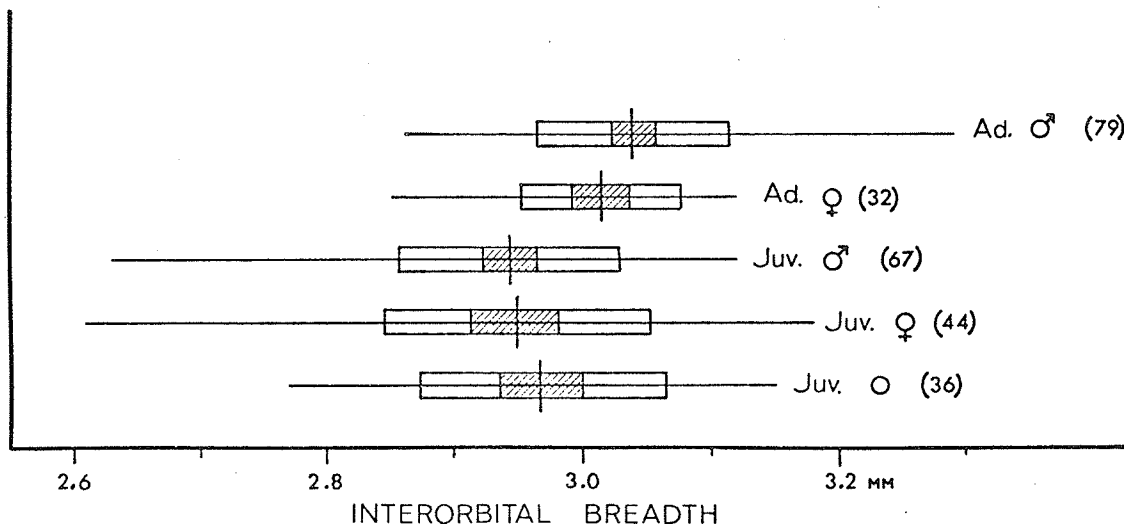


Figure 24. Interorbital breadth of Newfoundland *Sorex cinereus*. Symbols as in Figures 16 and 17.

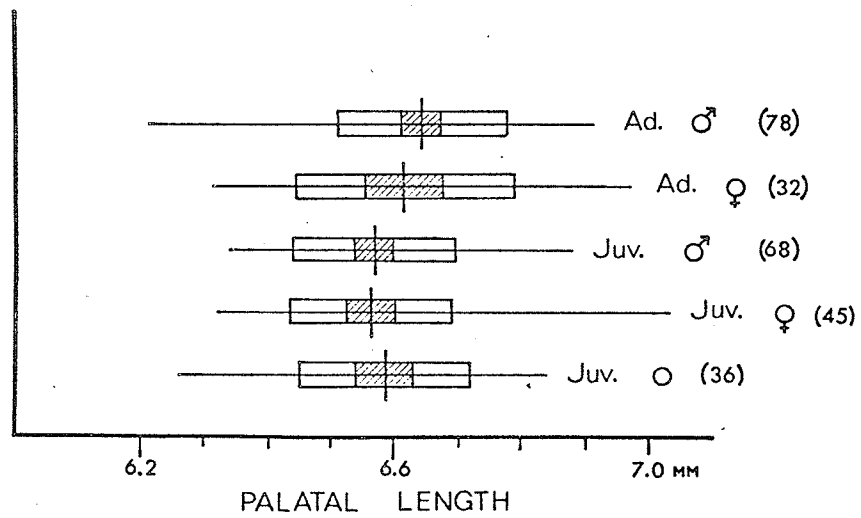


Figure 25. Palatal length of Newfoundland *Sorex cinereus*. Symbols as in Figures 16 and 17.



(Buckner, 1966b; Peterson, 1966). I obtained a number of specimens from northern New Brunswick and compared this sample with the Newfoundland specimens. Appendix III is a list of the mainland specimens used in the following comparison. A large number of these specimens were damaged or poorly cleaned, and complete measurements were not always possible.

Data from Newfoundland indicated there was little sexual dimorphism in skull measurements, but that there were considerable age differences. In order to get a sufficiently large sample I had to combine the sexes of the mainland specimens (many were not sexed). Adult (overwintered) specimens were separated from juveniles (young-of-the-year).

Figure 26 shows the condylobasal length of mainland and Newfoundland specimens. Both classes of mainland shrews have longer skulls, although the range of variation of Newfoundland specimens completely overlaps that of the mainland shrews. The difference is, however, significant.

The maxillary tooth rows are compared in Figure 27. Again mainland shrews are significantly larger. Similar results were obtained with the mandibular tooth rows (not shown).

Mainland specimens had significantly longer palates than Newfoundland shrews. (Figure 28).

The above measurements were the only ones which showed a consistent difference between the Newfoundland and the mainland populations. In all these cases the mainland population was significantly larger.

In the other skull measurements which I compared (interorbital breadth, frontal depression, cranial depth, cranial depth) I was unable to detect any differences. However, few mainland specimens were complete

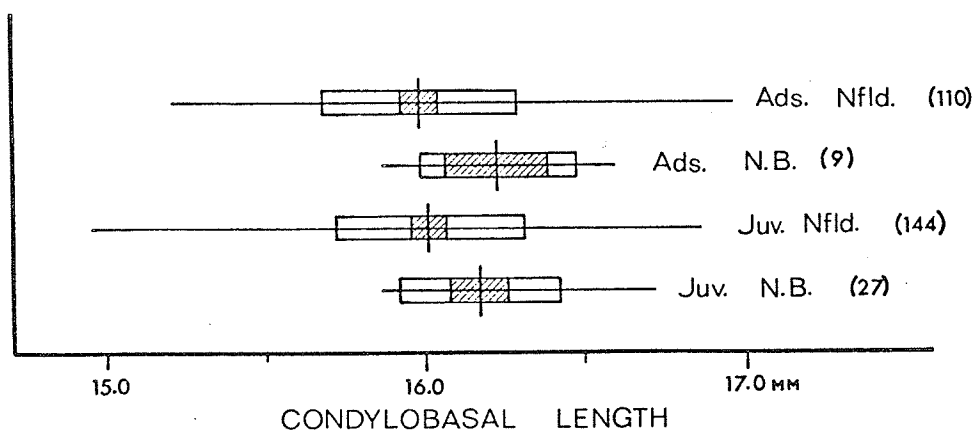


Figure 26. Condylbasal length of Newfoundland and Mainland *Sorex cinereus*. Symbols as in Figures 16 and 17.

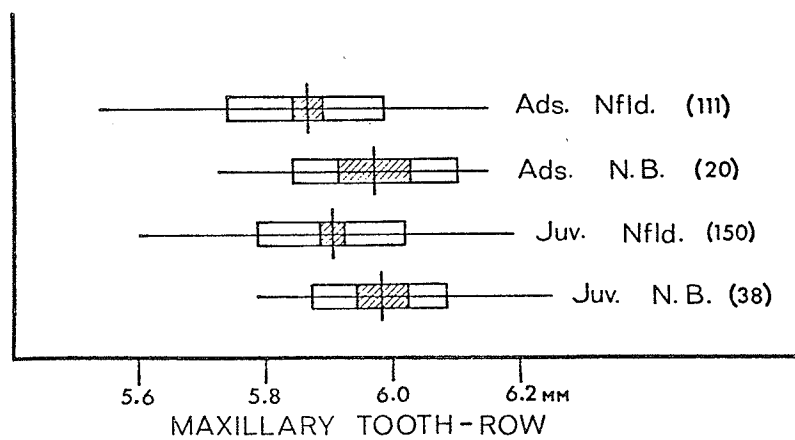


Figure 27. Length of the maxillary tooth row of Newfoundland and Mainland *Sorex cinereus*. Symbols as in Figures 16 and 17.

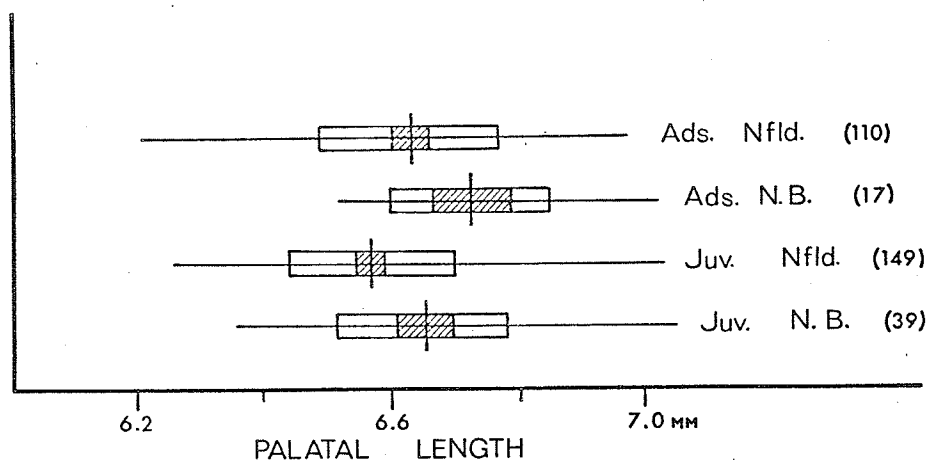


Figure 28. Palatal length of Newfoundland and Mainland *Sorex cinereus*. Symbols as in Figures 16 and 17.

enough to allow measurements of the cranium to be taken. Comparison of measurements made by the collector on the fresh carcass (total length, weight) were not made, due to individual variation in these measurements, and to the fact that almost none of the mainland specimens were weighed.

In addition to these morphological differences which may indicate genetic differences between the two populations, there are other apparent differences. Buckner (1966b) first pointed these out. He stated the populations were "unquestionably higher than any that have been recorded before". He also felt that there had been a size and colour change, with the Newfoundland population being larger and lighter in colour than the mainland shrews. He did not confirm this by comparisons with mainland specimens. Buckner also felt that Newfoundland shrews were of a more docile nature than mainland ones.

In view of the morphological differences I found between the two populations, it is likely that the differences noted by Buckner are real. I could, however, detect no colour difference.

There are several possible causes of these differences. Firstly, the differences might not be genetic at all, but might merely be a phenotypic variation caused by a difference in environmental conditions, such as food supply, or some other factor.

However, it can be shown that there probably was considerable selection of the introduction stock by the process of the introduction, and this could have caused a number of genetic changes. The population in Newfoundland was established from 22 individuals, and this small sample probably did not have the same gene frequencies as the parent

population. It is likely, for example, that genes which were present in only a small percentage of the parent population were lost in the transfer. There is a strong possibility that there was selection of the introduction stock for those animals which were capable of surviving in captivity. Of 69 animals originally trapped, only 22 survived to be released (Warren, in press). As Buckner (1966b) pointed out, those individuals which survived were probably the least nervous and most docile of those captured. In addition to the original transfer there were two subsequent transfers of shrews from the St. Georges site to points in central Newfoundland. Here again there may have been selection of those individuals which survived better in captivity.

There may also have been genetic changes following the introduction. Conditions in Newfoundland are undoubtedly not identical to those in New Brunswick, and selection pressures are presumably different. Selection probably has not had a major effect in the 12 years since the introduction of shrews, but it may have contributed somewhat to the observed differences between the populations.

## ABNORMALITIES AND INJURIES

During the course of this study I observed a number of abnormal and injured shrews. One specimen (CEB 82, immature, sex unknown)<sup>1</sup> had two supernumerary unicuspid teeth. The extra teeth were between the third and fourth unicuspid teeth and slightly overlapped both neighboring teeth. The other unicuspid teeth were forced slightly out of position. The supernumerary tooth in the right maxilla was small, about the size of the fifth unicuspid. The other supernumerary tooth was larger, about the size of the third or fourth unicuspid. The other teeth were normal in all respects. There are to my knowledge no other reports of the bilateral presence of supernumerary unicuspid teeth in the genus *Sorex*.

One specimen (JDF 452, immature female) had only four unicuspid teeth in the left maxilla. The very small fifth unicuspid was missing, and the other teeth had moved slightly posteriorly, filling in the gap. There was no trace of an alveolus for the missing tooth. The other teeth were normal.

There are a number of reports of abnormal dentition in soricids, although such abnormalities are not common. Jackson (1928) reported only one case of a supernumerary unicuspid and three examples of subnumerary dentition in over ten thousand specimens. Hooper (1946) found a specimen of *Sorex saussurei* with seven instead of five unicuspid teeth in the right maxilla. Pruitt (1957) reported a specimen of *Sorex tundrensis* (= *S. arcticus*)

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<sup>1</sup>Collection of C. E. Button

lacking the fourth unicuspid. Setzer (1957) reported an example of an extra molariform tooth in *Crocidura*. Jones (1957) reported a case of fusion of teeth in *Crocidura*. Long (1961) reported a specimen of *S. palustris* with an abnormally small fourth unicuspid. Meester (1959) reported three examples of abnormal dentition in soricids, including one example of bilateral absence of an upper unicuspid and two examples of supernumerary molariform teeth. Choate (1968) found 49 specimens of *Blarina brevicauda* (out of 712 examined) to have abnormal dentition. Subnumerary dentition is more common than supernumerary dentition, with the reductions usually occurring in the unicuspid series.

Several specimens had broken or deformed bones. One live specimen (juvenile, sex unknown) taken at Northern Arm Brook had a healed fracture of the tibia-fibula. The break was about three millimetres above the heel, its position clearly indicated by a sharp abnormal bend in the bone and a slight swelling. When released the shrew scampered away with what appeared to be a normal gait.

Two specimens had similar malformations of the angular processes of the mandible. In one specimen (JDF 282, adult female) only the left angular process was affected, the the other (JDF 307, adult male) both processes were damaged. It appeared as if the processes had been broken close to the ramus of the mandible and then fused with a slight swelling and and abnormal bend close to the ramus of the jaw. The damaged processes were also shorter than normal.

One of these specimens (JDF 307) also had multiple fractures of the left innominate bone. Four fractures were visible, three between the acetabulum and the ventral part of the bone and one at the

posterior end of the bone. Examples of healed fractures in soricids are almost unknown. To my knowledge there is only one other report, that of Dolgov (1968). He reports cases of healed fractures of the ribs, scapulae and caudal vertebrae of *Sorex araneus*.

Missing digits were common among adult males. Of 165 adult males examined, 46 (27.9%) had one or more missing toes. A few adult females (3 out of 61; 4.9%) had missing digits. Injuries of this sort were confined to adults.

Hamilton (1929) found two specimens of *Blarina brevicauda* with missing toes. Pearson (1945) reported missing digits in *Blarina*. Hamilton (1940) found male shrews tended to have more heavily scarred tails than females, possibly as a result of fighting. It is logical to assume that male shrews tend to fight more than females and are more likely to lose toes. It is also possible that males are more accident prone for other reasons.

Often it was difficult to distinguish digits removed by toe clipping from those lost otherwise. There is some possibility of confusing accidentally toe clipped animals with deliberately marked ones. Two of the three males which were known to have survived the winter of 1968-69 were recaptured with one additional missing digit. In both cases however, the missing digit was not completely removed, and it is almost certain the animals were correctly identified. However, the possibility of confusing toe clip numbers should not be overlooked, especially in the case of long distance movements where the origin of the specimen may be in doubt.



## PREDATORS AND PREDATION

Hawks and owls are uncommon to rare in Newfoundland, at least when compared to other areas of boreal forest (northern and western Alberta) with which I am familiar. During the time I spent on the Island of Newfoundland I saw only the following: one sparrow hawk (*Falco sparverius*), one pigeon hawk (*Falco columbarius*), two rough-legged hawks (*Buteo lagopus*), one marsh hawk (*Circus cyaneus*), and a number of bald eagles (*Haliaeetus leucocephalus*) and ospreys (*Pandion haliaetus*). I saw no owls on the island, but did hear one great-horned owl (*Bubo virginianus*).

Corvids (ravens, crows and jays) are common in Newfoundland, and I saw these birds almost every day while in the field. Ravens (*Corvus corax*) and gray jays (*Perisoreus canadensis*) are resident throughout the winter, while crows (*Corvus brachyrhynchos*) migrate south.

Gulls (*Larus* spp.) are common and were often seen flying over the camp at Northern Arm Brook.

Mammalian predators are quite common on the island. I observed weasel (*Mustela erminea*) tracks nearly every day in the winter, and caught three weasels in small mammal traps. I saw nine foxes (*Vulpes fulva*) in the three summers, and observed fox tracks both summer and winter. Lynx (*Lynx canadensis*) seemed fairly common, I saw one in 1969 and observed numerous tracks during the winters.

I found *Sorex* remains in only one of the 18 predator scats I examined, a fox scat collected near Gambo in 1968. This was the only example of

predation on shrews observed during the study. Other material in predator scats included moose hair, *Microtus* hair and bones, *Lepus* hair and bones, bird remains (feathers and bones) and unidentified plant material.

Latham (1950) reviews the food habits of predators in the north-eastern United States. Almost all predators were reported to have taken shrews, but shrews were common only in the diets of weasels and the smaller owls. Small owls are rare in Newfoundland (Peters and Burleigh, 1951) and for this reason are probably relatively unimportant as shrew predators. However, the addition of the shrew as an alternate prey species may result in an increase in owl populations. Weasels are common, and probably are the most important shrew predator. Foxes will take small numbers of shrews (Latham, 1950) and may be fairly important in Newfoundland, where alternate prey is scarce. Mammal predators such as foxes, lynx and weasels may be more important than food habits studies indicate, as these animals may kill and refuse to eat shrews, probably due to the musky taste or odour of the prey (Peterson, 1966).

Corvids are not primarily predators, but will kill and eat small mammals. Cade (1953) observed ravens and jays hunting along a shoreline where shrews were abundant. Ouellet (1970) reported a number of cases of predation by gray jays. I saw a raven with a freshly killed *Microtus* near Gander in 1968.

Gulls are also somewhat predatory and may take a few shrews. Cade (1953) observed predation on *S. vagrans* by gulls (*Larus canus*). It is unlikely that gulls would be of any great importance.

Fish probably take small numbers of shrews which fall into the water by accident or which deliberately enter the water for some other reason. There is one report of shrews in sea trout stomachs in New-

foundland (Anonymous, 1969). This type of predation would be of limited importance to the species, although it might tend to slow dispersal over large water barriers, such as open sea.

## SUMMARY

The masked shrew, *Sorex cinereus* Kerr, was introduced into Newfoundland in 1958. The object of this study was to describe the biology of the introduced shrew population, in particular those aspects of the biology which are unique to the island situation, including the expansion of the population into a previously unoccupied area.

The study was conducted mainly in central Newfoundland, but brief trips were made to other parts of the island. A mark-recapture study was conducted near Grand Falls; shrews were captured in pitfalls, toe clipped, and released. Over 500 specimens were collected and preserved. The habitat preference of the species in Newfoundland was studied by systematic trapping.

Following its introduction, *S. cinereus* has spread over nearly the entire island. The rate of dispersal averaged 33 km per year; this is roughly comparable to observed dispersal rates of other species of introduced animals. There was no evidence that topographic barriers limited the rate of dispersal.

The masked shrew was found in virtually all habitats and it is unlikely that habitat restrictions limited dispersal. Shrew populations were highest in areas of deciduous scrub; populations were lowest in wet, open areas such as bogs and fens.

Little indication of home ranges was found in the mark-recapture study, but this may have been due to the low recapture rate. No shrew was taken more than four times. Sexually mature shrews tended to move

longer distances than did immatures.

The breeding season extended from early May at least until September, but reproductive activity declined sharply after July. The average embryo count was 7.88, ranging from six to nine. Sexual maturity in young-of-the-year was very rare, but two individuals (one male, one female) showed signs of reproductive activity.

In summer the population consisted of two age classes, young-of-the-year and overwintered adults, readily separable by means of tooth wear. Adult males outnumbered adult females by two to one; the sex ratio in juveniles was equal. Greater activity of adult males may have been responsible for the disproportionate sex ratio.

Mature shrews ranged in length from 99 to 122 mm; juveniles were somewhat smaller, ranging from 94 to 110 mm. Adults weighed between 3.1 and 8.0 grams, juveniles from 2.4 to 4.4 grams. There were a number of skeletal differences between young and old shrews. Old shrews had longer femurs, showed a decrease in the depth of the frontal depression, a decrease in cranial depth and breadth, and an increase in interorbital breadth. Some skeletal measurements, including maxillary tooth row, mandibular tooth row, and condylobasal length, did not change with age.

Differences between the Newfoundland and the parent population were clearly demonstrated in the smaller skulls of Newfoundland shrews. There were apparent behavioral differences; Newfoundland shrews were docile and easy to handle; there was no difficulty in keeping them alive in traps. These differences may be genetically controlled.

Two specimens with abnormal dentition were collected, one with

two supernumerary unicuspid in the maxilla, and one with unilateral absence of the fifth unicuspid. Broken or deformed bones were found in four specimens, including a broken tibia-fibula, and a broken innominate bone. These fractures had healed. One-quarter of the adult males were found to have lost one or more digits.

Predators were relatively rare; the mammalian predators (foxes, weasels) were the most common and probably the major shrew predators. Cats kill a few shrews around settlements.

## APPENDIX I

## A description of the habitat trap lines

1. Alder-maple-willow forest.

This habitat was a dense shrub forest, with extensive shrub and herb cover, considerable leaf and twig litter, little moss, on a level, moderately well drained site. The soil was somewhat sandy.

The dominant species were *Alnus rugosa*, *Salix* sp., and *Acer spicatum*. *Alnus* made up about 50% of the canopy, with about 25% cover from each of the other two dominant species. These dominants were three to four metres high, and three to ten centimetres in diameter. A few *Betula papyrifera* and *Populus tremuloides* were also present. The under-story consisted of *Acer spicatum*, *Viburnum cassinoides*, *Vaccinium angustifolium*, with a few *Cornus stolonifera*, *Ledum groenlandicum*, *Kalmia angustifolia*, *Rhododendron canadense*, *Rubus* sp., *Amelanchier Bartramiana*, *Ribes* sp., and *Juniperus communis*. A well developed herb layer of *Cornus canadensis*, *Rubus* sp., *Viola* sp., and *Dryopteris* sp. was present, with a few *Trientalis borealis*, *Epilobium angustifolium*, *Aster* sp., *Solidago* sp., *Linnaea borealis*, and *Maianthemum canadense*. Mosses (*Dicranum* spp.) were present on rocks and stumps. Figure 1 shows a typical area of this habitat line.

2. Alder-birch-mountain ash forest.

This site supported a dense shrub forest of alder, birch, and mountain ash with a poorly developed herb layer, a small amount of litter, and considerable exposed rock and soil. The site was level, poorly drained, with standing water present most of the summer; the soil was a

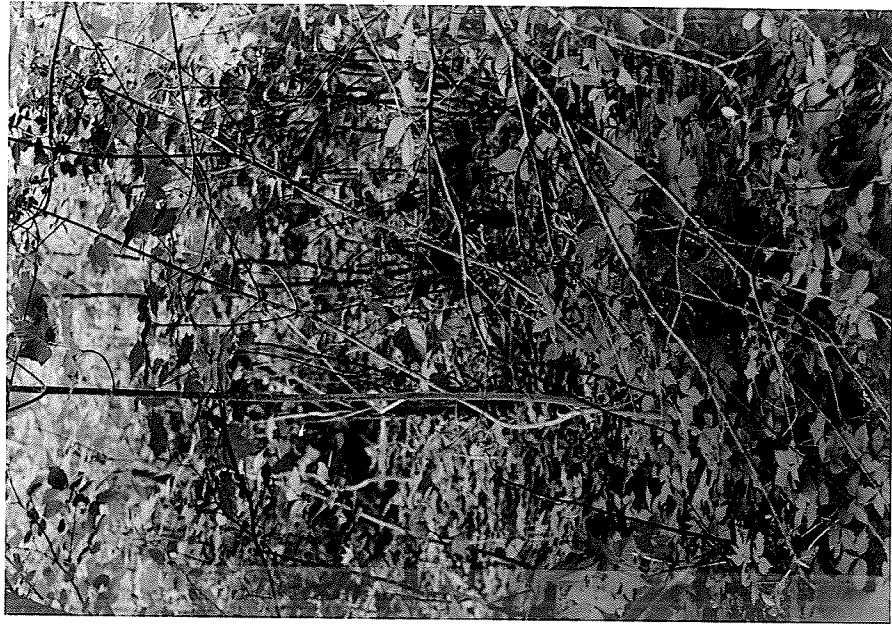
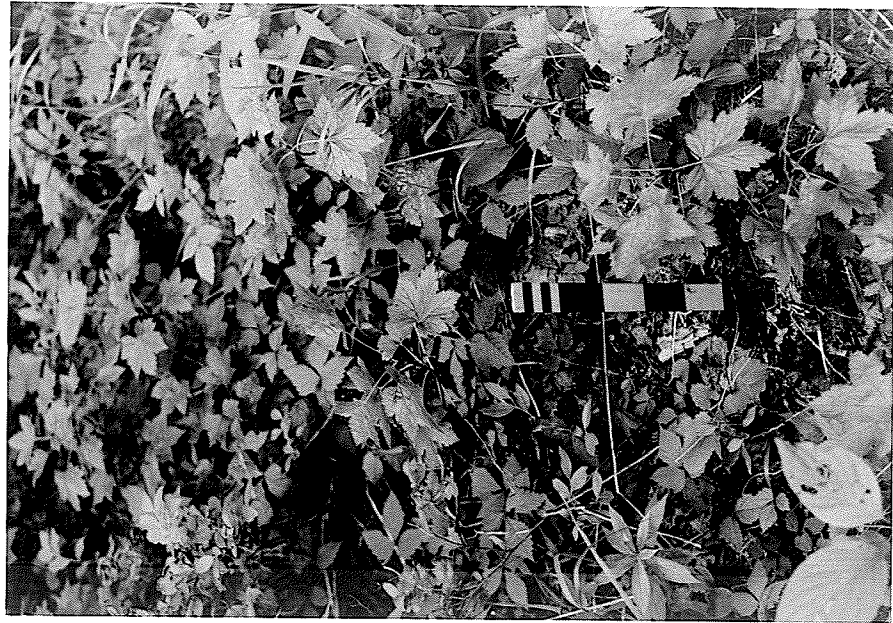


Figure 1. Two views of Habitat Line 1. Left, a general view; right, a close-up of ground cover. The scale (right) is 30 cm long, marked in 5-cm and 1-cm units.



heavy organic muck.

The dominant species were *Alnus rugosa*, *Betula papyrifera*, and *Pyrus americana*, all about equally abundant. Average height was three to four metres, the tallest about seven metres. A few *Salix* and one *Acer rubrum* were present. The understory consisted of *Acer spicatum*, *Viburnum cassinoides*, *Alnus rugosa*, with a few *Pyrus americana*, *Amelanchier Bartramiana*, *Kalmia angustifolia*, and *Vaccinium angustifolium*. There were few herbs, with only *Trientalis borealis*, *Cornus canadensis*, *Maianthemum canadense*, and *Rubus* sp. present. Mosses (*Dicranum* spp.) were found only on stumps or rocks. Figure 2 shows a typical area of this habitat.

### 3. Balsam fir forest.

This site (Figure 3) supported a dense, even-aged stand of balsam fir, with a few birch and poplar. The ground cover was a nearly complete carpet of feather mosses, with some leaf litter. The site was well drained and rocky, with a moderate slope. The vegetation was very uniform.

The dominant species was *Abies balsamea*, eight to ten metres in height. A very few *Betula papyrifera* and *Populus tremuloides* were present. There were no shrubs, but a sparse herb layer of *Cornus canadensis*, *Linnaea borealis*, *Clintonia borealis*, *Coptis groenlandica*, *Maianthemum canadense*, *Trientalis borealis*, and *Gaultheria hispidula* occurred. A well developed layer of mosses (*Hylacomium splendens*, *Hypnum cristacastrensis*, *Pleurozium schreberi*) carpeted most of the area.

### 4. Spruce-balsam fir forest.

This site supported a mixed stand of black spruce and fir, with a

6



Figure 2. Two views of Habitat Line 2. Left, a general view; right, a close-up of ground cover.



Figure 3. Two views of Habitat Line 3. Left, a general view; right, a close-up of ground cover.

poorly developed understory, some leaf and needle litter, and considerable moss under the spruce. The site was level and well drained, with a thick layer of duff over sandy soil.

The dominant species were *Abies balsamea* and *Picea mariana*, in about equal numbers, with a few *Betula papyrifera* and *Populus tremuloides* also present. The understory consisted of a few *Kalmia angustifolia* and *Vaccinium angustifolium* under the spruce, with no shrubs under the fir. A very few *Amelanchier Bartramiana*, *Pyrus americana*, and *Alnus rugosa* also occurred. A few herbs, *Cornus canadensis*, *Linnaea borealis*, *Gaultheria hispidula*, *Dryopteris* sp., and *Lycopodium* sp. were present. A dense cover of feather mosses, *Pleurozium schreberi* and *Hypnum cristacastrensis*, was present under the spruce trees. Needle and twig litter was the only ground cover under the fir. Figure 4 shows a typical area of this habitat.

##### 5. Spruce-birch forest.

This was a well stocked stand of mixed spruce, birch, and fir, with few shrubs, but a well developed herb layer of *Cornus canadensis*, *Clintonia borealis*, and *Lycopodium* sp. About one-half of the ground was covered by feather mosses, the rest by leaf and needle litter. The site was level, well drained, on the shoulder of a hill, with the last trap at the base of a fairly steep rock face.

The dominant species were *Picea mariana*, *Betula papyrifera*, and *Abies balsamea*. Spruce was most abundant, with birch next and with a few fir. A very sparse understory of *Kalmia angustifolia*, *Vaccinium angustifolium*, *Salix* sp., and *Alnus rugosa* was present. The herb cover included *Cornus canadensis*, *Clintonia borealis*, *Pyrola* sp., *Linnaea*



Figure 4. Habitat Line 4. Above, a general view; below, a close-up of ground cover. Note the difference in the ground cover in the two views. Some areas of this line had good ground cover, some none at all.





Figure 4. Habitat Line 4. Above, a general view; below, a close-up of ground cover. Note the difference in the ground cover in the two views. Some areas of this line had good ground cover, some none at all.

*borealis*, *Lycopodium* sp., and *Vaccinium uliginosum*. The feather moss *Pleurozium schreberi* occurred in some areas, and in drier spots a few *Cladonia* spp. were present. A typical area of this habitat line is seen in Figure 5.

#### 6. Fir-spruce-birch forest.

This site (Figure 6) was a mature fir-spruce-birch forest, with few shrubs, but a well developed herb and moss layer. The site sloped to the east, with well drained rocky soil covered with a thick layer of duff.

The dominant species were *Abies balsamea* and *Picea mariana*, with a few *Betula papyrifera*. *Populus tremuloides* also occurred. The poorly developed shrub layer consisted of *Alnus rugosa*, *Kalmia angustifolia*, *Amelanchier Bartramiana*, and *Vaccinium angustifolium*. A well developed herb layer of *Gaultheria hispidula*, *Cornus canadensis*, *Linnaea borealis*, *Trientalis borealis*, *Solidago* sp., *Lycopodium* sp., and *Dryopteris* sp. was present. Moss (*Pleurozium schreberi*) covered most of the area.

#### 7. Black spruce-ericaceous shrub forest.

This site supported a rather open stand of black spruce, with a considerable number of ericaceous shrubs, and an abundant moss and lichen cover. The site was a level, well drained hill top.

The dominant species was *Picea mariana*. The well developed shrub layer consisted of *Kalmia angustifolia*, *Rhododendron canadense*, *Vaccinium angustifolium*, with a few *Alnus rugosa* and *Amelanchier Bartramiana*. The more open areas had a number of herbs, including *Cornus canadensis*, *Maianthemum canadense*, *Gaultheria hispidula*, and *Clintonia borealis*. *Pleurozium schreberi* and *Cladonia* spp. formed a nearly complete ground



Figure 5. Two views of Habitat Line 5. Left, a general view; right, a close-up of ground cover.



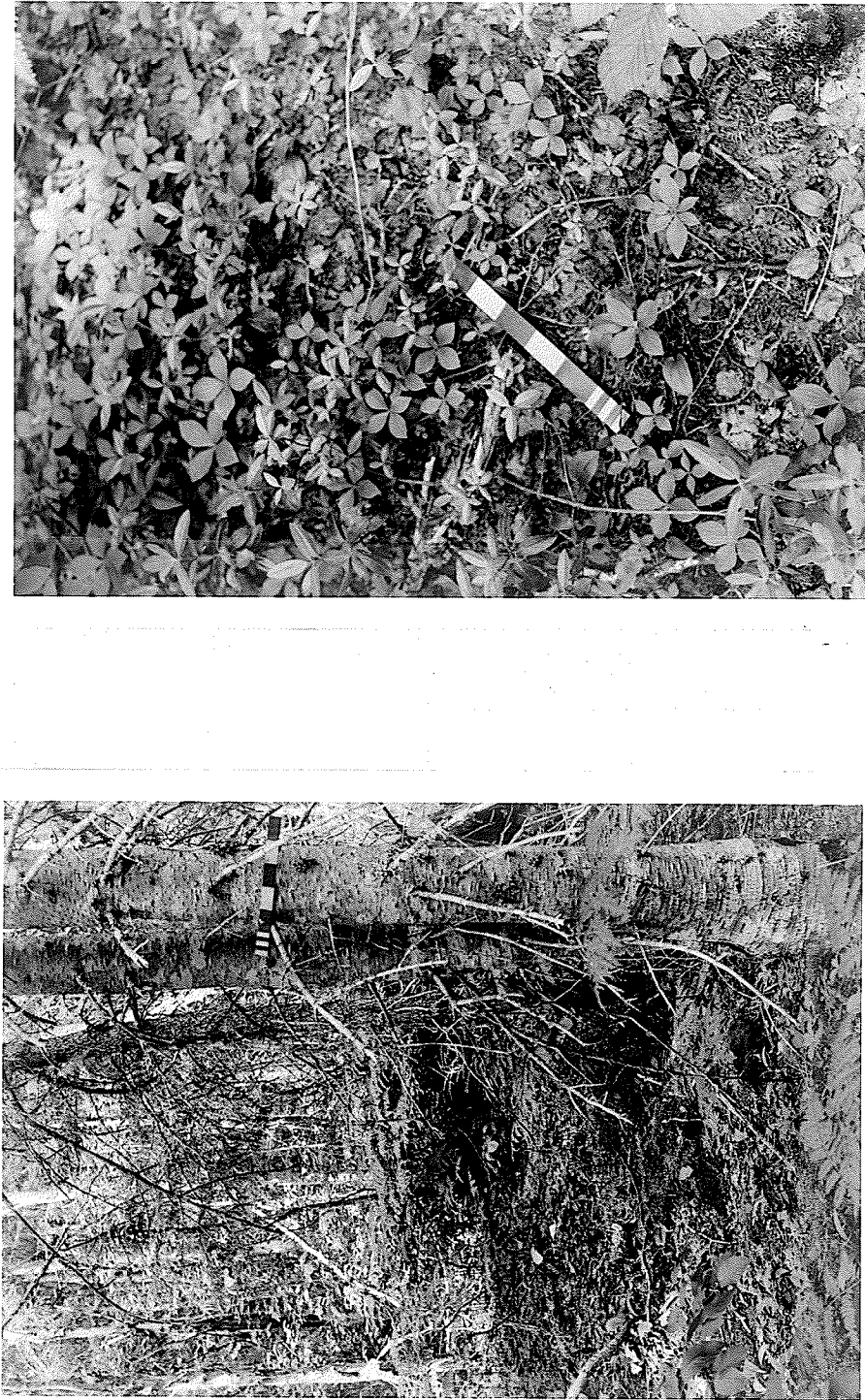


Figure 6. Two views of Habitat Line 6. Left, a general view; right, a close-up of ground cover.

cover. Figure 7 shows a typical area in this habitat line.

8. Black spruce-ericaceous shrub forest.

This site was similar to Line 7, a black spruce forest with a well developed layer of *Kalmia*, some herbs, and a complete moss and lichen cover. The site was well drained, on rocky soil, with a moderate south-east slope.

The dominant species was *Picea mariana*, with a few *Abies balsamea* and *Betula papyrifera*. *Kalmia angustifolia* and *Vaccinium angustifolium* were common, with a few *Alnus rugosa* and *Salix* sp. also present. *Clintonia borealis*, *Cornus canadensis*, *Gaultheria hispidula*, and *Vaccinium uliginosum* were the only herbs present. *Hypnum cristacastrensis* and *Pleurozium schreberi* covered about half the area, with some *Cladonia* spp. in drier spots. A typical area of this line is shown in Figure 8.

9. Cutover.

This site (Figure 9) ranged from an area of relatively undisturbed deciduous forest, (*Betula*, *Viburnum*, *Rubus*, *Kalmia*) to a clear-cut area with good regeneration of poplar (one-half to two metres tall). There was an abundant growth of herbs in the undisturbed area, with only leaf and twig litter under the poplar. The site was well drained.

The dominant species was *Populus tremuloides*, with *Betula papyrifera* occurring in the uncut part of the line. A few small *Picea mariana* and *Abies balsamea* were also present. *Kalmia angustifolia*, *Viburnum edule*, *Prunus pensylvanica*, *Amelanchier Bartramiana*, *Rubus* sp., *Pyrus* sp., and *Sambucus pubens* were the common shrubs. *Cornus canadensis*, *Linnaea*



Figure 7. Two views of Habitat Line 7. Left, a general view; right, a close-up of ground cover.



Figure 8. Two views of Habitat Line 8. Left, a general view; right, a close-up of ground cover.



Figure 9. Two views of Habitat Line 9. Left, a general view; right, a close-up of ground cover.

*borealis*, *Clintonia borealis*, *Maianthemum canadense*, and some *Lycopodium* sp. were present.

10. Cutover.

This site was similar to Line 9, but more recently cut, with no regeneration. There was a small area of relatively undisturbed deciduous brush, with birch and alder, at one end of the line; the rest of the area consisted largely of logging slash, tops and branches, and needle litter. The area was well drained, with a gravel substrate.

The dominant species were *Alnus rugosa* and *Betula papyrifera*, with most of the trap line in an area of little or no vegetation. A good cover of *Cornus canadensis*, *Linnaea borealis*, *Lycopodium* sp., *Dryopteris* sp., *Rubus* sp., *Solidago* sp., *Aster* sp., and *Viola* sp. occurred under the alders. The rest of the line had only a few small shrubs, including *Prunus pennsylvanica*, *Amelanchier Bartramiana*, *Populus tremuloides*, and *Sambucus pubens*. *Viola* sp., *Linnaea borealis*, *Clintonia borealis*, *Maianthemum canadense*, *Rubus* sp., *Solidago* sp., and *Epilobium angustifolium* were widely scattered throughout this area. Mosses were absent. Figure 10 shows a typical area of this cutover.

11. Fen.

This site (Figure 11) was a small, isolated area of fen, fed and drained by a small stream. The water table was fairly stable, although it dropped slowly throughout the summer. Sedges were the main vegetation, but small shrubs and trees occurred on the drier hummocks.

The dominant forms were *Carex* spp. and *Scirpus cespitosus*. *Sphagnum fuscum* and *S. rubellum* formed hummocks, with a few *Larix laricina*, *Picea*



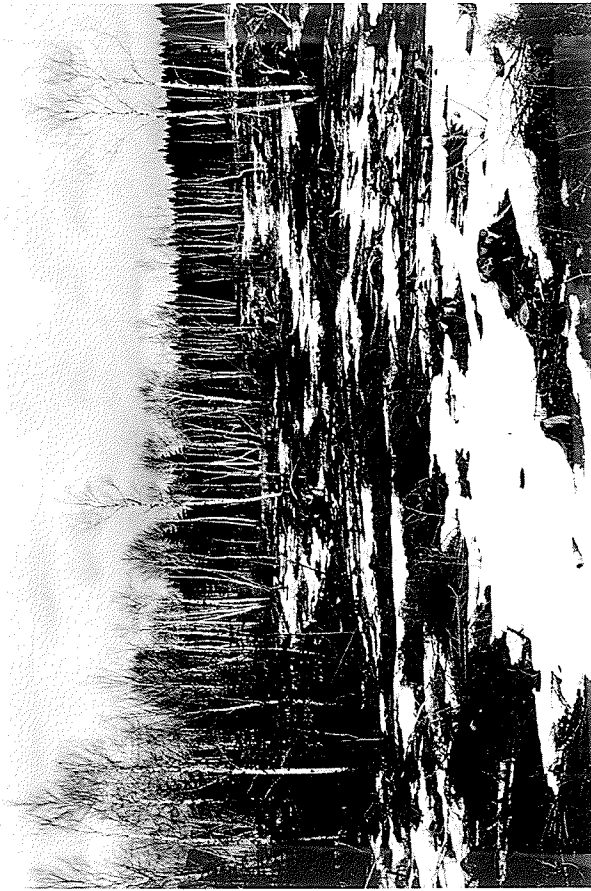


Figure 10. Two views of Habitat Line 10. Left, a general view taken in early spring (April 1969); right, a close-up of ground cover.

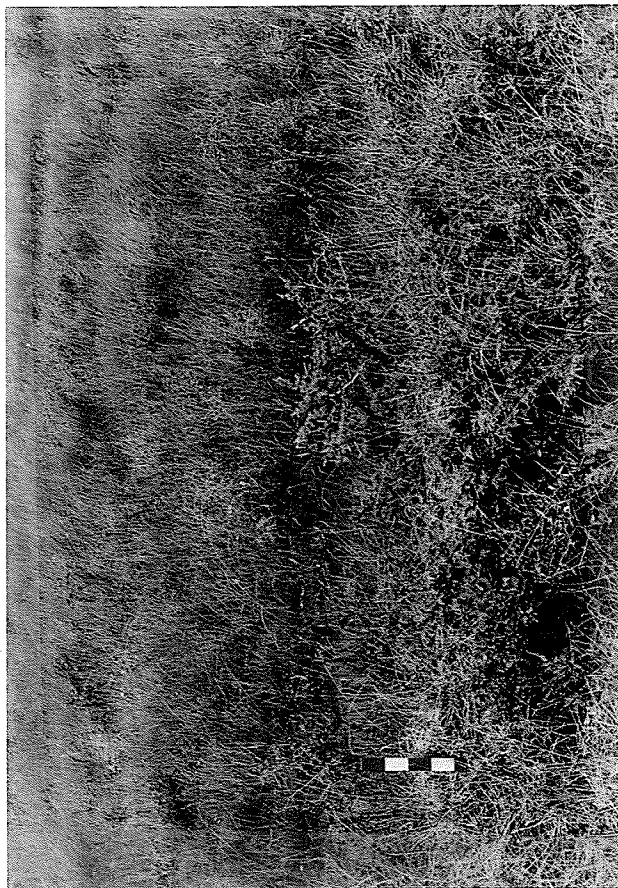
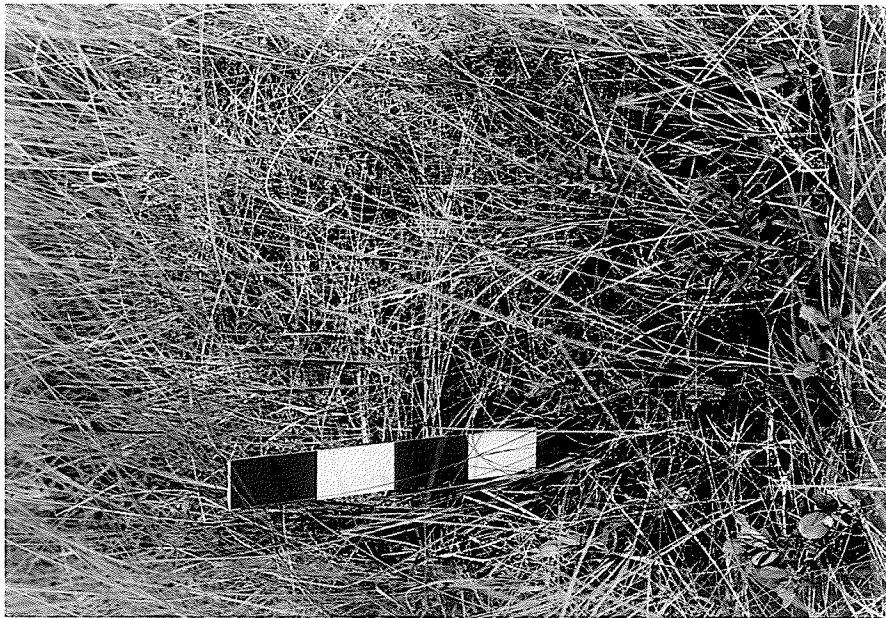


Figure 11. Two views of Habitat Line 11. Left, a general view; right, a close-up of ground cover.



*mariana*, and *Potentilla fruticosa* occurring on these. *Myrica Gale*, *Juniperus communis*, and *J. horizontalis* were also present. A small number of herbs including *Solidago uliginosa*, *Sarracenia purpurea*, *Hypericum* sp., *Aster* sp., and *Utricularia* sp. also occurred.

12. Dwarf shrub bog.

This site was a moderately dry raised sphagnum bog, supporting a good cover of ericaceous shrubs, herbs, and lichens (Figure 12).

The dominant plants were *Sphagnum fuscum* and *S. rubellum*, and these formed small tussocks. *Sphagnum tenellum* also occurred. *Picea mariana*, *Ledum groenlandicum*, *Chamaedaphne calyculata*, *Kalmia angustifolia*, *Empetrum nigrum*, *Vaccinium Oxycoccus*, *Rubus Chamaemorus*, and *Sarracenia purpurea* also occurred, usually on the drier hummocks. Lichens (*Cladonia alpestris*, *C. sylvatica*, *Certraria islandica*) were common.

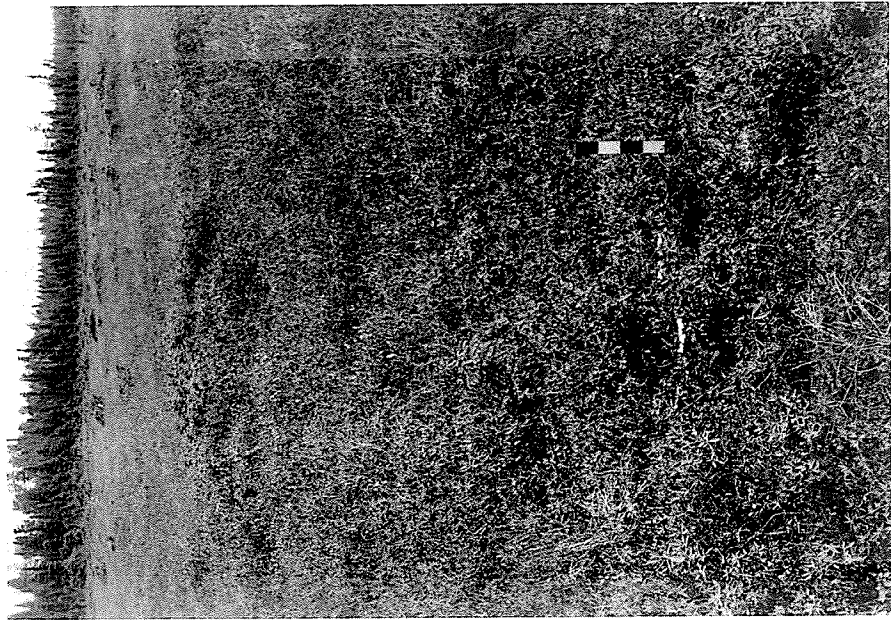
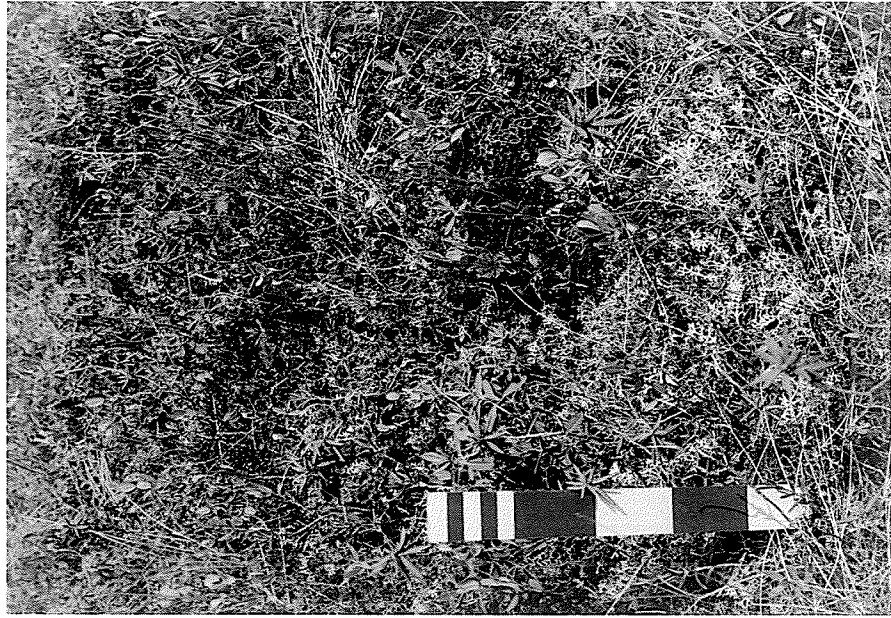


Figure 12. Two views of Habitat Line 12. Left, a general view; right, a close-up of ground cover.

APPENDIX II  
Results of the dispersal trapping

Trap sites	Location Lat. Long.	Date set	Last checked	Traps	Habitat	Results
<u>1967</u>						
1	51° 25' N 56° 15' W	2 Aug.	3 Aug.	50 S*	Coastal barrens and meadows; bog.	10 <i>Microtus</i>
2	50° 29' N 57° 26' W	8 Aug.	11 Aug.	50 S	Fen; spruce forest	2 <i>Microtus</i>
3	50° 04' N 52° 26' W	10 June	13 June	60 L <sup>†</sup> , 40 S	Various habitats--barrens, tuckamoor, alpine sedge bogs	Nil
4	48° 20' N 58° 22' W	12 Aug.	16 Aug.	50 S	Bog--some spruce and shrubs	4 <i>Sorex</i> 5 <i>Microtus</i>
5	48° 47' N 56° 52' W	5 July	14 July	140 S	Spruce-fir forest; cutover bog.	16 <i>Sorex</i>
<u>1968</u>						
1	49° 48' N 56° 33' W	1 July	7 July	7 P <sup>§</sup>	Mixed deciduous forest	10 <i>Sorex</i>
2	49° 48' N 56° 19' W	30 June	7 July	5 P	Mixed forest	7 <i>Sorex</i>
3	49° 50' N 56° 18' W	28 June	7 July	23 S	Roadside gravel bank	1 <i>Microtus</i>
4	49° 54' N 56° 15' W	29 June	7 July	10 S	Alders along road	1 <i>Mustela</i>
5	49° 54' N 56° 13' W	30 June	7 July	5 P	Spruce-fir-birch forest	4 <i>Sorex</i>
6	49° 47' N 56° 19' W	30 June	7 July	7 P	Mixed forest, spruce-fir-birch	3 <i>Sorex</i>
7	49° 43' N 56° 23' W	28 June	7 July	10 S	Spruce-alder swamp	1 <i>Sorex</i>
8	49° 37' N 56° 27' W	28 June	7 July	10 S	Burn--poplar regenerating	Nil

\* S indicates snap traps

† L indicates live traps

§ P indicates pitfall traps

CONTINUED

## APPENDIX II (continued)

Trap sites	Location Lat. Long.	Date set	Last checked	Traps	Habitat	Results
1968 (continued)						
9	49° 30' N 56° 28' W	28 June	7 July	15 S	Bog with small spruce; spruce-ericaceous forest	1 <i>Sorex</i> 3 <i>Microtus</i>
10	49° 05' N 55° 35' W	12 July	16 July	20 P	Alder swamp; spruce forest	24 <i>Sorex</i>
11	49° 17' N 54° 5' W	9 July	22 Aug.	10 P	Mixed spruce-fir-birch forest	16 <i>Sorex</i> 1 <i>Microtus</i>
12	49° 14' N 55° 02' W	9 July	22 Aug	5 P	Spruce forest	10 <i>Sorex</i>
13	49° 08' N 55° 04' W	9 July	22 Aug.	5 P	Alders-grass; roadside	11 <i>Sorex</i> 1 <i>Microtus</i>
14	49° 07' N 55° 07' W	13 July	15 July	50 S	Boggy forest--old burn	Nil
15	49° 04' N 55° 02' W	9 July	16 July	5 P	Spruce-alder forest	1 <i>Sorex</i>
16	49° 02' N 54° 56' W	9 July	16 July	5 P	Spruce-ericaceous forest	1 <i>Sorex</i>
17	49° 00' N 54° 55' W	9 July	16 July	5 P	Spruce-fir forest; swampy	2 <i>Sorex</i>
18	48° 59' N 54° 51' W	8 July	22 Aug	5 P	Mixed deciduous forest	Nil
19	48° 58' N 54° 48' W	8 July	16 July	5 P	Spruce-fir forest; alders	1 <i>Sorex</i>
20	48° 57' N 54° 45' W	6 Oct.	9 Nov.	5 P	Spruce-fir forest	Nil
21	48° 57' N 54° 40' W	8 July	22 Aug.	5 P	Mixed spruce-fir-birch forest	Nil
22	48° 58' N 54° 37' W	5 Sept.	10 Nov.	5 P	Fir forest	Nil
23	49° 04' N 54° 34' W	5 Sept.	10 Nov.	5 P	Birch-poplar-maple forest	Nil
24	49° 09' N 54° 30' W	5 Sept.	10 Nov.	5 P	Mixed forest	Nil
25	49° 14' N 54° 29' W	5 Sept.	10 Nov.	5 P	Dense brush, logging slash	Nil
26	49° 20' N 54° 24' W	5 Sept.	10 Nov. q	5 P	Birch-alder forest	Nil

CONTINUED

## APPENDIX II (continued)

Trap sites	Location Lat. Long.	Date set	Last checked	Traps	Habitat	Results
1968 (continued)						
27	49° 23' N 54° 21' W	5 Sept.	10 Nov.	5 P	Fir forest; roadside brush	Nil
28	48° 54' N 54° 32' W	6 Oct.	9 Nov.	5 P	Alder swamp; fir-spruce forest	4 <i>Sorex</i>
29	48° 54' N 54° 27' W	6 Oct.	9 Nov.	5 P	Spruce-fir forest	2 <i>Sorex</i>
30	48° 52' N 54° 22' W	27 July	22 Aug.	11 P	Alder-birch forest	15 <i>Sorex</i>
31	48° 51' N 54° 21' W	27 July	30 July	15 P	Spruce-fir-birch forest	1 <i>Sorex</i>
32	49° 50' N 54° 06' W	5 Sept.	10 Nov.	5 P	Fir forest	1 <i>Sorex</i>
33	48° 53' N 53° 59' W	5 Sept.	10 Nov.	5 P	Alder-birch forest	4 <i>Sorex</i>
34	48° 58' N 53° 56' W	5 Sept.	10 Nov.	5 P	Maple-alder forest	2 <i>Sorex</i>
35	49° 05' N 53° 56' W	5 Sept.	10 Nov.	5 P	Maple-alder forest	Nil
36	48° 41' N 54° 40' W	17 July	22 July	20 P	Spruce forest; burn; mixed forest	13 <i>Sorex</i>
37	48° 41' N 54° 28' W	17 July	27 July	10 P	Alder swamp	8 <i>Sorex</i>
38	48° 44' N 54° 16' W	25 July	30 July	32 P	Spruce-fir-birch forest;	8 <i>Sorex</i>
39	48° 44' N 54° 12' W	22 Aug.	3 Sept.	25 P	Spruce-fir forest; cutline	2 <i>Sorex</i>
40	48° 43' N 54° 09' W	23 Aug.	20 Sept.	5 P	Spruce-fir-birch forest	2 <i>Sorex</i>
41	48° 39' N 54° 02' W	23 Aug	22 Sept.	15 P	Spruce forest; roadside alders	25 <i>Sorex</i>
42	48° 39' N 54° 00' W	29 Aug.	22 Sept.	20 P	Alders; Fir-spruce-birch forest	4 <i>Sorex</i>
43	48° 30' N 54° 14' W	26 Aug.	20 Sept.	10 P	Fir-spruce-birch-alder forest	2 <i>Sorex</i>
44	48° 32' N 54° 08' W	26 Aug.	8 Nov.	10 P	Fir-spruce-birch-maple forest	1 <i>Sorex</i>
45	48° 32' N 54° 02' W	29 Aug.	8 Nov.	10 P	Spruce with ericaceous shrubs	1 <i>Sorex</i> 1 <i>Microtus</i>

CONTINUED

## APPENDIX II (continued)

Trap sites	Location Lat. Long.	Date set	Last checked	Traps	Habitat	Results
<u>1968 (continued)</u>						
46	48° 23' N 54° 12' W	6 Oct.	2 Nov.	11 P	Spruce-fir forest; alders	3 <i>Sorex</i>
47	48° 55' N 54° 20' W	22 July	25 July	35 P	Spruce forest	Nil
48	48° 55' N 54° 16' W	22 July	25 July	15 P	Mixed forest	Nil
<u>1969</u>						
1	49° 25' N 54° 30' W	28 July	7 Aug.	5 P	Spruce forest	20 <i>Sorex</i>
2	49° 20' N 54° 29' W	28 July	7 Aug.	5 P	Spruce; disturbed roadside	24 <i>Sorex</i>
3	48° 58' N 54° 37' W	26 July	28 July	5 P	Fir forest	3 <i>Sorex</i>
4	49° 04' N 54° 34' W	28 July	7 Aug.	5 P	Birch-poplar-maple forest	1 <i>Sorex</i>
5	49° 09' N 54° 30' W	28 July	7 Aug.	5 P	Mixed forest	7 <i>Sorex</i>
6	49° 14' N 54° 29' W	28 July	7 Aug.	5 P	Dense brush, logging slash	1 <i>Sorex</i>
7	49° 20' N 54° 24' W	28 July	7 Aug.	5 P	Birch-alder forest	6 <i>Sorex</i>
8	49° 23' N 54° 21' W	28 July	7 Aug.	5 P	Fir forest; roadside brush	5 <i>Sorex</i>
9	47° 30' N 54° 48' W	27 July	8 Aug.	5 P	Spruce-ericaceous shrubs	Nil
10	47° 35' N 54° 41' W	27 July	8 Aug.	5 P	Fir forest; dense underbrush	1 <i>Sorex</i>
11	47° 43' N 54° 36' W	27 July	8 Aug.	5 P	Bog, with a few small spruce	4 <i>Sorex</i>
12	47° 48' N 54° 29' W	27 July	8 Aug.	5 P	Fir with ericaceous shrubs	3 <i>Sorex</i>
13	47° 53' N 54° 21' W	27 July	8 Aug.	5 P	Fir forest; alders	9 <i>Sorex</i>
14	47° 55' N 54° 16' W	27 July	8 Aug.	5 P	Poplar forest, some underbrush	<i>Sorex</i> --number undetermined

CONTINUED

## APPENDIX II (continued)

Trap sites	Location		Date set	Last checked	Traps	Habitat	Results
	Lat.	Long.					
1969 (continued)							
15	47° 53' N	54° 08' W	27 July	8 Aug.	5 P	Spruce-fir forest; cutline	3 <i>Sorex</i>
16	48° 01' N	53° 57' W	26 July	8 Aug.	5 P	Fir forest	6 <i>Sorex</i>
17	47° 54' N	53° 57' W	27 July	8 Aug.	5 P	Fir-spruce forest	2 <i>Sorex</i>
18	47° 47' N	53° 58' W	8 Aug.	2 Sept.	10 P	Spruce forest; open streamside	2 <i>Sorex</i>
19	47° 42' N	53° 56' W	8 Aug.	2 Sept.	10 P	Mixed forest, with dense shrubs	Nil
20	47° 38' N	53° 51' W	8 Aug.	2 Sept.	10 P	Spruce with ericaceous shrubs	Nil
21	47° 35' N	53° 48' W	8 Aug.	2 Sept.	10 P	Spruce forest	Nil
1970							
1	49° 22' N	55° 00' W	Aug. 1969	June 1970	10 P	Birchy Island: spruce-fir forest	Nil
2	49° 21' N	54° 59' W	Aug. 1969	June 1970	10 P	Sivier Island: Spruce forest	Nil
3	48° 18' N	54° 59' W	Aug. 1969	June 1970	5 P	Unnamed Island: spruce-fir forest	12 <i>Sorex</i>
4	49° 16' N	55° 01' W	Aug. 1969	June 1970	5 P	Mussel Island: spruce-fir forest	2 <i>Sorex</i>
5	49° 16' N	55° 01' W	Aug. 1969	June 1970	5 P	Rice Island: spruce fir forest	Nil

### APPENDIX III

#### Localities of the mainland specimens of *Sorex cinereus* examined

All specimens are from New Brunswick, Canada, and were collected between 1893 and 1957. Unless otherwise specified, all specimens are from the collection of the National Museum of Canada, Ottawa. Several specimens from the American Museum of Natural History, New York, are indicated by the letters AMNH following the citation.

Specimens examined.--Total number, 62. New Brunswick: Madawaska Co., Edmunston, 9 miles northeast, 1; Madawaska Co., St. Leonard, 6 miles north, 2; Madawaska Co., St. Leonard, 5 miles north, 8; Restigouche Co., Green River, 5; Trousers Lake, 6 AMNH; Youghall, 12; Bathurst, 8; Bathurst, 15 miles from, on Miramichi Road, 20.



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#### ADDENDUM

The specimens collected during the course of this study are currently in the possession of Dr. W. O. Pruitt, Jr., Department of Zoology, University of Manitoba, and are destined for deposition in the collection of the National Museum of Canada, Ottawa.