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Ecology and Life History of the Raccoon (Procyon lotor hirtus Nelson and Goldman) in the Northern Part of its Range

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ECOLOGY AND LIFE HISTORY OF THE RACCOON
(*Procyon lotor hirtus* Nelson and Goldman)
IN THE NORTHERN PART OF ITS RANGE

by

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Ecology and Life History of the Raccoon

(<u>Procyon lotor hirtus</u> Nelson and Goldman)

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The University of North Dakota, 1973

Faculty Advisor: Dr. James R. Reilly

A study of the ecology and life history of the northern raccoon (<u>Procyon lotor hirtus</u> Nelson and Goldman, 1930) was conducted in southwestern Manitoba between June, 1967, and August, 1969. Information concerning growth, development, reproduction and population characteristics was gathered from carcasses of 293 raccoons of juvenile, yearling, and adult age. Seasonal activities and home ranges were determined by marking 84 mobile raccoons and 13 nestlings, and by recaptures of 27 of these. Movements of 11 raccoons were monitored electronically. A total 1,109 scats and 298 stomachs and colons were analyzed for food content and to determine seasonal requirements of nutrition. Eighty-six dens were investigated to determine seasonal needs for protection. Body weights were compared with ages of 354 raccoons collected at various seasons, and with winter mortality. Winter denning activities were compared with ambient temperatures and with den quality to determine the effects of the winter environment on survival. Recent changes in the ecology of the aspen parklands, mortality factors, and limiting factors were investigated to determine the present status of raccoons in the

northern part of their range.

Three age classes of raccoons were described, based on eye lens weight. Juveniles became yearlings at nine months when eye lens weight was 85 mg. Yearlings became adults at 15 months, when eye lens weight was 114 mg. Mating took place from late February to June, with the peak in activity in March; the peak of parturition occurred in May. However, 13.6% of births were as late as the first week in September; these were attributed to malnutrition and disease in winter. Adults produced 4.1 young per female and yearlings produced 0.8; an average 2.5. This was an increase from a minimum spring breeding population of 3.9 per square mile to a total summer population of 8.4 per square mile. Only 26% of the yearlings and 86.5% of the adults produced litters; prenatal mortality was 67% and 4%, respectively.

Home range and distribution of raccoons varied with sex and age, breeding behaviour, seasonal food availability, and denning requirements. Travel was infrequent in winter but was greatly increased during the spring mating period and when protein became available as ice thawed in potholes. Yearlings were found to disperse at that time. Females were restricted in their movements until litters became mobile. Activities were concentrated in tree bluffs when wild fruits were available in late summer and fall and stored grain was sought the year round. Winter dens in scrub piles, cellars, and burrows were replaced by spring breeding dens in scrub piles, attics, and hay lofts, and these in turn by summer day beds in scrub piles and pothole edge vegetation.

Juvenile body weight decreased approximately 30% over winter and yearling mortality rate was high, possibly 60%. Mortality rate for the entire population was greater than 50%. Mean life span was 1.8 years and turnover rate was 7.4 years.

The major limiting environmental factors were lack of food and denning sites in winter. These have been replaced in large part by stored grain, vacant farmsteads, and scrub piles which have greatly increased in number since the 1940s, due to changes in agriculture and economic policies. Raccoons have become established in Manitoba and are presently increasing in the northern part of the aspen parklands.

This dissertation submitted by Wayne Fraser Cowan in partial fulfillment of the requirements for the degree of Doctor of Philosophy from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

Chairman

Dean of the Graduate School

Permission

Title ECOLOGY AND LIFE HISTORY OF THE RACCOON (*Procyon lotor hirtus* Nelson and Goldman) IN THE NORTHERN PART OF ITS RANGE

Department Biology

Degree Doctor of Philosophy

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Date August 17, 1973

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ABSTRACT

A study of the ecology and life history of the northern raccoon (Procyon lotor hirtus Nelson and Goldman, 1930) was conducted in southwestern Manitoba between June, 1967, and August, 1969. Information concerning growth, development, reproduction and population characteristics was gathered from carcasses of 293 raccoons of juvenile, yearling, and adult age. Seasonal activities and home ranges were determined by marking 84 mobile raccoons and 13 nestlings, and by recaptures of 27 of these. Movements of 11 raccoons were monitored electronically. A total 1,109 scats and 298 stomachs and colons were analyzed for food content and to determine seasonal requirements of nutrition. Eighty-six dens were investigated to determine seasonal needs for protection. Body weights were compared with ages of 354 raccoons collected at various seasons, and with winter mortality. Winter denning activities were compared with ambient temperatures and with den quality to determine the effects of the winter environment on survival. Recent changes in the ecology of the aspen parklands, mortality factors, and limiting factors were investigated to determine the present status of raccoons in the northern part of their range.

Three age classes of raccoons were described, based on eye lens weight. Juveniles became yearlings at nine months when eye lens weight was 85 mg. Yearlings became adults at 15 months, when eye lens weight was 114 mg. Mating took place from late February to June, with the peak in activity in March; the peak of parturition occurred in May. However,

13.6% of births were as late as the first week in September; these were attributed to malnutrition and disease in winter. Adults produced 4.1 young per female and yearlings produced 0.8; an average 2.5. This was an increase from a minimum spring breeding population of 3.9 per square mile to a total summer population of 8.4 per square mile. Only 26% of the yearlings and 86.5% of the adults produced litters; prenatal mortality was 67% and 4%, respectively.

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The major limiting environmental factors were lack of food and denning sites in winter. These have been replaced in large part by stored grain, vacant farmsteads, and scrub piles which have greatly increased in number since the 1940s, due to changes in agriculture and economic policies. Raccoons have become established in Manitoba and are presently increasing in the northern part of the aspen parklands.

INTRODUCTION

Raccoons (*Procyon lotor hirtus*, Nelson and Goldman) have moved north since the 1940s to latitudes previously unattained in the aspen parklands of Canada. They can cope with rapid and extensive, man-made changes in the environment and occupy successfully new habitats. A great increase in numbers throughout the range in North America occurred along with the northward migration (Sanderson, 1960). The first recorded occurrence of the species in the Manitoba potholes region was in 1954 (Olson, 1964) and since that time, they have increased their numbers and inhabited large new areas of the province (Lynch, 1967). Reports of raccoons are now common as far north as The Pas, Manitoba, about 400 miles north of the Canada and United States boundary.

The effects of this newly established population in Manitoba's agricultural areas are well known. Raccoons have caused damage to corn fields, stored grain, domestic fowl, and farm buildings, but on the other hand, the province's fur industry has profited. Interactions between raccoons and indigenous wildlife species require investigation; for example, substantial annual increases in predation rates on duck nests in Manitoba potholes have occurred since the influx of raccoons in the middle 1950s (Stoudt, 1965).

Studies of raccoon biology and life history previously completed include the work of Stuewer (1942, 1943a, 1943b) in Michigan, Sanderson (1949, 1950, 1951, 1960, 1961a, 1961b, 1961c, 1966) in Missouri and Illinois, Cabalka (1952) and Cabalka *et al.* (1953) in Iowa, Stains (1956) in Kansas, and Johnson (1970) in Alabama. Schoonover (1950), Schoonover and Marshall (1951), Mech and Turkowski (1966), Mech et al. (1966), and Mech et al. (1968) in Minnesota, and Geis (1966) in South Dakota provided information on raccoons in woodland and prairie habitats in the northern United States. The literature concerning Manitoba raccoons consists primarily of notes on sights, range extensions, and long-range movements. One study of raccoon predation on duck nests in Manitoba (Lynch, 1972) has been published.

Recent rapid changes in the ecology of southern Manitoba and the northward migrations of many animal species have generated new and important problems of biologic interest. This project was initiated to investigate the northward expanding raccoon population in Manitoba, to determine its life history, to compare these findings with similar information concerning raccoons in the United States, and to assess the effects of Manitoba's severe environment and man's activities upon the successful establishment of the raccoon population. The specific objectives were to determine characteristics of growth and development, reproduction, and population size and structure; to analyze the seasonal requirements for nutrition and protection from the environment; to determine the effects of Manitoba's climate on mating, productivity, food gathering, winter activities, and survival.

DESCRIPTION OF THE STUDY AREA

The study area is situated in the aspen parkland seven miles south of Minnedosa, Manitoba in Odanah Municipality. It incorporates portions of sections 1, 2, 3, 10, 11, and 12 of township 14, range 18; sections 22 through 27, 34, 35, and 36 of township 13, range 18; sections 5 to 8 of township 14, range 17; and sections 19, 20 and 29 through 32 of township 13, range 17; it includes 16 square miles.

The maximum elevation is 1,750 feet in the northwest corner of the area, and the land slopes to 1,650 feet diagonally across the study area toward the Manitoba Plains. The area is characterized by an undulating to steeply sloping topography, drainage is poor, and runoff water from the knolls and ridges accumulates in enclosed depressions or potholes which drain through shallow channels. Remnant ice blocks from receding glaciers melted to form numerous kettles, locally called potholes, which occupy more than 35% of the total land acreage (Ehrlich et al., 1957).

The area is underlain by Upper Cretaceous shale of the Riding Mountain Formation. Overlying the shale are moderately calcareous glacial deposits of the Pleistocene Epoch. Loam to clay soils cover glacial deposits (Wallace, 1925).

The climate of the aspen parkland is designated Dfb according to Koppen's scale, that is, mid-continental, subject to great extremes in weather. The annual average temperature range of -1 in January to 67.4 F in July is much greater than the world average for 50 degrees north latitude. There are about 100 frost free days a year, and the growing season is from late April to early October, or 170 to 180 days (Kendrew and Currie, 1955). Snowfall occurs from November to March and accounts for 20% of the total precipitation. The average annual precipitation for the aspen parkland between 1885 and 1894 was slightly greater than 17 inches (Bird, 1930). June is the wettest month with an average rainfall of 3.21 inches and February is the driest with 0.70 inches (Ehrlich et al., 1957).

The aspen parkland is a transition zone between the boreal forest and the grassland formation. According to Evans et al. (1952), the vegetation is diverse because of great variability in soil moisture and temperature. The effects of land use, including the cultivation of small grains and grazing, are apparent in the patterns of native vegetation. Aspen (Populus tremuloides) is the dominant tree form with burr oak (Quercus macrocarpa) occupying the drier sites. Trees occur as small groves, locally termed tree bluffs, invading the grassland or as closed woodlands. In the drier areas, these are rimmed by a shrub zone that includes snowberry (Symphoricarpos albus), chokecherry (Prunus virginiana), saskatoon (Amalanchier alnifolia), and hawthorn (Crataegus chrysocarpa). The aspen groves on moist sites also contain balsam poplar (Populus balsamifera) and are bordered by willows (Salix spp.), which are replaced on the more alkaline soils by sedges (Carex spp.) and grasses.

Bird (1930) described a direct succession from marsh to prairie grasses on very alkaline soils. These grasses are: wheatgrass (Agropyron richardsonii), junegrass (Koeleria cristata), bentgrass (Agrostis hyomalis), and needlegrass (Stipa comata). Tall grasses dominate the knolls, south- and west-facing slopes. These include speargrass (Stipa spartea), big bluestem (Andropogon gerardi), wild rye (Elymns spp.), and wheatgrass. The dominant species of emergent vegetation vary from pothole to pothole and include sedges (Carex spp.), whitetop (Scholochloa festucacea), broad-leaved cattail (Typha latifolia), narrow-leaved cattail (Typha angustifolia), bullrushes (Scirpus spp.), and pondweeds (Potamogeton spp.). "Foxtail" (Hordeum jubatum), or sloughgrass (Beckmannia syzigachne) form distinct bands around the margins of some potholes.

Large numbers of waterfowl breed in and about the prairie potholes. According to Olson (1964), the potholes of southern Manitoba are the most important breeding areas for canvasback ducks (Aythya valisineria) in North America. Redhead (Aythya americana), lesser scaup (Aythya affinis), ruddy duck (Oxyura jamaicensis), mallard (Anas platyrhincos), pintail (Anas acuta), gadwall (Anas strepera), green-winged teal (Anas carolinensis), blue-winged teal (Anas discors), baldpate (Mareca americana), and shoveller (Spatula clypeata) are abundantly represented. Others included are coot (Fulicia americana), horned grebe (Colymbus auritus), pied-billed grebe (Podilymbus podiceps), American bittern (Botaurus lentigunosis), Virginia rail (Rallus limicola), sora rail (Porzana carolina), black tern (Chlidonias niger), and red-winged blackbird (Agelius phoenicius) (Evans et al., 1952).

In Odanah Municipality, most available land is planted to grain or is fallowed preparatory to grain growing. In 1951, approximately 20% of the area was fallowed, 40% was planted to small grains, 36.5% was marsh and wasteland, and 1.5% was hay and pasture land. Less than 40% was unimproved land (Ehrlich et al., 1957).

New agricultural programs, the increased cost of living, and modern technology have encouraged larger farms operated by fewer individuals.

Farmsteads are abandoned as retired farmers emigrate. Therefore, the number of active farms in Odanah Municipality has declined from 248 in 1941 to 209 in 1951, and to 163 in 1966. The total acreage of individual farms has increased from 358 to 439 to 531 acres, respectively. Of the 45 farmsteads on the study area, 16 are vacant (Ehrlich et al., 1957; Burns, 1972, Canada Department of Agriculture, personal communication).

Large tracts of available woodland have been cleared and an unknown number of potholes have been drained and filled to provide for extensive road construction and larger grain fields. Trees are cut and bulldozed into large piles, then are allowed to dry for several years before they are burned, or are pushed into adjacent potholes and used as fill. Smaller potholes are ditched and drained and the edge cover burned in spring, summer, or fall to retard the succession of woody growth. Livestock are grazed on pasture land, pothole edges, summer fallow, and stubble as the seasons and farm operations permit.

LITERATURE REVIEW

Historical Background

According to Cockrum (1952), the 27 geographic races of raccoons in North America range from southern Canada including Newfoundland to Panama (Whitney and Underwood, 1952), Cape Breton Island (Smith, 1940), the Bahamas (Sherman, 1954; McKinley, 1959), and the offshore islands of British Columbia and Washington (Scheffer, 1950). This species has been successfully transplanted to Europe, Asia, and Central America. Arant (1939) reported that raccoons were "abundant" in 16 countries, "common" in 42, and "scarce" in nine. Aliev and Sanderson (1966) estimated that populations of 45,000 raccoons in Russia and 50,000 in Europe resulted from the introduction of the species during the 1930s. Offspring of raccoons acclimatized in Germany expanded into France and have recently been recorded as far west as the Pyrennes Mountains; these have become a nuisance species in some areas (De Beaufort, 1968). Acclimatization studies in Kirgizia in 1936 and Azerbaijan in 1941 culminated in the successful establishment of a regular trapping season in the Caucasus in 1955 (Novikov, 1956). Groups of 58 and 75 raccoons released in 1954 and 1958 in the Poles's region increased their numbers by 10 times (Vasil'Kov, 1966).

Scheffer (1947) reported that the offspring of eight Indiana raccoons released on the Singa Islands in Sea Otter Sound, British Columbia, spread to nearby islands and became so well established that they supported a modest fur industry within six years. Raccoons were introduced into Providence Island, British West Indies, in 1784 and increased to become a nuisance to chicken farmers during this century (McKinley, 1959). The species was still confined to the islands where released when Goldman surveyed the Bahamas in the 1930s (Sherman, 1954). Another subspecies probably introduced from Florida was abundant on nearby Grand Bahama Island in the 1950s.

The northern raccoon, Procyon lotor hirtus Nelson and Goldman, occurs in the upper Mississippi and Missouri drainage systems, from the eastern slope of the Rocky Mountains to Lake Michigan and from Oklahoma and Arizona north into the aspen parkland of southern Manitoba, Saskatchewan and Alberta (Miller and Kellogg, 1955). Marginal records have been reported from the Texas panhandle; Duluth, Minnesota; Delta, Manitoba; and Banff and Wood Buffalo Park, Alberta (Hall and Kelson, 1959).

Recent raccoon population explosions within the normal range in North America have been associated with their immigration into new areas of the continent. Sanderson (1951) reported that raccoon populations are irruptive and that their numbers in east-central United States had increased from 1940 to a theoretical peak by 1950. However, this expansion continued for another 10 years until the population was 10 to 15 times that of the 1940 level (Sanderson, 1960). This irruption was recorded in many areas of the continent: Canada (Sowles, 1949; Priewert, 1959; Sanderson, 1960; Tamsitt, 1962; Soper, 1963; DeVos, 1964; Olson, 1964; Sutton, 1964; Stoudt, 1965), Ohio (Sagar, 1958), Iowa (Cabalka et al., 1953; Costa, 1951; Sanderson, 1951, 1960), Illinois (Sanderson, 1960), Missouri (Twitchell and Dill, 1949; Sanderson, 1951, 1960), Washington (Tyson, 1950; Scheffer, 1950), Colorado, Wyoming and New Mexico (Robinson, 1953; Tester, 1953), Delaware, Maryland and Virginia (Shaffer, 1948; Kellner, 1954), Alabama (Barkalow, 1949), and the British West Indies (Sherman, 1954; McKinley, 1959).

Migrations of raccoons have been recorded throughout the century. Sanderson (1966) listed raccoons, grey fox, mule deer, opossums and armadillos as animal species that had extended their ranges during the previous 10 to 20 years. DeVos (1964) reported that raccoons had been scarce in Minnesota, Wisconsin, and the lower Great Lakes region around 1900 but currently were common. Swanson <u>et al</u>. (1945) noted that the species was established state-wide in Minnesota by the 1940s; 22,570 were harvested within the state in 1948 (Schoonover, 1950).

Raccoons have recently extended their range northward. This trend has been apparent in the aspen parkland of the Canadian prairies since the late 1940s. Seton (1909) indicated irruptions in raccoon populations had occurred during the nineteenth century, in 1867, 1875 and 1899; they were scarce in Manitoba by 1900. He reported that two raccoons were trapped just south of 52 north latitude. Soper (1946) indicated that the species is not found north of Battle River, Alberta, but cited marginal records from Peace River, Bighorn Mountains, and Wood Buffalo Park. The Wood Buffalo Park occurrence, recorded in 1930, was further substantiated by the recollection of natives of a raccoon caught there 10 years previously. Rand (1948) considered this record "amazing" and postulated that escaped captive animals were involved. However, Lynch (1971) reported raccoons as far north as 56°15′ latitude in Manitoba and 55°10′ in adjacent Ontario.

Figure 1 is an outline of the changes reported in the literature that occurred throughout the normal range and in the northern part of the range from 1860 to the present. Generally, periodic influxes of raccoons

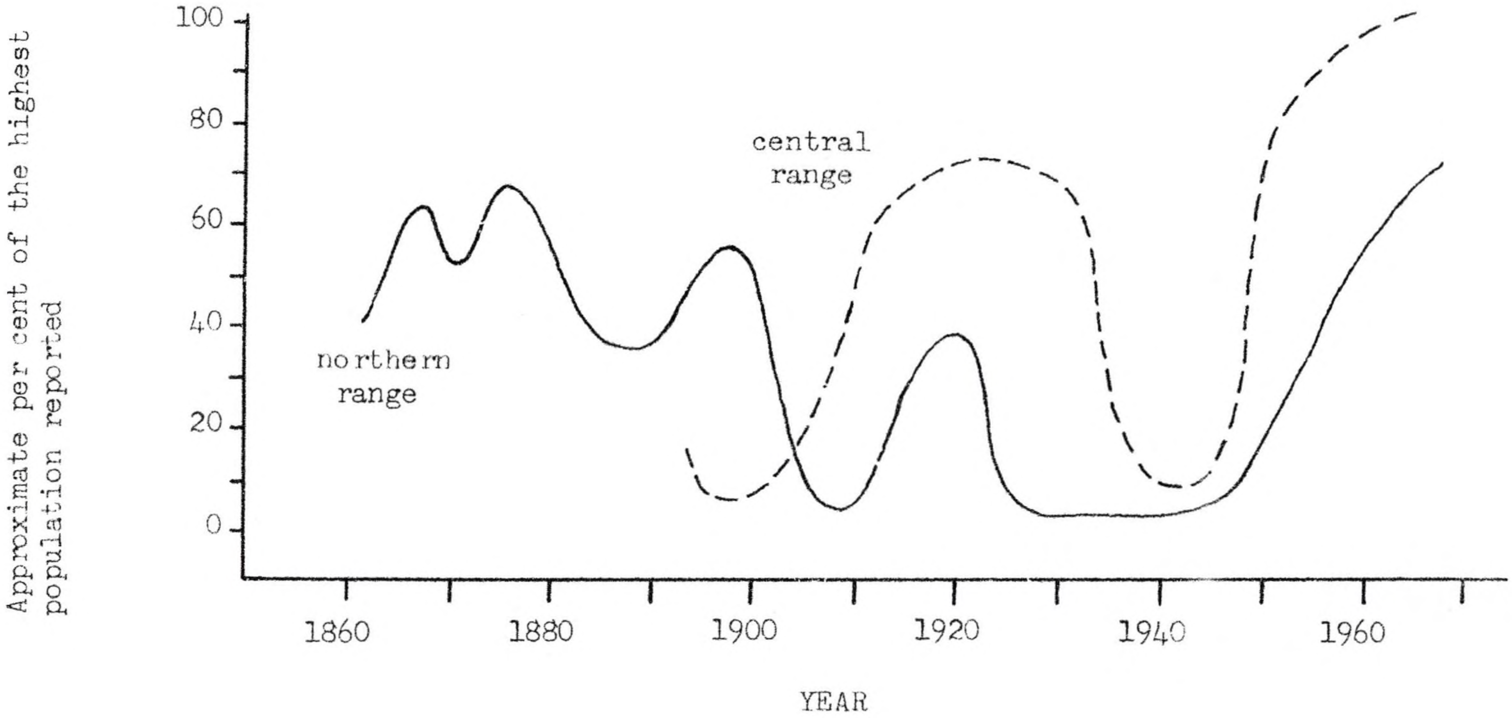

Figure 1.--Comparison of estimated raccoon populations in the centre and northern extension of the range; 1800 to the present time

into northern areas followed population irruptions in the normal range to the south, and decreases in numbers at the higher latitudes preceded declines in the continental population. Raccoons were present in substantial numbers in the 1920s and 1930s within the normal range (Linsdale, 1928; Bailey, 1933). In the late 1930s, there was a sharp reduction in numbers (Bennitt and Nagel, 1937; Trautman, 1939; Sanderson, 1960). Raccoons were scarce in the Canadian prairies during the entire period from 1920 to 1940 (Jackson, 1926; Bird, [illegible]; Green, 1932); they had disappeared from Manitoba's Riding Mountain, 120 miles north of the 49th parallel, by 1920 and had been reduced to a small population inhabiting the lower Assiniboine Valley by the end of the decade (Soper, 1963).

The increase in the population of North American raccoons began in about 1940 (Sanderson, 1949, 1960), and the population reached an estimated maximum five million by the 1960s (Rue, 1964). An increase in numbers of raccoons in Manitoba became apparent by 1950. Their occurrence in northern areas previously unfrequented by the species forecast this phenomenon. Raccoons were not harvested in Manitoba prior to the 1947-1948 winter trapping season when 28 pelts were purchased (Manitoba Department of Mines, Resources and Environmental Management, 1972, personal communication). The harvest increased subsequently and has exceeded 500 pelts annually since the 1959-1960 season. The record high was 871 pelts taken in 1960-1961. Raccoon fur prices ranged from $1.34 in 1958 to $4.00 in 1966; however the harvest did not fluctuate with the price.

Priewert (1959) reported the recapture of a raccoon three years after it was tagged in its juvenile year at Mud Lake National Refuge in northwest Minnesota, on a tributary of the Maskwa River near Great Falls, Manitoba, 165 miles north of the release site. A yearling raccoon bearing a radio transmitter was released near Delta Waterfowl Research Station and was later trapped near Camperville, Manitoba, on the west edge of Lake Winnipegosis. This was an airline distance of 165 miles (Lynch, 1967). MacLulich (1936) reported the capture of a raccoon near Sudbury, Ontario, an area from which the species had not been recorded previously. The nearest established populations were in southern Ontario and northern Michigan, distances in excess of 100 miles.

The raccoon has demonstrated its ability to cope with rapid and extensive man-made environmental changes and to occupy successfully new habitats while the population increases in previously established areas. Many theories have been offered regarding the factors involved. Bailey (1926) noted that the distribution in the upper midwest was almost identical with that of the burr oak. Visher (1918) commented that South Dakota raccoons were restricted to wooded stream valleys and Seton (1909) and Soper (1942) reported similar distributions in Canada during the years of low population levels and when the species was extending the range into new regions (Stoudt, 1965).

Shires (1921) noted that raccoons moved in behind second growth clearing and settlement by the white man in the southern Lake Superior region about the turn of the century. Trautman (1939) considered that the decrease in forest acreage and loss of den trees were responsible for the decline in the raccoon population in Ohio. Den trees were considered invaluable to large populations of raccoons in Michigan (Stuewer, 1948). However, den trees were less abundant in recent years, when raccoons were more numerous, than during the 1930s, when the raccoon population had declined (Sanderson, 1960). Whitney and Underwood (1952) postulated that man had provided new habitat for raccoons in many areas due to forest clearing procedures and abandonment of buildings.

Extensive coyote and wolf control programs in southern Manitoba, North and South Dakota, and Minnesota may have effectively opened a new niche, or portion thereof, for small predators such as red fox, skunks, badgers and raccoons (Stoudt, 1969, personal communication). These species of small predators have recently increased their numbers and have immigrated into northern regions of the Great Plains (Sanderson, 1966).

Sanderson (1949) indicated that an increase in the production of late litters may have contributed to the population explosion in Missouri during the 1940s; differential mortality in favour of females may have been the causal factor (Sanderson, 1960).

Growth and Development

Techniques for determining the age of raccoons were developed in the early 1940s and have evolved from the measurement of length of various external body characters and body weight to the study of growth rate of body tissues. Stuewer's (1943a) work on development served as a guideline and his techniques have been further developed by Petrides (1951) and Sanderson (1960). Methods developed for studies of hares, rabbits, and bears have been adapted to the study of raccoons.

Raccoons of northern latitudes were generally larger and matured more rapidly than those of southern climates (Table 1). The epiphyses closed at an earlier age, canines were longer, and body weights were increasingly greater in northern animals. Specimens collected from within the range of the northern raccoon, Minnesota, Wisconsin, Iowa, Illinois, and Missouri, were at least two pounds heavier than all other subspecies. Those from subtropical areas were decidedly the lightest in weight.

Table 1.--Maximum age, age at which the distal epiphyses of the forearm bones close, canine length, baculum weight, and body weight of adult raccoons in North America

REGION	Age at Epiphys. Closure (mo.)	Min. Canine Length (mm)	Min. Baculum Weight (g)	BODY WEIGHT (lb.)[a] mean	max.	season	Max. Age (yr.)	AUTHOR
Minnesota		8.5		16.7	22.3	summer		Schoonover (1950)
				17.5	26.0	"		Marshall (1956)
Iowa					19.0	winter		Sanderson (1949)
Illinois	14	10.0+		16.7	26.0	"	7	Sanderson (1960, 1961a)
	16	10.0+						Grau <u>et al</u>. (1970)
Missouri			2+		26.0			Sanderson (1949)
				14.9				Nagel (1943)
Michigan				14.4	21.6	summer		Stuewer (1943a)
Ohio		6.0		14.3	19.5	"		Preble (1941)
s.e. U.S.A.				12.6	17.4	"		Dozier (1948)
Washington				11.5	17.0	all yr.		Scheffer (1950)
S. Carolina				10.7				Cunningham (1962)
Mississippi				10+	12.3	spring		Cagle (1949)
Alabama	24		2.5	10.3	19.4	all yr.	16	Johnson (1970)
							13	Haugen (1954)
							9	Lueth (1967)
Georgia				10.7				Cunningham (1962)
Virginia				10.2				Kellner (1954)
				9+				Shaffer (1948)
Florida				12.4		winter		Caldwell (1963)
Key Vaca, Florida				5.3				Nelson & Goldman (1930)

[a] Body weights of females excluded

Adult raccoons may be separated from juveniles on the basis of weight. According to Stuewer (1943a), Michigan specimens weighing less than 14 pounds and with canine teeth less than 10 mm long could be considered juveniles. Sanderson (1949) divided the two age groups at 15 pounds during the hunting season in Missouri. Minimum weights of males and females were six and seven pounds in southwestern Alabama, and five and seven pounds in east-central Alabama (Johnson, 1970). A male and a female from the same litter captured in November at Horicon Marsh, Wisconsin weighed 17.5 and 16.3 pounds, respectively (Dorney, 1954). In Minnesota, Marshall (1956) recorded July weights of 6.5 and 6.0 pounds for juveniles; Mech et al. (1966) stated that yearlings and adults were seven pounds heavier than juveniles at any given time.

Stuewer (1943a) found that juvenile raccoons became emaciated in winter because fat accumulated in autumn was quickly used up during cold weather denning. Sanderson (1961a) measured an average weight loss in juveniles of 2.7 pounds in 63 winter days and a gain of 6.8 pounds in 116 summer days. Mech et al. (1968) stated that seasonal weight fluctuations were more extreme in raccoons in northern Minnesota than in southern Michigan. A female bore a litter in March although she had lost 11.75 pounds over winter. June, September, November and January weights of this animal were 10.5, 11.7, 19.0 and 8.5 pounds, respectively. She did not produce young that year and by August and October, weighed 11.0 and 21.0 pounds, respectively. Johnson (1970) reported similar but less extensive seasonal trends in Alabama raccoons, the average December weight being greater by 20% than the average May weight. Mean seasonal weights of adults in Ohio, from summer through spring, were: 10.9, 12.7, 15.3, and 10.3 pounds (Urban, 1970). Sanderson (1951) excluded body weights of females from age comparison data because of pregnancy; parous females weighed 1.8 pounds less than nonparous specimens.

According to Sanderson (1949), raccoons that weighed less than 8.0 pounds during the Missouri hunting season were from late litters. Late young of the year comprised 1.6% of the harvest in 1940-1941 and 3.4% in 1948-1949. The smallest juvenile killed in 1949-1950 on Horicon Marsh weighed 8 pounds 14 ounces; however, 7 of 17 raccoons taken the next year weighed less (Dorney, 1954).

Petrides (1950) found that canine length was unreliable for estimating age in captive raccoons. According to Johnson (1970), those with sharp, full grown canines with little attrition on the molars were one to two years old. Rue (1964) considered animals with canines with slight wear as two years old and Stuewer (1943a) believed well worn teeth an indication of animals older than two years. Extensive wear of canines indicated that raccoons were at least three years old (Rue, 1964) and complete erosion of molar crests, older than three years (Petrides, 1950).

As an animal grows older, the epiphyses at the ends of the long bones are gradually replaced by bone tissue until the cartilage disappears entirely. Hale (1949) demonstrated the presence of the proximal epiphyseal cartilaginous groove of the dried humerus of the cottontail rabbit (Sylvilagus floridanus) by scraping with a knife. Petrides (1950) used x-ray techniques to ascertain the degree of closure of the distal epiphyses of the radius and ulna of raccoons.

Sagar (1958) was able to identify three age classes in raccoons: class I, the epiphysis is separated from the end of the bone by a well defined gap; class II, a cartilaginous plate fills the gap; and class III, complete ossification of the epiphysial plate. Both Sanderson

(1961a) and Johnson (1970) cautioned that there is much overlap in age groups determined by this method.

Lord (1959) utilized the weight of eye lenses to determine birth dates for cottontail rabbits. Sanderson (1961b) employed this technique for raccoons of known age; he constructed a growth curve which determined the month of birth for specimens less than one year old and the year of birth for nonjuveniles. The curve was generally applicable to juvenile raccoons in Alabama although considerable overlap occurred between subadults and adults (Johnson, 1970).

According to Montgomery (1963), freezing and decomposition before fixing reduced dry weights of eye lenses. He calculated that erroneous results would be reduced to only 2% in any sample if only eye lenses with smooth, shiny surfaces and free from black residue of the equatorial ring were used.

Sexual characteristics have been used as criteria to determine age in raccoons. Stuewer (1943b) separated yearling and adult females by the size and condition of teats; teats of unbred animals were 3 mm long or less and pinkish in color, those of parous females were a minimum of 6 mm long, wrinkled and pigmented. Sanderson (1949) considered autumn females with small teats as either young of the year or nonparous yearlings approximately 20 months old. Petrides (1951), meanwhile, considered that teat size was an indication of breeding or nonbreeding only and could not be used to determine age. Seven females considered pregnant on the basis of teat size and condition had nonpregnant uteri (Sanderson, 1961a).

Size and condition of the baculum has been used successfully to establish age in males. Sanderson (1949) considered raccoons with bacula less than 90 mm long, less than 2 g, and with a cartilaginous distal end, juveniles. Os peni of adults were large and ossified at both ends, the basal portion porous (Sanderson, 1961a). Stuewer (1943a) and Petrides (1950) described an enlarged and roughened basal portion and a basal decurvature in adult bacula. Johnson (1970) established three age groups based on baculum weight: juvenile, not exceeding 1.2 g; subadult, 1.5 to 3.0 g; and adult, 2.5 to 5.4 g. Ossification of the penis was complete at approximately 15 months, however the weight increased until the third year.

Fetal and Early Juvenile Development

Llewellyn (1953) measured crown-to-rump lengths of a single litter at three stages of intrauterine development and at birth. He developed a growth curve for raccoon fetuses: measurements of 22, 45, 65, and 93 mm crown-rump length indicated raccoons in their twenty-first, thirty-fifth, forty-sixth, and sixty-third day of fetal development, respectively. According to Sagar (1958), hind foot measurements are accurate indicators of fetal age, and crown-rump measurements, of embryonic stages in raccoons. Fetuses preserved in AFA (Alcohol-Formalin-Acedic Acid) or formalin may twist and flex and thereby cause erroneous crown-rump length measurements.

Newborn raccoons weigh 2 to 3 ounces, are blind and fully furred (Rue, 1964; Doutt et al., 1966), and approximately 7 inches long (Linsdale, 1928). According to Whitney and Underwood (1952), they may be hairless. The eyes open at 18 to 24 days, most frequently at 19 days (Whitney and Underwood, 1952; Rue, 1964; Doutt et al., 1966: Johnson, 1970). Young are weaned before 12 weeks (Berard, 1952) and leave the den by the tenth week (Stuewer, 1943b; Whitney and Underwood, 1952; Doutt et al., 1966). According to Stuewer (1943b), milk teeth are shed at 16 to 20 weeks. Lehman (1968) estimated the ages of two juveniles at

13 to 15 weeks whose deciduous teeth were still present, although the permanent canines had broken through the gum. Their weights and standard measurements were: male, 1.78 kg, 527, 155, 85, and 51 mm; female, 1.85 kg, 540, 153, 85 and 50 mm.

Montgomery (1968) described development of the pelage in raccoons from birth to 12 days of age using as criteria the appearance of the face mask, tail rings, and fur growth on the flanks. These animals moved and climbed well at six to seven weeks and began eating solid food at nine; growth rate decreased during this period but accelerated with the intake of solid food and functional weaning. Schoonover (1950) captured juveniles away from the den as early as June 29 and August 2 in Minnesota and Scheffer (1950) reported young accompanying females on August 24 and 30 in Washington.

Mating and Reproduction

According to Stuewer (1943b), raccoons are promiscuous. This may not be the case; Cahalane (1947) reported that males seek females in winter dens and copulate with the mother and perhaps all receptive daughters that are denning with her. Whitney and Underwood (1952) reported pairing in January followed by an inactive period, copulation, and semihibernation until warmer weather. A short time before parturition, some 63 days following copulation (Stuewer, 1943b: Sanderson, 1960), the female chases out last year's litter and her current mate and fiercely defends the den from all intruders until the young have been raised (Rue, 1964). Lactation occurs for 12 to 14 weeks (Stuewer, 1943b; Berard, 1952); nurslings begin taking solid food and are functionally weaned before 14 weeks.

It is apparent that raccoons indigenous to more severe climates in the northern and northeastern parts of the range reproduce at about the same time of year as those elsewhere (Table 2). Schoonover (1950) established that the breeding season of northern Minnesota raccoons occurred one to two weeks later than that of the southern Michigan population. The peak of the breeding season was during February and March, although January matings were noted. Parturition occurred as late as September throughout the range. So the breeding season of raccoons in North America may extend from January to July, or a period of six months.

Lord (1960) suggested that mortality rates that decimate northern animal populations may be compensated for by an increased litter size. Raccoon litters reported for the range of the northern raccoon contained 3.5 or more raccoons, or a mean of 4.3. Litter size of southern subspecies, on the other hand, varied from 1.9 to 4.0, with a mean 2.9 (Table 2).

Sanderson (1949) suggested that raccoons born in the wild in August and September were the result of second matings by females that had lost their first litters. This theory was upheld by Whitney and Underwood (1952) who reported second matings two to six months after unsuccessful pregnancies. In captivity, a second litter was produced when the first was lost; a second female became receptive within 16 days after her newborn litter was removed (Bissonnette and Csech, 1938).

It is generally agreed that female raccoons are physically capable of breeding at the age of 10 months although the proportion of yearlings that bear young is unknown. Stuewer (1943b) and Sagar (1958) reported that 50% of female raccoons bred during their first mating season in Michigan and Ohio. According to Sanderson (1949, 1960), most

Table 2.--Reproductive seasons and mean litter sizes of raccoons in North America

REGION	REPRODUCTIVE PERIODS Estrus	Parturit.	MEAN NO. BORN	LATE LITTER	AUTHOR
Alberta	Feb-Mar	Apr-May	4.0		Soper (1946)
Minnesota	---	---	4.6		Mech & Turkowski (1966)
	---	May	---		Schneider (1968)
Wisconsin	---	---	1.8+		Dorney (1954)
Illinois	mid-Feb	mid-Apr	3.5	Aug	Sanderson (1961c)
	---	May	4.5		Ellis (1964)
Iowa	Feb-Mar	Apr-May	3.6		Cabalka (1952)
Missouri	Feb	Apr	4.0	Aug	Sanderson (1949)
Kansas	---	---	4.6		Stains (1956)
Michigan	Feb	Apr	4.0		Stuewer (1943a)
	mid-Jan[a]	mid-Mar	4.6		George & Stitt (1951)
New York	---	---	5.0		Llewellyn (1952)
Indiana	Jan-Feb	Mar-Apr	---	July	Brooks (1959)
	---	---	---	Sept	Lehman (1968)
Ohio	Feb	Apr	4.1	May	Sagar (1958)
Pennsylvania	Jan	Mar	---		Doutt et al. (1966)
New England	Jan	Mar	---	Aug	Whitney (1931)
	Feb	Apr	---		Whitney & Underwood (1952)
s.e. U.S.A.	Feb-Mar	Apr-May	3.2	Sept	McKeever (1958)
Texas	Feb-Mar	Apr-May	3.4		Wood (1955)
Arkansas	---	---	---	Aug	Cahalane (1947)
Maryland	---	---	2.3		Llewellyn (1952)
N. Carolina	---	---	1.9		Llewellyn (1952)
S. Carolina	Mar	May	2.8	Sept	Cunningham (1962)
Virginia	Feb-Mar	Apr-May	2.3		Shaffer (1948)
	Jan-Feb	Mar-Apr	4.0	Aug	Kellner (1954)
	---	---	---	Aug	Berard (1952)
Alabama	Feb	Apr	2.5		Johnson (1970)
Louisiana	---	---	3.8		Cagle (1949)
Georgia & Florida	---	---	3.2		McKeever (1958)
n.e. Florida	Jan	Mar	---		Ivey (1948)
Washington	---	---	2.0		Scheffer (1950)

[a] Unseasonally mild January temperatures

yearling females mated in Missouri and 35% in Illinois. Less than 10% mated in Minnesota (Schoonover, 1950) and in Alabama (Johnson, 1970).

Asdell (1946) reported that the large proportion of animals that have multiple births are less fecund immediately after puberty than at older age. Whitney and Underwood (1952) observed this phenomenon in raccoons; in New England, litters from yearlings were three to four, whereas those from adults were five to six. Neither Stuewer (1943b) nor Sagar (1958) found significant differences in mean litter size between yearlings and adults.

It has been reported that male raccoons are capable of copulating at any time of the year (Stuewer, 1943b; Asdell, 1946; Rue, 1964). However, fertile matings probably do not result during every season. Sanderson (1949) reported that Missouri raccoons bred from January to June, and litters were born as late as August; the testes of three males examined in April did not contain motile sperm; therefore it was concluded that part of the population was infertile by that time.

Data concerning whether or not male raccoons breed during their first spring is incomplete. Johnson (1970) found sperm in epididymides of Alabama raccoons in December; whether they produced offspring was not determined. Sanderson (1951) reported that captive yearling males in Missouri were capable of breeding by late March. It was doubtful that many had bred successfully because the female population had probably been serviced by older males that became reproductively active a month earlier.

There are external and internal criteria for determining breeding condition in raccoons. According to Asdell (1946), females become receptive to males one to two weeks after the onset of vulval swelling and remain in heat for three days. Stuewer (1943b) noted that the vulva returned to normal size and color in three to four weeks. He described nipples of females in estrus and following parturition as dark, wrinkled and more than 6 mm in length. Teats of nonparous females were smooth, pinkish and 2 to 3 mm long. The former were considered to be either pregnant or postpartum. However, Sanderson (1961a) examined seven females that would be considered parous by secondary sexual characteristics but which contained nonparous uteri.

Lechleitner (1959) observed a 7% difference between the numbers of corpora lutea and rupture sites in ovaries of blacktailed jackrabbits and suggested sectioning in order to observe all corpora lutea present. Corpora lutea counts and indices of ovarian size have facilitated productivity studies in raccoons (Sagar, 1958; Sanderson, 1950, 1961c; Lord, 1960; Johnson, 1970). Sanderson (1961c) found that corpora lutea persisted approximately 75 days following ovulation in raccoons; Sagar (1958) reported that they were unreliable as indicators of litter size only 30 days after parturition.

Sanderson (1961c) explained that a pigmented scar indicating the site of implantation forms in the uterine mucosa for each 20-day old raccoon embryo. This is discernable for at least six months and infrequently may persist for 30 months. However, in order to see all pigmented areas clearly and obtain accurate counts, inspection should take place within three months of parturition (Sanderson, 1949). Sagar (1958) found that placentation sites more than a year old could be demonstrated in uteri which had been cleared in wintergreen oil.

Dozier (1947) described two embryos in the process of resorption in one of 15,000 muskrats. These were smaller than the live ones and of an abnormal grey color. Intrauterine deaths observed in two raccoon litters by Sagar (1958) were of similar appearance but in a third, were indicated by two round, pink swellings. Although transuterine migration of fertilized eggs has been found frequently in animals with bipartite uteri, reports of this phenomenon in the raccoon are infrequent (Llewellyn and Enders, 1953; Sagar, 1958).

The criteria for determining breeding ability of male raccoons have been size of testes and the presence of sperm in testes and epididymides. The testes reach full size, about 30 mm length (Stuewer, 1943b), in autumn of the second year of life (Stuewer, 1943a; Asdell, 1946; Whitney and Underwood, 1952; Johnson, 1970). Sanderson (1961c) reported maximum and minimum testis lengths in December and July, respectively. Johnson (1970) found that testicular weights in March were significantly greater than those in May or June but noted that they were directly proportional to body weight; maximum testis weights occurred prior to periods of maximum conception rates. Testicular volume was used successfully to indicate breeding ability in blacktailed jackrabbits (Lechleitner, 1959); however, this technique had not been reported for raccoons prior to this study.

Plenert (1962) estimated relative abundance of sperm in epididymal and testicular smears of blacktailed jackrabbits and assigned numerical indices: 0 = no sperm, 1 = occasional, 2 = frequent, 3 = many, and 4 = masses of sperm. Sanderson (1961c) used a similar technique for raccoons and concluded that more accurate counts were obtainable from epididymides. According to Sanderson (1949), size of testes or presence of sperm do not indicate breeding ability; it is first necessary to establish that the sperm present are viable.

Whitney and Underwood (1952) believed the mating season was determined by increasing day length. In controlled experiments (Bissonnette and Csech, 1938) whereby raccoons were subjected to 24 hour daylight periods, the normal breeding time was advanced from February to December and the mean date of parturition occurred 40 days early. Similarly, raccoons fed high-protein diets produced a larger number of litters than those fed high levels of carbohydrates. Increased ambient temperature may stimulate reproduction; George and Stitt (1951) recorded an unprecedented peak in breeding rate during unseasonally warm weather in mid-January.

Raccoon Activities

Evaluation of raccoon movements and home range has been facilitated by live-trapping and marking procedures (Stuewer, 1943a; Schoonover, 1950; Lueth, 1967; Cunningham, 1962). However, Geis (1966) pointed out the superiority of radio telemetry for studying seasonal activities and behaviour of raccoons as they related to food availability, denning, and breeding. Schneider (1968) used this technique to locate pregnant females in dens and to maintain surveillance of litters throughout summer and fall. Data concerning maternal behaviour, litter size, cub growth and mortality rates, weaning, and movement of the family unit was collected.

Burt (1943) defined home range as that area traversed by an individual in its normal activities of food gathering, mating, and caring for its young. Although complex designs of home range measurement exist, the most useful has been developed by Hayne (1949), who constructed a polygon from the external points of activity that delimit a minimum home range.

It is generally agreed that males move greater distances and utilize larger areas than females (Stuewer, 1943a; Cunningham, 1962). Adults maintain larger home ranges than juveniles (Stuewer, 1943a). Stuewer measured maximum home ranges of 2, and 1.4 square miles for adult male and female raccoons, respectively, and 0.6 square miles for juveniles. The area of activity of an adult male in Alabama was 245 acres (Johnson, 1970); in Minnesota it was 40 and 600 acres (Schoonover, 1950).

Whitney and Underwood (1952) noted that raccoon families commonly travelled about 1 mile per night but in all, extended this to as much as 5 miles. A family of five limited their activities to less than 0.25 square miles during summer (Sanderson, 1950) and a female with a juvenile remained with a 0.5 square mile area until August (Geis, 1966).

Schneider (1968) described the summer and fall activities of raccoon families in Minnesota. Cubs remained in the den for the first 50 to 60 days before they were moved to ground beds in wetlands. The female and litter fed together and remained in close contact throughout the summer. In autumn the young often travelled separately but congregated prior to the denning period in November. Sunquist (1967) studied postwinter movements of a female raccoon and three juveniles and found that they travelled as a unit 1% of the time and maintained individual activities 68% of the time. A common area of 110 acres was used.

Young raccoons dispersed from natal areas most frequently during spring the year after their birth; older, established animals usually lived in the same vicinity year after year (Whitney and Underwood, 1952). Stuewer (1941) reported that raccoons travelled a maximum distance of 27 miles from the point of release. Lueth (1967) and Cunningham (1962) recorded movements of 7 and 4.7 miles, respectively. On the basis of a calculated sex ratio of 14 males to 86 females, Butterfield (1944) concluded that males dispersed more frequently than females. Geis (1966) and

Urban (1970) reported that males travelled farther than females.

Of 256 raccoons transplanted to unfamiliar areas in Arkansas, males were captured at points 3 to 75 miles distant and females 2 to 16 miles (Giles, 1943). Distances of 27, 33 and 75 miles were reported by Cahalane (1947). According to Priewert (1959), a juvenile male moved from Minnesota to a point 165 miles distant in Manitoba. Lynch (1967) recorded a dispersal of the same distance by a juvenile male in Manitoba.

According to Sanderson (1966) and Johnson (1970), conventional concepts of home range cannot be applied to raccoons. Sanderson cautioned that "... sizes and shapes of species home ranges have little significance in themselves ..."; the interaction between the animal and its environment are factors essential to understanding the significance of home range. Ellis (1964) noted that raccoons changed the location of their home ranges from month to month and Cunningham (1962) noted regular shifts from one habitat type to another. Geis (1966) found that activities of South Dakota raccoons were affected by seasonal availability and palatability of foods. Animals with well established home ranges periodically relocated at distant points, apparently attracted to ripening fruits (Grinnell _et al._, 1937; Costa, 1951; Geis, 1966); entire family units made these relocations (Whitney and Underwood, 1952; Sharp and Sharp, 1956).

Shallow water had an effect on raccoon movements. Salt marsh raccoons in Florida actively fed day or night during low tieds and rested on floating mats of vegetation during high tides (Ivey, 1948). Urban (1970) noted that raccoons along Lake Erie's south shore spent 87% of their time in marshes. He concluded that raccoons were directly dependent on the amount of available shallow water in areas where food was abundant.

Movements of raccoons during the breeding season differ from those of the remainder of the year. Johnson (1970) found that adult males extended their normal range in late winter to establish temporary residence with sexually active females. On the other hand, Urban (1970) described an equal distribution of males throughout the year, indicating that changes in movement patterns did not occur. Schneider (1968) reported that pregnant raccoons in Minnesota used one tree cavity for winter dormancy and breeding activities, and another in which to give birth and raise their litters. The home range of a female was limited, some 34 acres, before and after parturition, and movement decreased from 107 to 9 yards (Ellis, 1964). Similarly, Urban (1970) was unable to live-trap adult female raccoons March 15 to June 1, the peak in nesting activities.

The effects of weather on raccoon movement during summer and early autumn have been partially clarified by field observations. Stuewer (1943a) stated that raccoons were less susceptible to inclement weather than other species; however, little is known concerning this. According to Shaffer (1948), raccoons were more active during high temperatures and abundant rainfall in summer. During heavy rainfall, a female and two cubs did not cease hunting activities (Slagle, 1965). Although neither nocturnal cold nor rain had any noticeable influence on raccoons, high daytime temperature made them seek cool retreats in marsh vegetation (Geis, 1966). Stuewer (1943a) and Cunningham (1962) found that June through August was the period of maximum travel.

Stains (1961) claimed that temperature had the greatest influence on raccoon activities in winter; wind velocity was of secondary importance. Geis (1966) noted movement during periods of mild temperatures and Johnson (1970) reported extensive activity on warm, rainy winter nights.

Temperatures of approximately 30 F associated with high wind velocity reduced feeding activities, and a subsequent reduction in temperature induced dormancy (Sharp and Sharp, 1956). Temperatures of 25 F curtailed movement by Georgia raccoons (Cunningham, 1962).

Whitney and Underwood (1952) believed that the winter denning period was controlled by temperature. Whitney (1931) reported that inactivity was induced in New England raccoons in autumn at 30 F and was maintained at 15 F during winter. In Ohio, a raccoon remained inside the den when temperatures dipped to 25 F in September (Urban, 1970).

Several workers have observed that deep snow may hamper winter travel by raccoons. In Maine, inactivity resulted when an overnight drop in temperature to -6 F was followed by a 15 inch snowfall (Johnson, 1939). Stuewer (1943a) stated that deep snow was more influential than low temperature in forcing raccoons to seek cover in early winter, however, cold weather was the predominant factor during the remainder of the winter. Cabalka (1952) pointed out that, with the onset of cold fall weather, Iowa raccoons sought winter dens, and deep snow did not restrict their activity until late November.

Male raccoons travelled great distances in search of receptive females when temperatures were as low as 0 F in late winter and early spring.

Denning

Den types utilized by raccoons in North America are summarized in Tables 3 and 4. Within the range of Procyon lotor hirtus Nelson and Goldman, tree cavities were used extensively in winter; underground dens and cellars were of secondary importance (Table 3). However, in northern

Table 3.--Den types utilized by raccoons during winter and early spring in North America[a]

AREA	DEN TYPE							AUTHOR
	Tree Cavity[b]	Squirrel Nest	Tree Branch	Basement	Burrow	Ground Surface	Islands[c]	
Manitoba						1		Sowles (1949)
Minnesota	8							Schoonover (1950)
				8				Mech & Turkowski (1966)
	8							Mech <u>et al</u>. (1966)
						8		Mech <u>et al</u>. (1968)
South Dakota	3			8				Geis (1966)
Wisconsin	1				8	1	1	Dorney (1954)
Iowa	8				4			Cabalka (1952)
Missouri	8	5	1					Sanderson (1949)
Kansas	8							Stains (1961)
Michigan	8				4			Berner & Gysel (1967)
	8				3			Stuewer (1943a)
Ohio	8							Preble (1941)
Kentucky	8				6			Bailey (1933)
Alabama	8			3				Johnson (1970)

[a] Intensity of use of each den type assigned an arbitrary value between one and eight; maximum utilization given eight unit value

[b] Includes wood duck nests

[c] Includes muskrat and beaver houses

and prairie areas, where suitable den trees are not abundant, wood duck boxes, ground vegetation, and squirrel nests were used. Mech and Turkowski (1966) found 23 raccoons denning together in an abandoned basement, and Geis (1966) reported several cellars used by raccoons in winter. Raccoons have been known to live in haystacks and outbuildings of inhabited farmsteads during severe weather. Dorney (1954) reported exclusive use of underground dens in winter and ground beds and muskrat houses in summer on Horicon Marsh. He concluded that availability of tree dens was not a factor limiting large raccoon populations.

A general shift to more exposed day beds was apparent in the summer samples from northern regions (Table 4). Ground beds were used in every state except Missouri and Kansas; they provided the only summer resting sites in Minnesota. Abandoned buildings gave protection especially in late spring and early summer when the young were raised. According to Geis (1966), federal programs have promoted the abandonment of farmsteads in South Dakota and vacant buildings have provided new denning sites for raccoons.

Tree cavities were used most frequently as dens where they were available. The lack of tree dens was claimed one of the most important factors limiting the abundance of raccoons in Ohio and elsewhere (Preble, 1941; Stuewer, 1943a; Gysel, 1961; Johnson, 1970). Wood duck nests frequently replaced tree cavities as the preferred den type. Although burrows were used infrequently, surface beds of marsh or forest vegetation, or of the roofs of muskrat houses, were in common use in summer.

Stains (1961) reported that fluctuations in temperature inside two tree dens reflected those of the ambient temperature but were not as

Table 4.--Den types used by raccoons during summer and fall in North America[a]

AREA	Tree Cavity[b]	Tree Branch	Attic	Burrow	Ground Surface	Islands[c]	AUTHOR
	DEN TYPE						
Minnesota					8		Schoonover (1950)
					8		Mech *et al.* (1966)
South Dakota			3	1	8	1	Geis (1966)
Wisconsin	1				8	4	Dorney (1954)
Centr. Iowa		3	1		8		Cabalka (1952)
East. Iowa				8			Giles (1942)
Missouri	8	2		2	2	2	Noren (1941)
Kansas	4	1		1			Linsdale (1928)
Michigan		8		3			Stuewer (1943a)
	2						Stuewer (1948)
Ohio	9					1	Sagar (1958)
	6			2		6	Urban (1970)
Virginia	8			3	2		Kellner (1954)
	1				8		Shaffer (1948)
Texas	3					1	Baker & Newman (1942)
Florida		4				4	Ivey (1948)

[a] Intensity of use of each den type assigned a value between one and eight; maximum utilization given value of eight

[b] Includes wood duck nests

[c] Includes muskrat houses

pronounced, varying 1 F for every 5.4 F ambient. Microenvironmental temperatures followed the daily ambient by one to two hours in one tree, and by four to five hours in the other. Berner and Gysel (1967) observed greatest den activity in hollow trees and in ground burrows in April and May and least activity in August and September.

Food Habits

The first published report of raccoon food habits was that of Alexander Henry in 1809 (Seton, 1929) who observed that mice were the principal prey in southern Michigan. Burroughs (1900), Stone and Cram (1904), and Seton (1929) reported additional observations. However, it was not until the 1930s that fecal droppings and stomach and intestinal contents were used in investigations of food habits (Martin *et al.*, 1951).

Whitney (1931) identified, but did not quantify, the contents of 128 stomachs and intestines of New England raccoons collected October through January. They consisted of corn, oats, nuts, wild cheeries, apples, plums, crickets, white grubs, and trout. The diet was generally high in carbohydrates and there was a greater utilization of protein in spring. Sowles (1949) observed purple-tinted droppings, containing numerous chokecherry pits, in foot-high mounds in a tree bluff in Manitoba during February. These data were qualitatively important but the quantities of each food item were not reported.

Dearborn (1932) first presented qualitative and quantitative analyses of foods eaten by raccoons. These were reported as percent occurrence and percent of the total fecal volume. Johnson (1939) and Giles (1940) introduced the concept of seasonal availability and palatability of food species and their effects on seasonal diets of raccoons. This approach has been used by Schoonover (1950), Tyson (1950), Costa (1951), Hamilton (1951), Yeager and Elder (1945), and Geis (1966).

Foods eaten by raccoons in North America are presented in Table 5. Plant materials, especially wild fruits, mast and cultivated grains, were generally predominant in every season. Several workers have noted a correlation between raccoon utilization of cultivated grains and the availability of wild fruits and mast. According to Schoonover (1950), the sudden depredation on corn by raccoons in Minnesota was due to a failure in the wild berry crop; corn was not normally taken throughout summer whenever wild fruits were available. Giles (1940), Stuewer (1943a), Hamilton (1951), and Dorney (1954) reported shifts in preference by raccoons from corn to ripening wild fruits or nuts in mid-summer and fall.

Mammals were classified as important foods of raccoons in seven states; these were mainly muskrat and meadow voles. Of the 19 states reported, only in Illinois was waterfowl an important part of the raccoon diet; this was 65% by volume following the hunting season. According to Schoonover (1950), less than 0.5% of the spring diet of Minnesota raccoons consisted of waterfowl. Noren (1941) found remains of five ducks and two coots in 200 scats collected in Missouri; they accounted for 3.5% of the diet.

Duck eggs have been eaten by raccoons. Dorney (1954) reported that egg remains composed 7% of raccoon scats collected during a low duck population. Andrews (1952) and Bandy (1965) attributed poor duck nesting success on Lake Erie marshes to predation; black duck and mallard egg shells were found in 2 of 30 raccoon scats (Urban, 1970).

Many species of wild fowl other than ducks have provided food for

Table 5.--Important foods reported for North American raccoons[a]

Area	Summer	Fall	Winter	Spring	Author
	SEASON				
North Dakota		Grain Insects Crayfish Rodents [b]			McKean (1948)
Minnesota	Wild fruit Crayfish Insects Acorns	Corn Sm. mammal Insects *Sylvilagus* [b]			Schoonover (1950) Mech & Turkowski (1966)
South Dakota	Crayfish Corn Insects Mammals	Corn Insects Plums Vertebrates	Corn Mammals Insects Birds	Corn Fish Insects Birds	Geis (1966)
Wisconsin	Muskrats Crayfish Fruit Snails	Grapes Crayfish Fish ---		Crayfish Muskrats Corn Fish	Dorney (1954)
Iowa	Fruit Insects Corn Crayfish	Corn Fruit Insects Crayfish	Corn Crayfish Birds *Sylvilagus*	Corn Insects Grass Crayfish	Giles (1939, 1940) Costa (1951)
Illinois		Fruit Insects Corn Crayfish	Geese Fruit Insects ---		Yeager & Rennells (1943) Yeager & Elder (1945)
Missouri		Insects Corn Crayfish Fruit [b]			Noren (1941)

[a] Only the four most abundant items are included

[b] Combined seasonal analyses

Table 5.--Continued

Area	SEASON Summer	Fall	Winter	Spring	Author
Colorado		Corn Fruit Insects Crayfish			Tester (1953)
Michigan	Crayfish Fruit Corn Insects	Fruit Corn ---- ----	Fruit Corn ---- ----	Fruit *Microtus* Crayfish Corn	Dearborn (1932) Stuewer (1943a)
Ohio		(Corn *Sylvilagus* Vegetation Insects)[b]			Baker *et al.* (1945)
New England	Grain Insects Fruit Frogs	(Fruit Corn Wood Mammals)[b]			Whitney (1931) Johnson (1939) Hamilton (1936, 1940)
New York	(Fruit Corn Insects *Ondatra zibethica*	Corn Fruit ----)[b]			Hamilton (1936, 1940)
Washington	(Molluscs Crustaceans Fish Annelids)[b]				Tyson (1950)
Pennsylvania		(Fruit ---- ---- ----)[b]			Grimm & Roberts (1950)

Table 5.--Continued

Area	SEASON				Author
	Summer	Fall	Winter	Spring	
Texas	Fruit Crayfish Insects ----	Fruit Crayfish Insects ----	Fruit Crayfish Mammals Insects	Crayfish Fruit Fish ----	Baker *et al.* (1945) Wood (1954)
Maryland	Fruit Crayfish Snails ----	Fruit Insects Corn ----	Fruit Corn Insects ----	Tubers Crayfish Rodents Snails	Llewellyn & Uhler (1952)
South Carolina	Insects Fruit ---- ----	Insects Fruit ---- ----	Insects Birds ---- ----	Insects Birds Fruit ----	Kinard (1964)
Alabama	Fruit Corn Tubers Insects	Fruit Tubers Insects Corn	Fruit Tubers Corn ----	Tubers Fruit Insects Crayfish	Johnson (1970)
Florida		(Fruit Insects Peanuts ----)[b]			Caldwell (1963)

raccoons: geese (Yeager and Elder, 1945; Llewellyn and Webster, 1960), coots (Noren, 1941; Stoudt, 1965), pheasants, Phasianus colchicus (Hamilton, 1951), sharp-tailed grouse, Pediocetes phasianellus (McKean, 1948), and ruffed grouse, Bonasa umbellus and wild turkeys, Meleagris gallopavo (Henry, 1969).

Pennsylvania was the only state in which invertebrates were found not to be important raccoon foods. However, 82% crayfish and insects were reported for South Dakota (Geis, 1966), and a majority of marine invertebrates for Washington (Tyson, 1950). Invertebrates were described as staple foods of raccoons by Dearborn (1932), Preble (1941), and Dorney (1954).

Population Characteristics

Few attempts have been made to measure accurately numbers of raccoons. Johnson (1939) estimated fewer than one per square mile and Twitchell and Dill (1949) 627 per square mile. Densities ranging from 19 to 64 per square mile have been reported by Yeager and Rennells (1943), Stuewer (1943a), Butterfield (1944), Dorney (1954), Cunningham (1962), Mech et al. (1968), Urban (1970), and Johnson (1970). Lynch (1972) calculated a raccoon population of 3.3 per square mile on Delta Marsh, Manitoba.

Johnson (1939) censused raccoons with hounds, Stuewer (1943a) smoothed a road each day and counted tracks of toe-clipped raccoons the next morning, and Dorney (1954) multiplied by two the number of raccoon dens in an area, to estimate population size. Their estimates were low in relation to those obtained by applying live-trapping results to the Lincoln (1929), Schnabel (1938), and Schumacher-Eshmeyer (1943) indices and to the point-slope method of Hayne (1949).

Indices were used to estimate raccoon population sizes by Mech et al. (1968) and Urban (1970), however they reported exceedingly wide confidence limits and questioned the precision of their results. Others have realized that the assumptions that validate the use of indices to measure population size do not hold for raccoons: differences in habitat types in the sample area (Cunningham, 1962), dispersal by juveniles and yearlings (Cunningham, 1962; Caldwell, 1963; Urban, 1970), trapping bias as to sex or age (Preble, 1941; Cunningham, 1962; Urban, 1970; Johnson, 1970), and behavioural reactions by raccoons to traps (Stuewer, 1943b) were attributed to this effect. Caldwell (1963) compared relative number of raccoon trails struck by a hound in five different habitats and found that raccoons were most numerous in swampy areas, moderately abundant in farmland and second growth habitat, and least numerous in "flatwoods". Similar results were obtained, using this method, by Ivey (1948).

Current changes in size and structure of raccoon populations have been correlated with shifts in sample sex and age ratios. A sex ratio highly in favour of males during low population and an even sex ratio when raccoons were very abundant were observed in Missouri (Sanderson, 1951) and in Maine (Twitchell and Dill, 1949). The sex ratio dropped from 1.08 to 0.9 during a population increase between 1941 and 1959 in Illinois (Sanderson, 1960). During this period, Sanderson (1951, 1960) and Sagar (1958) reported increases in the proportion of juveniles. According to Caldwell (1963), a Florida raccoon population was declining on the basis of a 1.49 sex ratio and 0.59 age ratio. Sanderson (1949) proposed calculating average weights of the annual raccoon hunting take to determine population trends. A weight increase would mean fewer juveniles and therefore a decline in overall numbers.

Detailed study of population structure requires basic calculations of sex and age ratios, proportion of breeding females, and average litter size. Demographic data for North American raccoons are presented in Table 6. Stuewer (1943a) reported that spring populations of females in Michigan were composed of even numbers of breeding and nonbreeding yearlings and breeding adults. A breeding potential of 2.66 young per female was calculated from an even sex ratio among all breeding age groups and an average litter size of four.

Wood (1955) calculated the rate of increase in population: R = AYF, where A = number of adults, Y = number of young/adult, and F = percentage of reproductive females. Petrides (1950) defined turnover rate as the number of years required for the young produced in a given year to be reduced to 0.5% of their original numbers:

$$T = \frac{\log 0.005}{\log (1-j)} + 1,$$

where "j" represented the proportion of juveniles in the sample. Petrides included a calculation of life span, or average number of years an individual of a given population would be expected to live:

$$L = \frac{1}{j}$$

Sanderson (1951) converted the "j" in Petrides' formula to include juveniles and yearlings and produced estimates of life span of 1.8 years and population turnover rate of 7.4 years for Missouri raccoons. Johnson (1970) calculated 3.1 and 10.0 years, respectively for Alabama raccoons.

Natural mortality in raccoons has been due to starvation, extreme parasitism, and disease (Whitney and Underwood, 1952; Kellner, 1954; Doutt <u>et al</u>., 1966; Mech <u>et al</u>., 1968). Aliev and Sanderson (1966) found that deep snow at the end of a severe winter may make access to food

Table 6.--Sex and age ratios of North American raccoon populations

Year	Sex Ratio M/F[a]	Age Ratio J/A[b]	Author
1934	1.27		Bennitt and Nagel (1937)
1939	1.52		Preble (1941), Dellinger (1954)
1940	1.50		Noren (1941)
1941	1.45	1.00	Giles (1943), Sanderson (1951, 1960)
1942	1.31		Nagel (1943), Stuewer (1943b)
1947	1.72		Shaffer (1948), Petrides (1950)
1948	1.00		Twitchell & Dill (1949), Petrides (1950), Scheffer (1950)
1949	1.07	1.45	Schoonover (1950), Sanderson (1951), Dorney (1954), Cabalka (1952)
1950	1.00		Sanderson (1951)
1951	0.93		Wood (1955)
1952	1.26		McLaughlin & Grice (1952), Dellinger (1954)
1950+	2.60	3.40	Stains (1956)
1956	0.88		Sagar (1958)
1959	0.90	2.30	Sanderson (1960)
1960	1.44	0.45	Cunningham (1962), Caldwell (1963)
1960+	1.70	1.08	Wood & Odum (1964)
1966	1.18	1.00	Mech *et al.* (1968), Urban (1970)
1968	1.61	0.54	Johnson (1970)

[a] M/F = males per female

[b] J/A = juveniles per adult

impossible; since body fat has been exhausted, many die (Novikov, 1956). According to Robinson et al. (1957) and Johnson (1970), malnutrition may weaken the animal and increase susceptibility to disease and parasitism. Mech and Turkowski (1966) stated that 65% of juvenile mortality in Minnesota was due to starvation and parasitic infection during winter and spring. Disease and parasites of raccoons were listed in detail by Whitney and Underwood (1952), Sanderson (1960), Scatterday et al. (1960), Mech et al. (1968), and Johnson (1970).

Natural enemies of raccoons include many predators that have been extirpated from large portions of their former ranges. Bobcats (Lynx rufus), wolves (Canis lupus) and fishers (Martes penanti) have disappeared from large areas of the North American continent and have been replaced by man and his hounds (Preble, 1941; Sanderson, 1960). Preble calculated that raccoon mortality due to feral dogs was approximately 20% as extensive as the annual hunter kill of raccoons in Ohio. Kellner (1954) listed dogs as the only natural enemy of Virginia raccoons. Predators of young raccoons are: fishers, foxes, lynx (Lynx canadensis), bobcats, owls, hawks, and alligators (Preble, 1941; Whitney and Underwood, 1952; Sanderson, 1960: Doutt et al., 1966; Aliev and Sanderson, 1966; Johnson, 1970). Giles and Childs (1949) found remains of raccoons in 4 of 38 alligator stomachs. Coyotes have been suspected of preying on raccoons, however Bond (1939) and Murie (1945) found no trace of raccoon remains in coyote stomachs.

According to Sanderson (1960), Mech et al. (1968), and Johnson (1970), mortality is greatest in immature raccoons; the highest rate occurs during the first winter and early spring of life and early in the yearling year. Sanderson (1950) marked young in the den and found them alive in midsummer. Therefore, he concluded that death rate of nestling raccoons in Missouri was less than 10%. Llewellyn (1952) reported unaccountable losses of juveniles during summer and early fall and concluded that a high mortality rate was common during that season.

Ricker (1958) described a method to estimate mortality rate in animals older than one year. He expressed the ratio between the number of animals retrieved one year (sample B) and two years (sample A) after marking as juveniles, as per cent survival (S):

$$S = \frac{B}{A} \times 100$$

Maximum juvenile mortality within family groups has been estimated by comparing the number of young accompanying the female with the number of placental scars. Maximum mortality rates of 35% (Mech and Turkowski, 1968), 4% (Sanderson, 1960), and 21% (Cunningham, 1962) were reported. Schneider (1968) recorded the loss of two entire litters and one individual from each of three other litters by March of the year following birth; a mortality of 57%. Mech <u>et al</u>. (1968) investigated seven litters; two were lost before leaving the nest and three more died or dispersed from the study area; a mortality of 71%. Five of 13 remaining yearlings died in March, the most critical month for young raccoons. It is not known whether wild raccoons eat their young, although this has been observed in captivity (Sanderson, 1949; Sagar, 1958).

Lord (1960) estimated preimplantation, postimplantation and postparturition losses in litters of raccoons by comparing numbers of corpora lutea, uterine scars, and embryos. An excess of corpora lutea over implantation sites indicated death of zygotes before implantation; a greater number of uterine scars than embryos, feti or nestlings indicated postimplantation losses and accounted for resorption of embryos. Sanderson (1950) found equal numbers of placental scars and nestlings in five captive females and, in a sixth, four scars and three young; postimplantation mortality for the entire sample was 4%. The mean number of placental scars and feti reported by Johnson (1970) was 2.45 and 2.62, respectively, or a mortality rate of 6.1%.

Economic Relationships

Raccoon furs were valued at $135,000 a year during the 1920s and 1930s by the Canadian fur industry (Rand, 1948). In the United States, more than $7,000,000 was realized from the export of an annual average of 1.5 million raccoon pelts during the period 1960 to 1964 (U.S. Department of Commerce, 1966). The number of pelts sold annually in various states has been reported: 100,000 in Missouri and Illinois, 80,000 in Iowa (Sanderson, 1960), 174,000 in Alabama (Johnson, 1970), and a minimum 22,500 in Minnesota (Schoonover, 1950). The fur industry in Russia reported similar numbers in the 20 years since raccoons were imported (Redford, 1962).

The United States economy has been enhanced by the purchase of licenses, sales of pelts and carcasses, and development of the coon-hound market. In Tennessee, 17,170 raccoon hunters spent $65,172 on food and lodging during the 1966-1967 hunting season; Alabama hunters expended 214,422 man-days hunting raccoons (Johnson, 1970). Sanderson (1960) reported that the raccoon was a major game species in mid-eastern United States and calculated that 29,000 Iowa hunters made 376,000 trips to hunt raccoons. This was approximately 8% of all hunting in 1955-1956. Kansas hunters spent $240,000 annually for upkeep of raccoon hounds (Stains, 1956). Some 25,000 to 50,000 raccoons were sold annually as food in the United States (Sanderson, 1960) at values from $0.75 to $1.50 each (Schoonover, 1950).

Schoonover (1950) recalled the "year of the 'coon" in Minnesota when extensive damage to corn fields, cribs, and shocks resulted in the shooting of 50 raccoons in one 50-acre field. In South Dakota, a $\frac{1}{4}$-acre sweet-corn patch was destroyed in one night (Geis, 1966). Costa (1951) reported that 5 of 17 farmers censused had experienced significant corn damage.

Raccoons have taken domestic fowl when wild foods were not available and, according to Mech et al. (1968), visited farmyards as a last resort during periods of extreme hunger. Tester (1953) reported minor predation on poultry in Colorado, and Sanderson (1960) and McKean (1948) found infrequent predation on chickens in Illinois and North Dakota.

Raccoon predation on duck nests may be locally extensive (Table 7). In the prairie potholes of Manitoba, canvasback duck nest losses increased from the 1940s (Evans et al., 1952) to the 1960s (Olson, 1964; Stoudt, 1969) with the influx of raccoons into the area. Stoudt (1969) reported nesting success rates for redhead ducks, mallards, ruddy ducks, pintails, blue-winged teal, and coots that were equivalent to those of canvasback ducks (mean = 43.5%) in the years 1963 to 1969. These ranged from 32 to 59% for coots and ruddy ducks, respectively. He found raccoons to be the major predator on all species; they were responsible for more than 50% of the nests destroyed. Stoudt studied the possibility that natural loss of habitat may have been responsible for high predation rates. The number of potholes that dried up throughout the duck nesting season of each year was considered an index to the amount of available nesting cover lost. He noted that an average 25.4% of the potholes dried up between 1964 and 1969 and the range was 1 to 44%.

Table 7.--Rates of predation on duck nests by raccoons in North America

Area	Species	NESTS DESTROYED n	No. Lost	% by Raccoons	Author
Maryland	Mallard, Canvasback, et al.	227	92	100	Stotts (1958) Llewellyn & Webster (1960)
Vermont	Wood duck	50	16	100	Miller (1952)
Maine	Ring-necked	552	26	100	Mendall (1958)
Illinois	Wood duck	3000	1230	37	McLaughlin & Grice (1952) Bellrose (1953)
Iowa	B.W. Teal	186	146	7	Glover (1956)
Manitoba	Canvasback	---	87	35	Olson (1964)
	"	1200	680	58	Stoudt (1969)

Bellrose (1953) claimed that raccoons killed one wood duck hen for every three nests destroyed. Nests in natural tree cavities in Illinois were taken in large numbers, 42% (Sanderson, 1960); metal nest boxes provided were also subject to predation (Eaton, 1966). Vasil'Kov (1966) attributed reductions of goldeneye duck populations in Russia to raccoon predation and Onno (1966) reported a 59% loss of eider duck nests to foxes, raccoons, crows and man in Eatonia.

Yeager and Elder (1945) noted 3% bird, mostly goose, in the diet of Illinois raccoons prior to the goose season; during the post season, this figure was 65%. Ducks and coots were utilized by raccoons on Horicon Marsh (Dorney, 1954), and 90% duck material in the diet of California raccoons was ascribed to use of crippled ducks (Rue, 1964).

Mendall (1958) found that nests of ring-necked ducks on floating islands were seldom preyed upon except those near shore. Hammond and Mann (1956) showed that nesting success was considerably greater on offshore islands and that nests in shooting blinds located more than 100 yards from land were seldom destroyed. Miller (1952) believed raccoons followed the biologist to wood duck nest boxes. According to Hammond and Forward (1956), ducks flushed from the nest during routine nesting studies defecate on the nest as they take flight and the resulting odor serves to attract predators.

Wilson (1953) found 64 of 85 muskrat houses in a North Carolina tidal marsh destroyed by raccoons and noted that the number of muskrat pelts sold annually declined by 90% during five years. Bednarick (1953) found 8% muskrat remains in raccoon scats, and Urban (1970) reported a high utilization of muskrats from the same marsh in Ohio. Urban concluded that raccoons had eaten large numbers of diseased muskrats or had scavenged on the carcasses. Rue (1964) stated that raccoons fed on muskrats in traps.

Many species of furbearer and game animal have been killed by raccoons. These include mink (Mech and Turkowski, 1966), cottontail (Llewellyn and Uhler, 1952; Rue, 1964; Mech and Turkowski, 1966), and squirrels, Sciurus spp. (Rue, 1964), and trout (Whitney, 1931).

According to Johnson (1970), there is no clear-cut evidence that raccoons have been involved in outbreaks of disease in man or domestic animals, with the possible exception of rabies. Scatterday et al. (1960) reported an outbreak of epizootic rabies in raccoons from western to central Florida and into the extreme southeastern United States; transmission of the virus to man during this time was not established.

Management

Management of raccoons has taken various forms usually dependent on whether their populations were of sufficient size to result in significant damage to agriculture and wildlife. Low population levels have prompted attempts to increase their numbers through stocking, habitat improvement, and manipulation of hunting laws. Eradication programs have been implemented to prevent depredations on grain and predation upon wildfowl nests.

Stuewer (1941) realized that stocking raccoons in Michigan was expensive and did not increase the hunter and trapper take; Whitney and Underwood (1952) advocated stocking raccoons in New England. Johnson (1970) cautioned against the possibility of introducing disease into populations and advised that it would be more profitable for hunters to improve habitat.

The most important deficiencies for Alabama raccoons were late-winter foods and den trees (Johnson, 1970). Maintenance of open areas next to woodlands was advised in order to provide a ready source of insects, the major buffer against starvation in winter and early spring; damage to cultivated crops could be alleviated by encouraging wild plum and blackberry growth. Maintenance of vacant buildings and protection of trees suitable as winter-spring dens was also suggested. Stuewer (1948) suggested the construction of artificial nest boxes to replace tree cavities that were being lost to man's activities.

Johnson (1970) encouraged laws to prevent extermination of entire raccoon families treed as a group by hunting hounds. Preble (1941) proposed killing only males when possible in order to maintain breeding stock.

Management has been used in attempts to completely eradicate raccoons when they were numerous and damaged crops or wildlife. Recently, biologists have suggested that such damage was usually by individuals which developed preferences for certain foods, therefore control should be on a local basis rather than by indiscriminant killing of entire populations (Geis, 1966; Johnson, 1970). The most effective means of killing large numbers of raccoons has been by the use of hounds. Noren (1941) reported that hunters harvested more than 70% of the raccoons taken in Ohio. Atkeson and Hulse (1953) considered public hunting to be the most effe- tive means of reducing a raccoon population in Alabama where trapping had been unsuccessful and Caldwell (1963) reported similar results in Florida. Johnson (1970) stated that hunting was extremely efficient and selective, and therefore a powerful raccoon management tool.

Balser et al. (1968) conducted a controlled predator extermination program over a six year period in an attempt to increase waterfowl production. Killing was indiscriminant of predator species. Nest success on the treated area was 2.05 times as great as that on the control plot and the number of ducklings surviving to flight stage was 1.56 to 1.65 times greater.

METHODS AND MATERIALS

The study consisted of eight broad phases: trapping and marking live raccoons, collecting carcasses, radio telemetry, examination of denning habits, quantifying foods utilized, investigating raccoon predation on diving duck nests, analyses of carcass materials, and investigation of population dynamics. Field work began on June 7, and continued through August 30, 1967. It was resumed on April 15, 1968 until August 31, 1969.

Raccoons were trapped, ear tagged, and toe clipped in order to determine population size and structure and extent of annual and seasonal movements. During 1967, 12 National live traps (no. 30) and 12 wood and wire box traps of the type described by Sanderson (1949) were used; 42 Sanderson traps were used for the remainder of the study. Sardines, eggs, corn, grain, meat scraps, and freshwater clams (*Anodonta grandis*, *Lampsilis radiata*) were used singly and in various combinations as bait. Shiny lures or aluminum foil were hung from the top of the trap.

Trapping continued into late fall of 1968 in order to determine the proportion of juveniles in the population and to equip raccoons with radio transmitters for determination of fall activities. Trapping was resumed from mid-March until the end of May, 1969 to equip additional animals with radio transmitters to determine spring activities.

Raccoons were anesthetized in a sealed chamber using equal parts of ether and chloroform. When the desired level of anesthesia was achieved, the animal was removed and this level was maintained with a nose cone containing the ether-chloroform mixture. Raccoons were tagged in both ears with consecutively numbered no. 4 self-piercing tags, style 4-1005 (National Tag Company, Newport, Kentucky) that were inscribed DWRS (Delta Waterfowl Research Station).

Raccoons were also marked by toe clipping (Stuewer, 1943a) in order to identify them by their tracks as a supplement to the recapture data. This technique employed a numbering system from left to right in which the toes of the front feet represented the number 1 to 0, and those of the hind feet, 10 to 100. This permitted the marking of 200 different animals numbered 0 through 199. Habitat conditions made the identification of animal tracks difficult, particularly when the outside toes of each foot were removed. Therefore, the method was modified and combinations of the three innermost toes were removed. Raccoons with missing digits or feet were not toe clipped.

Data collected included sex, age, and standard measurements. Standard measurements included length of the body, tail, hind foot, ear, and upper canine, and body weight. Tooth wear, teat size and condition of lactation in females, and any abnormalities were recorded.

Raccoons were collected from the pothole region and from other widespread points in southern Manitoba, by hunting, and from road kills, or were made available through the courtesy of professional trappers and local hunters. Nestlings were removed from dens located outside the designated study zone. Data similar to that obtained from live trapping raccoons were taken. A forearm, eye, and the reproductive tract were removed from each carcass and preserved in 10% formaldehyde for subsequent determination of age and reproductive condition. Digestive tract materials were removed for food habits analyses.

Raccoons were collected from the study area during July and

August, 1969, just prior to termination of the study, in order to retrieve as many marked animals as possible and to reclaim non-functioning radio transmitters. These animals were of particular value as indicators of approximate age and for determining reproductive history and movements for the entire three year study period.

A thorough search of raccoon breeding dens was carried out during spring to collect nestling raccoons and pregnant or nursing females. Nestlings located within the boundaries of the trapping area were tagged, standard measurements taken, and were returned to the nest. Those taken outside this area were killed and processed. Coon hounds were used to locate active dens as well as to collect weaned, mobile young of the year.

Lenses were removed from eyes, preserved in formaldehyde and dried in a Boekel oven at 100 C for 100 hours until their weight was constant. Those lenses with a black equatorial ring material or a milky opalescense indicating freezing or decomposition were discarded (Montgomery, 1963). Dried eye lenses were removed from the oven individually, to minimize hygroscopic weight gain, and immediately weighed to the nearest 0.001 g on a Sartorius (Sartorius Werke, Gottingen, Germany) analytical balance. Weights were compared to those of known-age raccoons reported by Sanderson (1961b) to estimate age.

A forearm and hand were collected from each raccoon carcass. The phalanges were removed and the radius and ulna were cut off proximal to the distal epiphysis. These were x-rayed using 14 x 17 inch cassettes to determine the degree of epiphysial closure. The specimens were grouped into three age classes, a modification of the criteria used by Lechleitner (1959).

Bacula were dried in the Boekel oven at 80 C for four days, removed and weighed to the nearest 0.01 g on an Ohaus Dial-O-Gram balance (Ohaus Scale Corporation, Union, New Jersey). These were assigned to the three age classes: juvenile, yearling, and adult, according to weight.

The three age classes were used to describe the developmental stages of raccoons collected in all seasons. Young of the year taken before February were categorized as juveniles and those collected at later dates were classified as yearlings. Yearlings were classified adults after August of the second year of life.

The reproductive condition of males was determined by testicular and epididymal volumes and smears. A testis and epididymis were immersed in water in a graduated cylinder and the resulting increase in volume recorded. Smears from each of the testis and epididymis were prepared by placing a drop of ground tissue in water on a glass slide, air drying, and staining with Geimsa stain. A compound microscope, with a 43X objective, was used to estimate the relative number of sperm. Sperm were counted by means of a modification of Plenert's (1962) system of indices: no sperm = 0; infrequent sperm = 1; many sperm = 2; and masses of sperm = 3.

Each ovary was sectioned longitudinally with a razor blade (Cheatum, 1949) into approximately 1 mm sections. These were stained with Geimsa stain, when necessary, and the number of corpora lutea counted.

Embryos and fetuses were removed from uteri and sexed when possible. The ages of fetuses were estimated by comparison of crown-rump (fetal position) lengths with the age curve presented by Llewellyn (1953). Dates of conception and parturition were determined by extrapolating from ages of embryos, using a 63 day gestation period. The number of placental scars and evidence of resorption were noted; uteri with longitudinal striations were considered parous.

Analysis of activities of raccoons was facilitated by a map of the study area constructed from a mosaic of aerial photographs. It included all roads, a railroad, potholes, tree bluffs, inhabited and uninhabited farms, and granaries. The locations of scrub piles (trees and shrubs bulldozed into mounds) and other possible raccoon denning sites were plotted following a reconnaissance of the area. This map was reduced to 8 x 11 inches and duplicated so that a large number were available for field use.

Information concerning seasonal movements of raccoons was provided from trapping and tracking data. Marked animals were captured repeatedly over a three year period at various points on the study area and were relocated infrequently by identification of the pattern of clipped toes. On occasion, raccoons were held at bay by coon hounds and anesthetized by means of intramuscular injection with sernylan (phencyclidine hydrochloride, Parks, Davis and Company) using a syringe pole. Marked animals killed outside the study area provided supplementary information. Habitat at the site of collection and distance travelled from the last location trapped were noted. Movements were plotted on maps and the minimum home range of each raccoon was estimated (Hayne, 1949).

Movements and denning activities of raccoons were monitored by radio telemetry during October and November, 1968. Raccoons were radio tracked from early April to the end of June, 1969 to observe dispersal of yearling raccoons and to correlate the time spent foraging on potholes with rate of predation on diving duck nests.

Radio transmitters similar to those developed by Cochran and Lord (1963) and modified by Verts (1963) were used. Six different frequencies at intervals of 25 hertz, from 27,000 to 27,125 hertz, were used. The receiver was similar to that used by Geis (1966) and consisted of a converted walkie-talkie (Lafayette HA 60, citizen's band) fitted with a manual sensitivity control and a directional loop antenna. Six crystals designed to receive signals at the selected frequences were inserted manually into the receiver.

Transmitter-equipped raccoons were located in the field by means of triangulation. Compass readings indicating the direction of strongest signal from three known positions were plotted on the field map. The average point of convergence of these three lines was accepted as indicating the position of the animal.

Each radio-tagged raccoon was tracked continuously for several hours after release, then fixes were taken at hourly intervals until the animal chose a daytime resting site and remained there for at least one hour. This resting site was checked several times during the day to ensure that an unexpected movement of some distance could be monitored and that the animal did not move out of range of the receiver. Vigilance was relaxed after the third day of tracking and the frequency of readings was reduced to four or five a night and one during the day.

During spring and summer, coon hounds were used to search scrub piles, granaries and vacant buildings for adult raccoons and family groups. Winter dens were located by tracking radio-equipped animals, through investigation of possible nest sites, and by following raccoon tracks in snow. The frequency of use of each type of den provided information concerning seasonal needs for resting and reproductive activities.

Two dens active at the beginning of the winter denning period were chosen for more thorough study of their protective qualities. These were the basement of a vacant house, monitored from November 22, 1968 to March 31, 1969; and an abandoned fox den, monitored from January 21 to March 31, 1969. Temperatures in the nest were taken twice daily to compare microenvironmental changes with the trends in ambient weather conditions. A thermister probe was placed in each nest so that the terminal sensitive bead was two inches above the den floor. It was not possible to determine the exact positioning of the probe inside the fox den; it probably was directly on the den floor. The plug end of the lead was placed so it was protected from accumulating snow and could be manipulated without disturbing the den occupants. Temperatures were read with a protable telethermometer (YSI Model 42 SC, Yellow Springs, Ohio) equipped with a cicuit jack into which each thermister plug was temporarily inserted.

Temperatures were taken at dawn and at mid-day, the coolest and warmest periods. Periods of emergence of raccoons from winter dens were assessed by radio telemetry during late November, 1968, and by daily reconnaissance for raccoon tracks in snow through March 31, 1969. Daily activity was compared to daily ambient temperatures and to temperatures inside the two winter dens.

Raccoon scats were removed from dens in spring and fall of each year; dens were revisited in early spring in order to collect droppings from overwintering raccoons. Scats were also gathered from the general area and from deposits by raccoons in traps. The contents of stomachs, intestines, and colons of raccoon carcasses were removed and stored in individual paper bags labelled with the number, date, locality and habitat in which collection was made. Moist samples were dried for several days before analysis.

Each scat was placed in a beaker of warm water, softened overnight, then thoroughly picked apart with probe and forceps. Anatomical parts were removed, studied with a binocular microscope employing a 1x or 3x objective and 10x ocular, and were identified using appropriate references and by comparison with identified materials in the Biology Department museum. The approximate proportion of each food item was estimated and recorded as percentage of the total volume of each scat.

Scat and digestive tract contents were analyzed separately, compared for points of agreement and categorized as spring, summer, fall and winter foods. Food types were recorded as to percentage occurrence and percentage by volume for each season. Results were compared with seasonal availability of food.

Live trapping, identification of toe-clipped animals, and the collection of nestlings and prenatal young provided the basis for determination of seasonal raccoon population trends. Mortality and turnover rate were calculated. This data was compared to similar statistics concerning raccoons of more temperate climates to assess the effects of the northern environment on survival of the Manitoba raccoon population.

The average number of corpora lutea, embryos and fetuses, placentation sites, resorbed embryos, and nestlings were compared to determine rate of intrauterine mortality and to establish the total production of young. The ratio of parous to nonparous females, and proportions of adult and yearling females in carcass collections were multipled by the mean number of young in a litter, to estimate minimum productivity.

Seasonal changes in structure of the population were established from the calculated production of young and from age ratios between adults, yearlings, and juveniles in the collection. Five periods of the year were defined as: I, March and April when juveniles were not present; II, May and June when production of young was maximum; III, July through September when late-born young were produced and those born earlier were mobile; IV, October and November when all raccoons were mobile and activity was intensive preparatory to winter denning; and V, December through February, the winter denning period.

A life table and survivorship curve were constructed to represent the average annual decline in numbers from 1,000 raccoons at birth until all were dead. The proportion of yearlings living to the age of two years, and of two year olds living to the age of three years were calculated from ratios of marked animals recaptured in subsequent years (Ricker, 1958). These results were compared with calculations of turnover rate and average longevity estimated by means of the summer yearling:adult ratio, an adaptation of the technique of Petrides (1951).

Sex ratios of yearlings and adults, collectively termed "nonjuveniles", were calculated from carcass data. Age ratios and average annual weights were determined in a similar manner. The results from 1967, 1968, and 1969 were compared in order to predict the long range trend in population size (Twitchell and Dill, 1949; Sanderson, 1951, 1960; Caldwell, 1963).

Digestive tracts of raccoons collected during May 1 to July 15, 1968 and 1969, were analyzed to determine whether proportions of duck materials present were comparable to intensity of predation rates as determined by the nesting study (Stoudt, 1969, personal communication). Viscera of recently killed raccoons were studied exclusively to ensure that approximate dates of feeding be known; scat contents were not considered. The number of locations of raccoons in pothole vegetation was compared to those in tree bluffs, fields, waste-lands, roadways, and farmsteads. This system was used for both the duck-nesting season and nonnesting period to indicate possible increase in intensity of pothole utilization by raccoons when duck eggs were available.

RESULTS

Live-Trapping

Eighty-four raccoons were marked (Table 8), including 45 males and 39 females, of which 15 were mobile young of the year. Of these, 82 were identified subsequently, 51 by retrapping, three by tracks in mud, and 27 were collected. Identification was made by toe-clip pattern on five occasions when recaptured animals had lost both ear tags. Single ear tags were lost on nine occasions. The total trapping effort was 8,382 trap-nights for 139 captures, or 60.3 trap-nights per raccoon taken.

Carcass Collection

A total of 293 raccoons were collected, 161 of which were killed using coon hounds and farm dogs (Table 9). Thirty-seven unweaned nestlings were taken by hand. Fifty unmarked raccoons were killed on the study area; 4, 16 and 30 in 1967 through 1969, respectively. Of 26 previously-marked animals, seven were killed outside the study area. In 1969, 13 marked and 30 unmarked animals were collected on the study area.

Collection of Nestlings

Nineteen raccoon litters, a total of 88 nestlings, were located in dens during May and June of the three study years (Table 10). Seventeen litters were complete family groups which averaged 4.88 young per litter. There were 39 males and 35 females in 16 litters in which determination of sex was possible; all but one of the other litter were not obtainable to be sexed. Thirteen individuals from six family groups were replaced

Table 8.--Histories of marking and subsequent location of 84 raccoons from the Manitoba pothole area in 1967, 1968, 1969

Year	Marked	Retrapped			Carcasses		
		1967	1968	1969	1967	1968	1969
1967	35	16	12	1	1	5	9
1968	43	--	23	1	--	4	8
1969	6	--	--	2	--	--	--
Total	84	16	35	4	1	9	17

Table 9.--Numbers of non-nestling raccoons collected in southwestern Manitoba in 1967, 1968, and 1969

Year	Method of Collection						
	Hounds	Traps	Farm Dogs	Hunters	Road Kills	Killed by Hand	Found Dead
1967	13	9	4	11	4	-	1
1968	49	31	6	6	12	3	1
1969	61	14	18	6	3	2	2
Total	123	54	28	23	19	5	4

Table 10.--Number of raccoons marked and released and number collected, from 19 nestling litters in southwestern Manitoba in 1967, 1968, and 1969

		Number of Nestlings			
Date	Litter	Total	Males	Marked	Collected
1967					
June 17	A	6	2	1	0
July 9	B	2	1	1	1
Subtotal	2	8	3	2	1
1968					
May 17	G	8	4	0	7
" 17	I	6	2	0	1
" 22	H	5	4	0	3
" 24	K	5	4	0	5
" 25	L	5	4	5	0
" 27	M	5	2	0	1
" 28	J	5	2	0	5
June 2	N	6	-	0	0
" 15	P	4	2	0	4
July 10	Q	3	3	3	1
Subtotal	10	54	28	8	27
1969					
June 10	EE	4	-	0	0
" 12	FF	4	-	0	0
" 14	CC	5	2	3	0
" 16	DD	4	0	0	4
" 21	GG	4	1	0	4
" 23	HH	5	5	0	1
Subtotal	6	26	8	3	9
GRAND TOTAL	18	88	39	13	37

in their nest. Five litters and portions of eight others, a total 37 young, were collected for growth and reproductive data. Forty-five weaned, mobile juveniles were collected for a total of 82 carcasses of young of the year.

Growth and Development

The anatomical structures selected to determine developmental changes and growth rate in female raccoons (Table 11) and male raccoons (Table 12) were eye lens weight and body weight. Baculum weight was accepted as a third category for males. The epiphyseal closure was chosen in order to have a convenient characteristic for preliminary determination of age of carcasses of raccoons in the field.

Since there was no difference in eye lens weight in males and females (Table 13), the data was pooled. Body weight of males was significantly greater than that of females, therefore this data was treated separately.

Estimates of age from eye lens weights of 54 juvenile, 15 yearling, and 19 adults compared favorably to the age curve described by Sanderson (1961b) (Figure 2). The maximum weight of 54 juvenile eye lenses was 87 mg. Of these, one was equal to, and one was greater than the minimum 85 mg for yearlings. The 15 yearling and 19 adult eye lens weights were from 85 to 119 mg and 114 to 155 mg, respectively. One yearling eye lens exceeded the minimum 114 mg weight for adults. Three adult eye lenses weighed less than the maximum 119 mg for yearlings. Averages were 49.6, 103.3, and 101.0 mg for juveniles, yearlings, and adults, respectively. Eye lens weights from raccoons to nine months of age were similar to those of Sanderson.

Two yearlings 11 months old were classified as juveniles, an error

Table 11.--Correlation of anatomical measurements of 99 male raccoons collected in southwestern Manitoba in 1967, 1968, and 1969

	Product-Moment Coefficient (r)					
	Weight		Length			
Characteristic	Body	Baculum	Body	Hind Foot	Ear	Canine
Weight						
Eye Lens	.738	.786	.764	.493	.387	.776
Body		.750	.802	.552	.421	.754
Baculum			.748	.382	.363	.637
Length						
Body				.614	.500	.753
Hind Food					.426	.479
Ear						.487

Table 12.--Correlation of anatomical measurements of 101 female raccoons collected in southwestern Manitoba in 1967, 1968, and 1969

	Product-Moment Coefficient (r)				
	Weight	Length			
Characteristic	Body	Body	Hind Foot	Ear	Canine
Weight					
Eye Lens	.678	.722	.640	.533	.595
Body		.855	.735	.649	.677
Length					
Body			.756	.678	.702
Hind Foot				.693	.551
Ear					.394

Table 13.--Comparison of anatomical measurements of 99 male and 101 female raccoons collected in southwestern Manitoba in 1967, 1968 and 1969

Characteristic	Sex	Mean	S.D.	t
Eye lens wt. (mg)	M	102.1	34.4	0.110
	F	92.1	37.6	
Body wt. (g)[a]	M	6090.3	2747.2	2.521[b]
	F	5445.5	2333.8	
Epiphyseal Closure	M	3.4	0.7	1.960
	F	3.3	0.8	
Baculum wt. (g)	M	2.2	1.7	

[a] Pregnant females excluded

[b] P)0.05

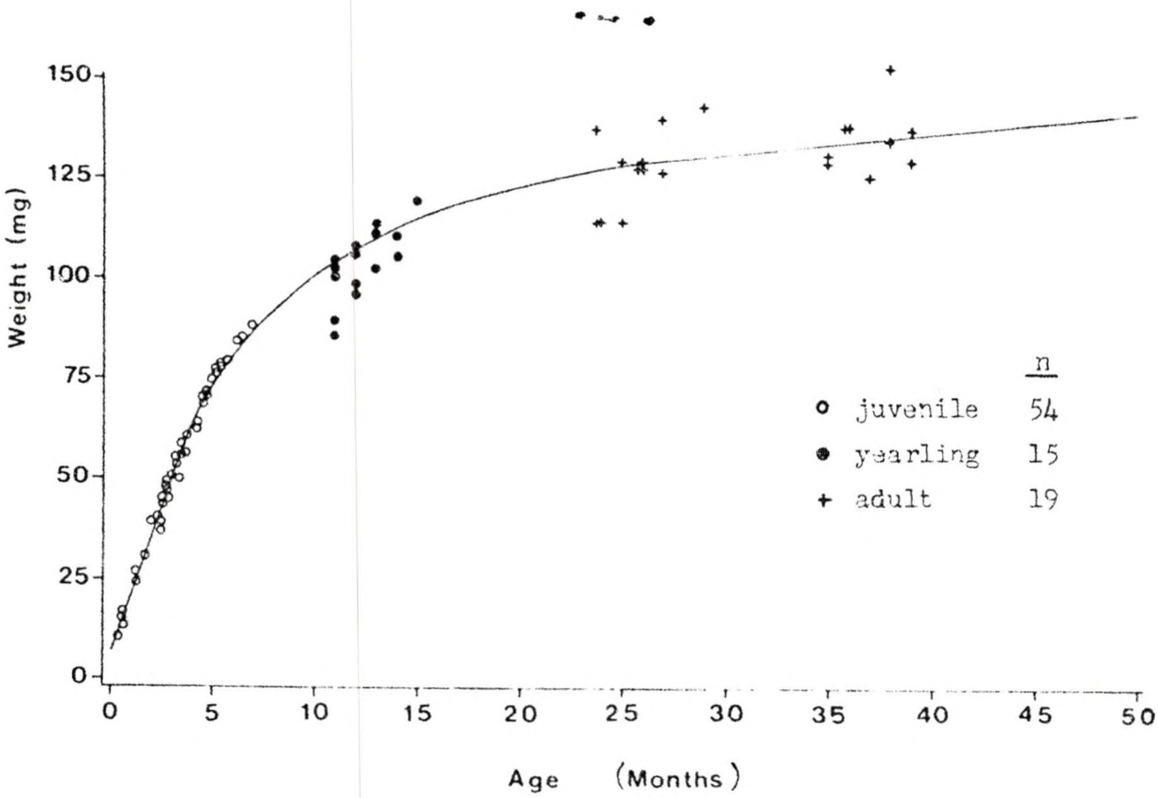

Figure 2.--Comparison of eye lens weights of juvenile, yearling and adult raccoons of approximate age collected in 1967, 1968 and 1969, with the eye lens growth curve of Sanderson (1961b)

of 2/15 x 100 = 13.3%, and one yearling (15 months) was classified as an adult, an error of 6.7%. Three raccoons at least 24 months old were designated 15 months old, an error of [illegible].

Eighty-six juveniles from birth through five months of age were classified by epiphyseal closure as age class I, 50 raccoons from 5 to 17 months old were age class II, and 23 raccoons from 12 months and older, age class III (Table 14). The majority of age class I animals became age class II at four and five months, and age class II became age class III at 14 and 15 months and infrequently at 17 months.

Baculum weights of 38 juveniles, 11 yearlings, and 11 adults were compared to age determined by eye lens weight (Table 15). Baculum weights ranged from 0.03 to 1.0 g for raccoons one to eight months old, 1.2 to 2.7 g for yearlings 9 to 17 months old, and 2.9 to 5.1 g for adults 21 months and older. Three bacula of 10 and 11 month old yearlings were less than 1.0 g and overlapped with the juvenile sample. Raccoons 18 to 20 months old were not collected; a baculum of a 17 month old yearling weighed 2.7 g, 0.2 g lighter than that of a 23 month old adult.

The criteria used to establish three age classes of raccoons: juvenile, yearling and adult, are summarized in Table 16. Raccoons with eye lenses 85 mg or less, epiphyseal category of 1 or 2, baculum weight less than 1.25 g, and collected April through January were designated as juveniles. Those with eye lens weights 85 to 114 mg, epiphyseal category 2 or 3, baculum weight 1.6 to 2.8 g, and collected February through November were yearlings. Raccoons with eye lens weights greater than 11 mg, epiphyseal closure of 3, and baculum weight of 3.0 g or greater were adults.

Body weight was variable between sexes and age groups, and seasonally;

Table 14.--Monthly occurrence of raccoons of three age classes as calculated by the degree of closure of the distal epiphyses of the radius and ulna collected in southwestern Manitoba in 1[illegible], 1968 and 1969

AGE (MONTHS)

Age Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	21	22	23	24	27	34	40	42	46	50+
I	30	20	27	8	1																						
II				15	14	4	2	3	1	2	3	2	1	1	1	1											
III												1		2	2	1	1	1	1	5	1	1	1	2	2	1	1

Table 15.--Baculum weights by monthly age of 99 raccoons collected in southwestern Manitoba in 1967, 1968, and 1969

WEIGHT	AGE (Month)[a]										
	1	2	3	4	5	6	7	8	9	10	11
Max.	.04	.20	.40	.60	1.00	.70	1.00	--[b]	1.30	--[b]	--[b]
Mean	.03	.07	.25	.34	.66	.60	.80	.80	1.25	.90	.80
Min.	.03	.04	.10	.10	.30	.50	.60	--	1.20	--	--
	AGE (Month)										
	12	14	15	17	21	23	24	34	40	42	50+
Max.	--[b]	--[b]	--[b]	2.70	--[b]	--[b]	4.80	--[b]	--[b]	--[b]	5.1
Mean	2.40	2.40	2.50	2.25	3.80	2.90	4.75	4.40	3.80	4.50	4.90
Min.	--	--	--	2.25	--	--	4.70	--	--	--	4.70

[a] Determined by eye lens weight

[b] Only one specimen

Table 16.--Comparison of eye lens weight, body weight, baculum weight, and epiphyseal closure as aging criteria for 99 male and 101 female raccoons of approximate age collected in southwestern Manitoba in 1967, 1968, and 1969

		Weight				
Age	Sex	Eye Lens (mg)	Body (g)	Baculum	Epiph. Closure	Approx. Age (mo.)
J	M	8-87	100-7500	0.1-1.5	1-2	0-8
	F		100-6000			
Y	M	85-119	3100-8800	1.25-3.0	2-3	9-15
	F		2100-8200			
A	M	114-160	4200-13000	2.9-6.3	3	15+
	F		5200-11700			

age differentiation was not precise. Maximum juvenile weights of fall specimens exceeded those of spring adults by as much as 3,300 g for males and 800 g for females. However, body weight was useful to determine age when time of year was considered.

The monthly increments in body weight of juvenile, yearling and adult raccoons reflected the effects of seasonal environmental stresses and age (Figure 3). Juveniles gained weight from birth until initiation of winter denning in November or December. Body weight of both sexes was reduced by an average of 1,500 g during the mating season. Yearling weight was 3,800 g in spring, similar to September juveniles, although body length was 22% greater than that of juveniles. This indicated that bone growth had proceeded through the first winter but that fat reserves had been depleted. Necropsy of yearlings in spring showed a lack of subcutaneous, pericardial, splenic, renal and omental fat deposits.

Body weight increased from April to November or December in the second year of life. During this time, body length measurements reached an asymptote at 580 mm. A less severe reduction in body weight occurred during the second winter and spring; mean weights of April and May adults were 1,500 g greater than those of yearlings while body length was 20 mm greater. Adult weights increased from April through mid-winter to 10,000 g and declined to a spring minimum of 7,000 g.

Exceptionally low body weights of November juveniles were probably due to an inclusion of late litters. Decreased weights of adult females during summer may have been due to an inclusion of a majority of post-partum individuals. These animals regained weight rapidly after the young were weaned and weighed the same as males by October.

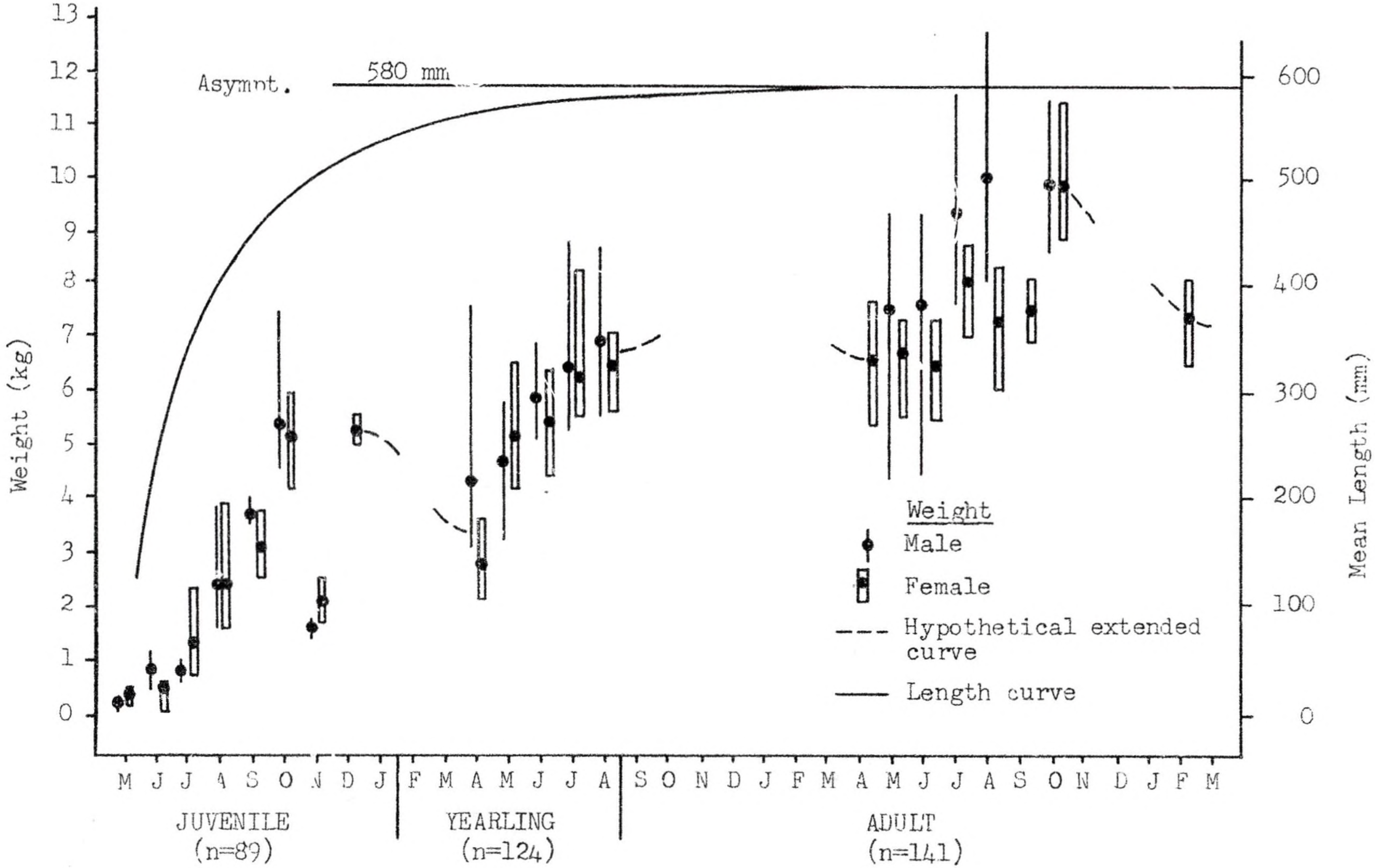

Figure 3.—Distribution of body weights and mean body lengths of 89 juvenile, 124 yearling and 141 adult raccoons to over 2 years

Prenatal Development

Information concerning the growth rate of raccoon embryos and fetuses was obtained from examination of gravid uteri; data for 11 intrauterine litters are presented in Table 17. Litters A and B were embryonic and the least developed. The crown-rump lengths were 14.6 and 15.8 mm, respectively. Although litter K had greater crown-rump, hind foot and pinna length measurements, litter J had a larger volume. Differences between the remaining groups were clearly separable.

Crown-rump lengths of all litters were compared to the curve presented by Llewellyn (1953) (Figure 4), and the approximate time of gestation determined. Ages of litters A to K ranged from 14 to 62 days, respectively. The two embryonic litters were smaller than all others and the phalanges were incompletely developed, milk ridges were apparent, and the eyelids unformed (Figure 5, Plates 1 and 2). Litter C was naked and the eyelids and nares closed (Figure 5, Plate 3); crown-rump length was over-emphasized because these specimens were extended, with the back straight and the head pulled back. Litter D was distinctly larger than C (Figure 5, Plate 4) but, due to the flexed position, the crown-rump length was only slightly greater. Litter F (Figure 5, Plate 6) was larger than both D (Plate 4) and E (Plate 5), but the eyelids were sealed and the fur was sparse.

Reproduction

Sperm was produced in adults from February to July (Table 18). However, none of these animals contained sperm of a count greater than 1 in February or July. Conversely, 77% were rated 2 or 3 in the May sample, and 25% were rated 2 or 3 in June.

Sperm was present in the testes and epididymides of 38 yearlings

Table 17.--Mean standard measurements and estimated time of gestation of 11 *in utero* raccoon litters collected in southwestern Manitoba in 1968 and 1969

	Litter										
	A	B	C	D	E	F	G	H	I	J	K
Crown-rump	14.6[a]	15.8	42.7	59.3	69.6	74.8	75.4	84.2	84.8	85.7	91.0
Hind Foot	2.5	2.5	5.4	11.8	14.3	17.7	20.2	21.8	22.7	23.0	23.9
Vibrissae	0.0	0.0	0.0	0.5	2.5	2.1	3.3	4.8	2.6	4.3	4.3
Pinna	1 -	1 -	2.0	3.5	7.0	7.0	10.0	10.5	8.0	10.0	11.0
Body Volume (ml)	0.8[b]	0.8	7.1	21.8	46.3	51.0	71.2	73.0	73.2	93.0	87.5
Approx. age (days)	14	15	33	43	48	52	53	57	58	59	62

[a] Mean length (mm)

[b] Mean volume (ml)

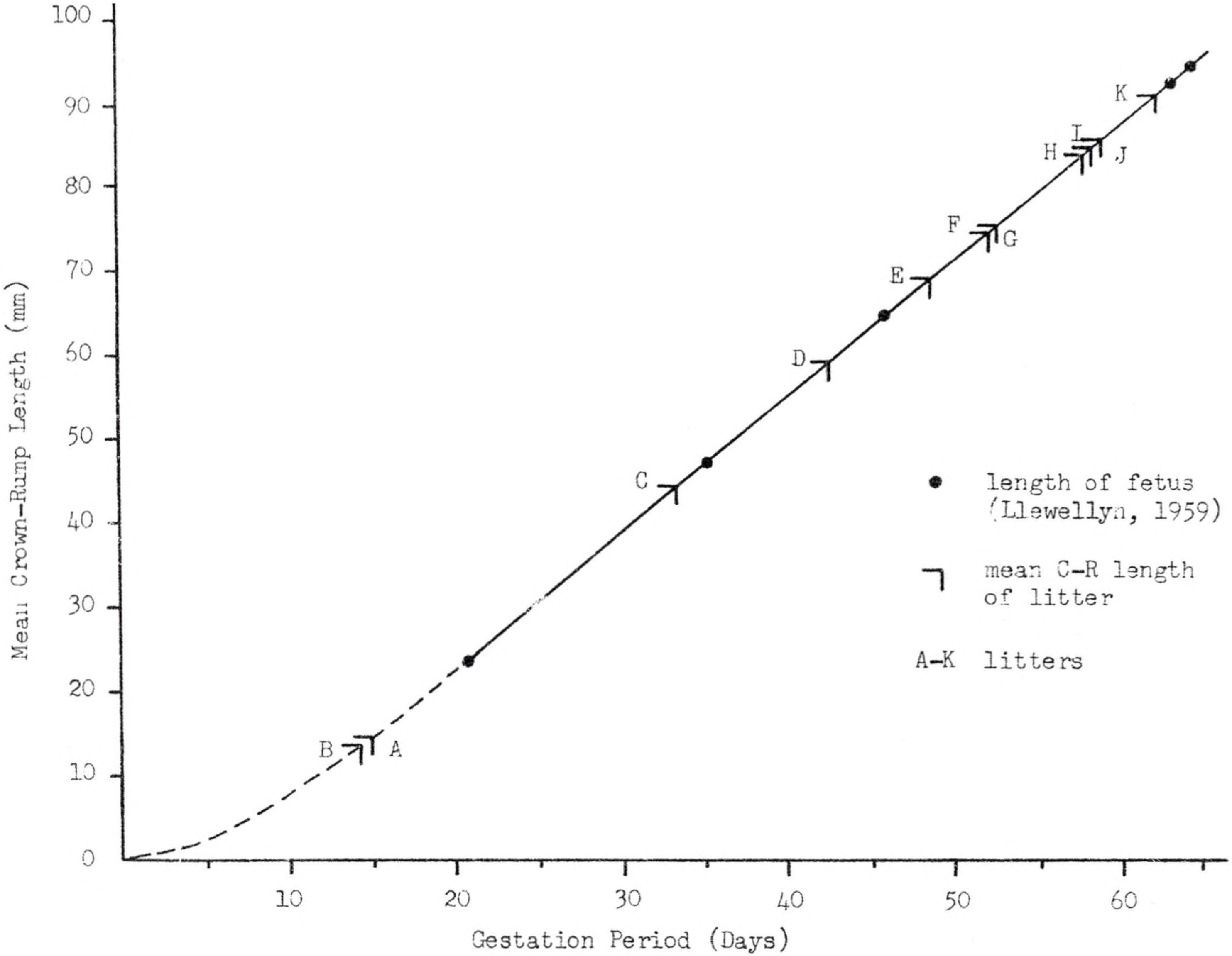

Figure 4.--Estimated ages of 11 intrauterine raccoon litters collected in the Manitoba pothole area in 1968 and 1969, using the crown-rump length curve of Llewellyn (1959)

Plate No. 1: 14 days gestation

Plate No. 2: 15 days gestation

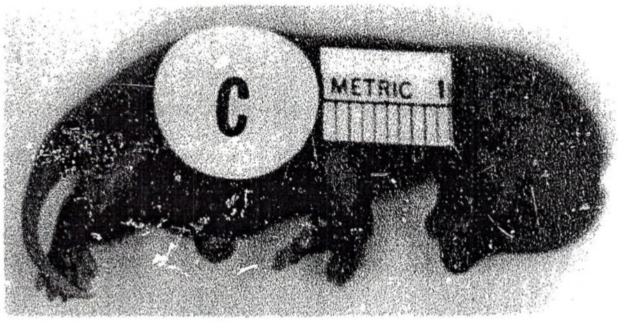

Plate No. 3: 33 days gestation

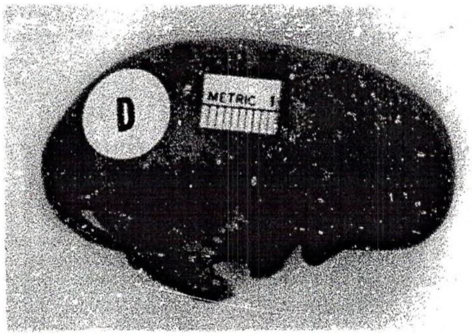

Plate No. 4: 43 days gestation

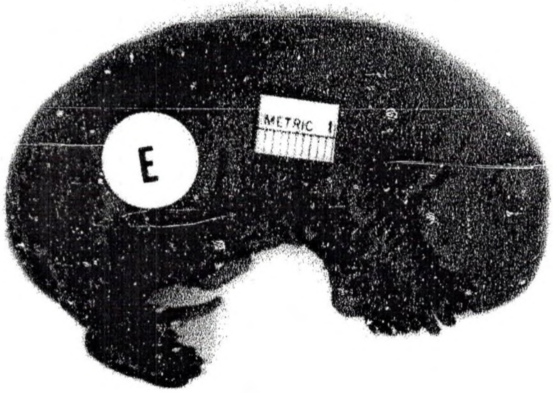

Plate No. 5: 48 days gestation

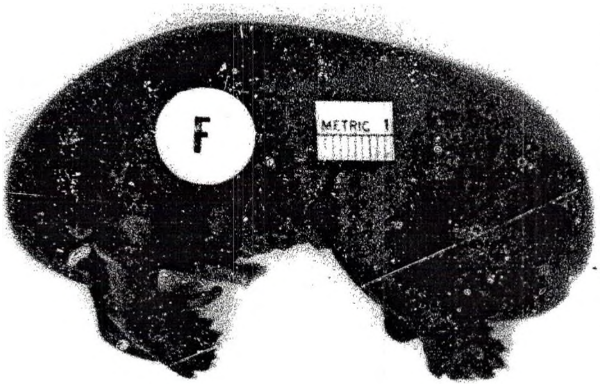

Plate No. 6: 52 days gestation

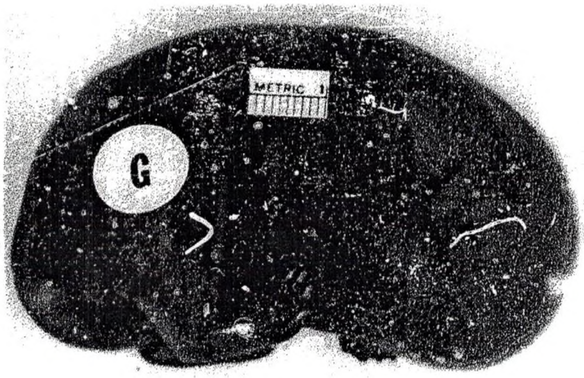

Plate No. 7: 53 days gestation

Figure 5.--Representative individuals from 11 intrauterine raccoon litters collected in the Manitoba pothole area; 1967, 1968, 1969

Plate No. 9: 53 days gestation

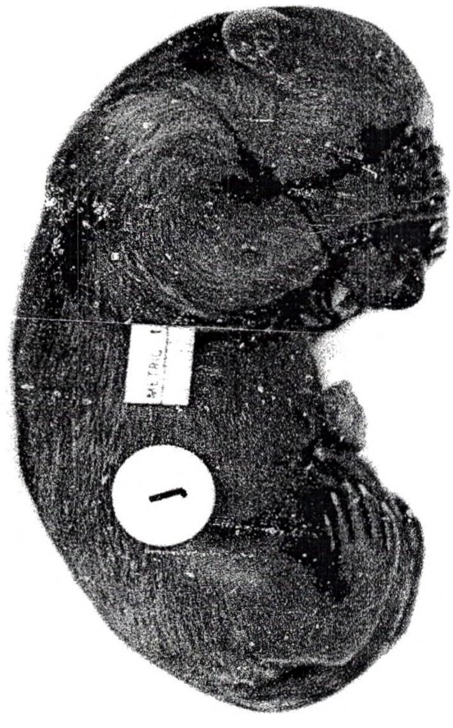

Plate No. 11: 62 days gestation

Plate No. 8: 57 days gestation

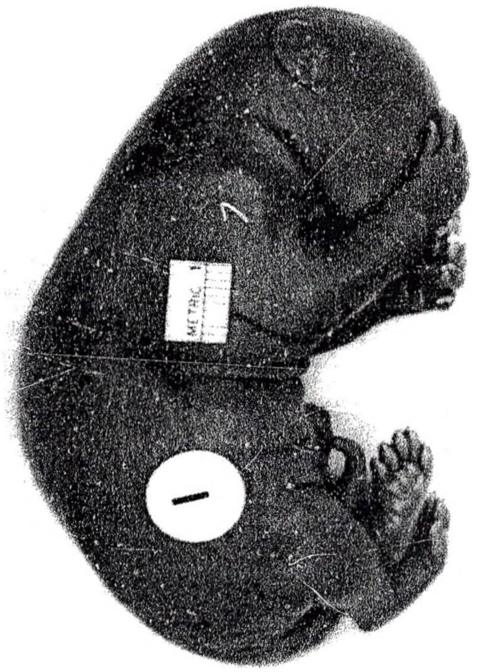

Plate No. 10: 59 days gestation

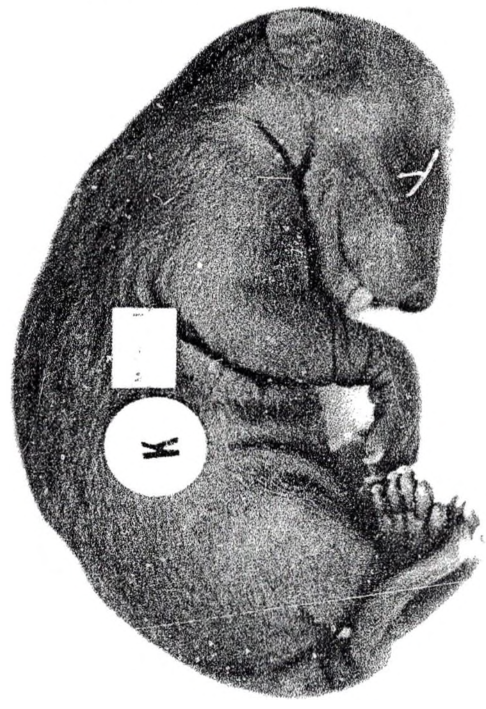

Figure 5.--Continued

Table 18.--Monthly variation in occurrence of sperm in 47 adult raccoons collected in southwestern Manitoba in 1967, 1968, and 1969

Month	Abundance of Sperm								Percent Reproductive		N
	Testis				Epididymides						
	0	1	2	3[a]	0	1	2	3[a]	Testis	Epidid.	
February		1			1				0	0	1
May	2	3	5	3	3		2	8	62	77	13
June	4	2	2		2	4	1	1	25	25	8
July	13				11	2			0	0	13
August	10				10				0	0	10
October	2				2				0	0	2

[a] Indices of 2 and 3 denote capability of inseminating

in March, April and May (Table 19). A rating of 3 was recorded for the epididymides of the single March specimen and a rating of 2 in three May specimens. Although sperm was found in yearlings collected in April, they were not determined to be capable of fertile mating. During May, the month of greatest production, 37.5% of the yearlings did not produce sperm, 24.5% produced small amounts, and 38% were considered capable of reproducing. Sperm was not found in yearlings collected June through November.

The monthly fluctuations in total testicular and epididymal volumes are demonstrated in Figure 6. Mean volumes of these organs in adults were greatest in February and May: 8.3 and 7.2 cm^3, respectively, and declined to 4.16 cm^3 in July. A gradual increase in mean volume of adult testes and epididymides was evident from August to February. March and April samples were not collected. Little variation occurred in the testicular-epididymal volumes in yearlings. A single specimen collected in March measured 3.3 cm^3; the maximum in the May sample was 3.0 cm^3. Gonadal volumes increased in June, probably due to overall growth and maturation of the animals.

Adult raccoons were more productive than yearlings. In adults, 86.5% gave birth at a rate of 415 young per 100 females (Table 20); 25.9% of the yearlings gave birth at a rate of 84 young per 100 females (Table 21). Prenatal mortality was 8.8% in adults and 69.4% in yearlings.

Time of birth varied between the last week in April and the first week in September (Figure 7); 83% of the births occurred between early May and mid-June. Although the period of parturition lasted until mid-July in all three years of the study, it extended into September in 1968. According to resident hunters and trappers, small, very young raccoons

Table 19.--Monthly variation in occurrence of sperm in 38 yearling raccoons collected in southwestern Manitoba in 1967, 1968, and 1969

Month	Abundance of Sperm								Percent Reproductive		N
	Testis				Epididymides						
	0	1	2	3[a]	0	1	2	3[a]	Testis	Epidid.	
March		1						1	0	100	1
April	5	1			5	1			0	0	6
May	6	2			3	2	3		0	38	8
June	9				9				0	0	9
July	6				6				0	0	6
August	5				5				0	0	5
October	1				1				0	0	1
November	2				2				0	0	2

[a] Indices of 2 and 3 denote capability of inseminating

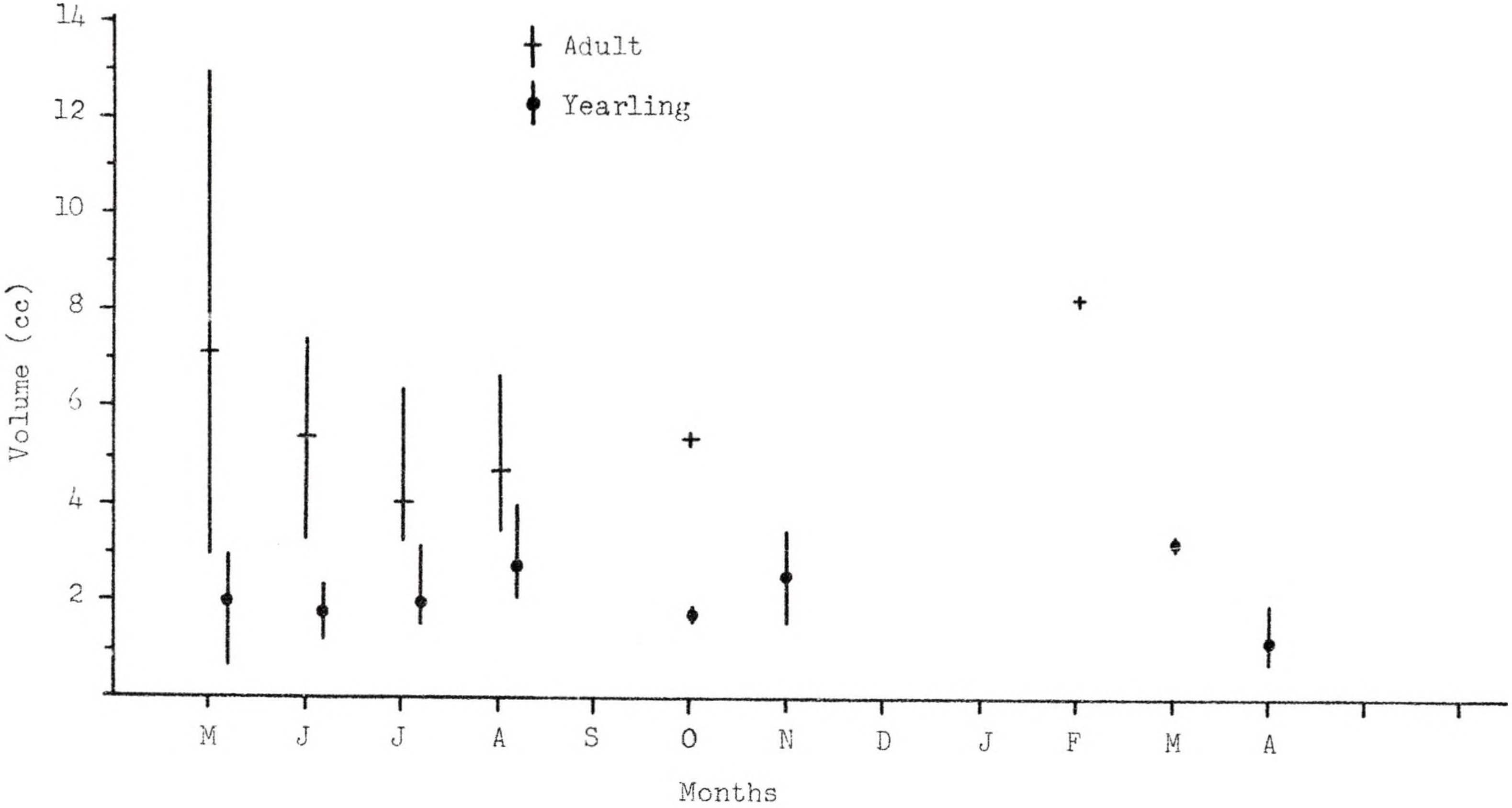

Figure 6.--Fluctuations in combined volumes of testes and epididymides of 47 adult and 38 yearling raccoons collected in southwestern Manitoba; 1967, 1968, 1969

Table 20.--Prenatal mortality rates in 52 adult raccoons collected in the Manitoba pothole area in 1967, 1968, and 1969

Month	N	Percent			Number			Loss	
			Litters						
		Preg.	Produced	Lost	Corpora Lutea	Uterine Scars	Feti	Pre-Implant.	Post-Implant.
April	5	100.0	80.0	20	25	24	20	1	4
May	12	100.0	100.0	0	67	65	61	2	4
June	9	100.0	100.0	0	43	39	39	4	0
Subtotal	26				135	128	4.8/F[b]	5.2%	
July	8	62.5	62.5	0	15[a]	24	24	-[a]	0
August	10	100.0	100.0	0	27	47	47	-	0
September	2	100.0	100.0	0	1	10	10	-	0
October	6	67.7	50.0	17.7	0	15	15	-	0
Total	52	90.4	86.5	3.9	-	224	216	-	3.6%

[a] Corpora lutea counts not reliable after June

[b] F = Female

Table 21.--Prenatal mortality rates in 27 yearling raccoons collected in the Manitoba pothole area in 1967, 1968, and 1969

Month	N	Percent			Number			Loss	
			Litters						
		Preg.	Produced	Lost	Corpora Lutea	Uterine Scars	Feti	Pre-Implant.	Post-Implant.
April	2	0.0	0.0	0.0	0	0	0	-	-
May	3	33.0	33.0	0.0	6	6	6	0	0
June	11	54.5	27.3	27.3	21	7	7	14	0
Subtotal	16	43.7			27	13	3.25/F[b]	55.6%	
July[a]	7	42.9	42.9	0.0	8[a]	12	12	-[a]	0
August		25.0	0.0	25.0	1	4	0	-	4
Total	27	40.7	25.9	14.6	-	29	25	-	13.8%

[a] Corpora lutea counts not reliable after June

[b] F = Female

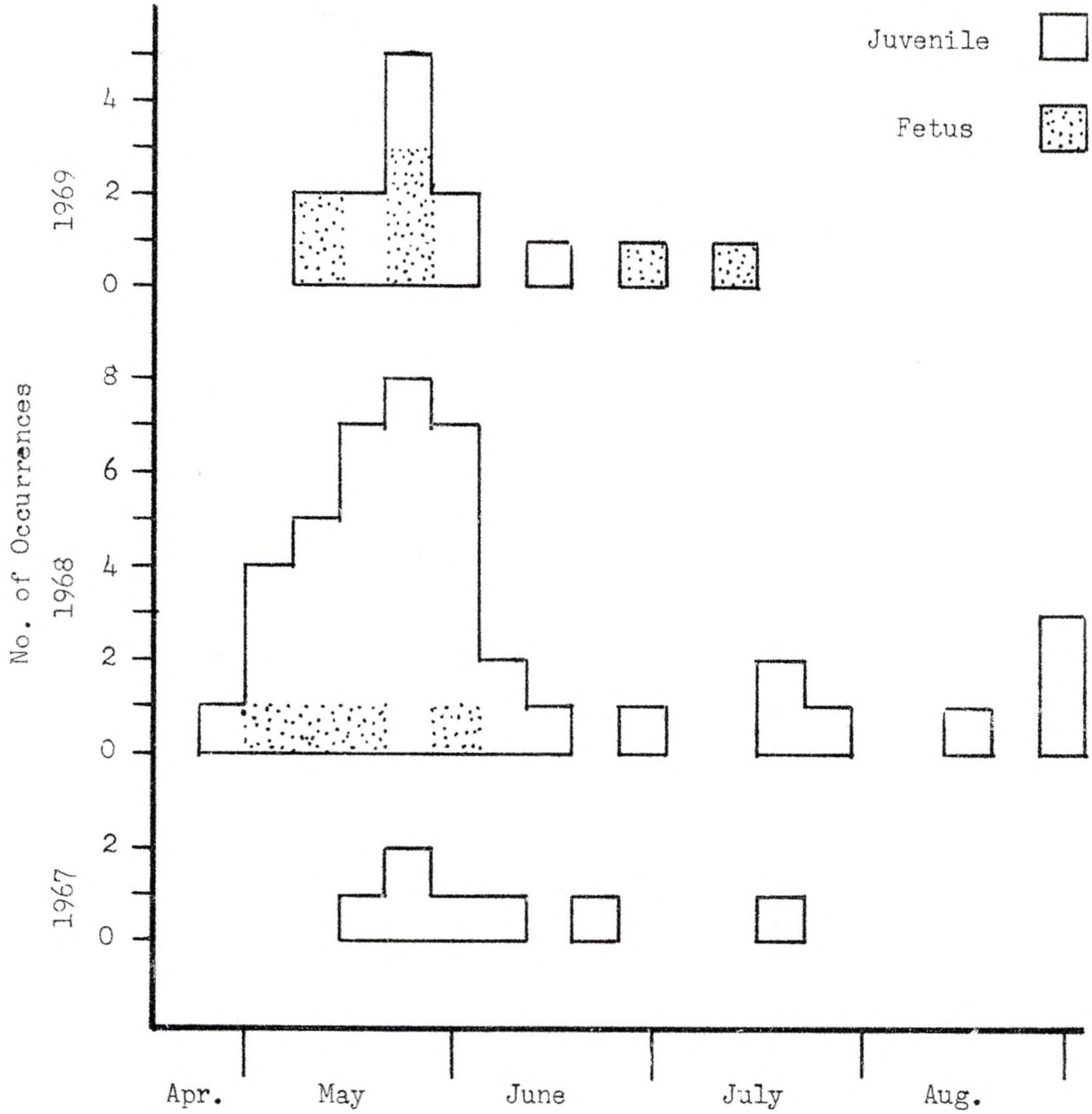

Figure 7.--Distribution of birth dates of 53 juvenile raccoons and 11 intrauterine litters collected in southwestern Manitoba in 1967, 1968 and 1969

were taken in late autumn of 1968.

Successful coitus occurred principally between the third week in February and the last week in March; the peak was the third week in March. Dates of conception ranged from the second week in February to mid-May in all years, and to early July in 1968.

Twenty mothers were with their nestlings or were pregnant when collected. The age of each mother was compared with the estimated date of parturition of the litter in order to establish whether July and August offspring were from yearlings. One female classified as a yearling gave birth on June 2, 1968. The age of another female was not determinable. Consequently, 18 or 90% of the females bearing young during the breeding season were adults.

Movements

The patterns of activity of juvenile, yearling and adult raccoons changed significantly (Ta .e 22). Males moved progressively greater distances during their juvenile, yearling, and adult years, respectively and relocated their areas of activity by as much as three miles from summer to summer. A yearling male was collected 10 miles from the natal den. Yearling females travelled significantly greater distances than juvenile and adult females both during the summer and between years; adults maintained restricted travel distances, not exceeding 0.25 miles between capture sites.

Distances between capture sites did not vary significantly between sexes for juvenile and yearling raccoons. Conversely, male adults travelled in excess of 0.75 miles between years, and females remained within that distance.

Adult male raccoon 8 was marked on June 27, 1967 at an abandoned

Table 22.--Distances between capture sites of each of 22 adult, 17 yearling, and 14 juvenile raccoons in the Manitoba pothole area in 1967, 1968, and 1969[a]

Age[a] and Sex	DISTANCES BETWEEN CAPTURE SITES (yards)					
	Annual[b]			Between Years		
	n	Mean (Range)	$t_{.05}$	n	Mean (Range)	$t_{.05}$
JM	7	943 (440-1760)		1	17600 (--- ---)	----
			0.59			
YM	10	1460 (0-7920)		5	3256 (2200-4400)	2.10*
			0.73			
AM	4	2505 (0-6160)		7	2722 (1230-5280)	0.14
JF	5	581 (0-880)		2	2200 (--- ---)	----
			3.26*			
YF	8	1933 (590-3960)		4	1772 (50-4400)	0.15
			2.13*			
AF	13	1003 (0-2200)		12	1338 (0-3960)	0.82

[a] Calculated t values between sexes for juveniles, yearlings and adults were 1.29, 0.63 and 1.13, respectively

[b] Spring, summer and fall of one year

* P>0.05

farmstead on section 30, Township 13, Range 17, and was recaptured 0.3 miles away 41 days later (Figure 8). It was trapped 2.5 miles west June 6, 1968 and was killed by coon hounds 1.5 miles east of that point on July 18, 1969.

Raccoon 18 was captured three times along a railroad bed between July 11 and August 4, 1967. Two years later, it and female E6 were killed by a dog 0.5 miles east of the original capture site and beside the same road bed. Raccoon 2 travelled four miles between capture sites in June, 1967. It was collected two years later, on July 28, 1969, one mile south of the first location.

Female E6 was taken initially on June 20, 1967, in a vacant farmstead at the centre of section 30 (Figure 9). It was recaptured three times within one mile of the farmstead by August 24, 1968, and was collected with male 18 on May 15, 1969. Female 44 was tagged on June 10, 1968 and was relocated within a 0.75 mile radius throughout the summer until September 23. Lactating female 68 was captured on May 28 of the same year at northeast section 29, and four times more within 0.6 miles by August 18. This female was collected in company of four young of the year near an abandoned farm (location 5) on August 2, 1969.

Juvenile male raccoons were not trapped more than twice. The locations of male F22 and female F37, presumed to be litter mates, are shown in Figure 10. The male was trapped in a vacant farm lot in the centre of section 30 on July 19, 1967. Both were caught in the same trap at location 2 on August 27, and the male was not caught again. The female was retrapped twice in May, 1968 within 0.5 miles of the farm.

Juvenile female 20 was taken in the same trap twice within two days in July, 1967 (Figure 11). It had lost the distal half of its tail and

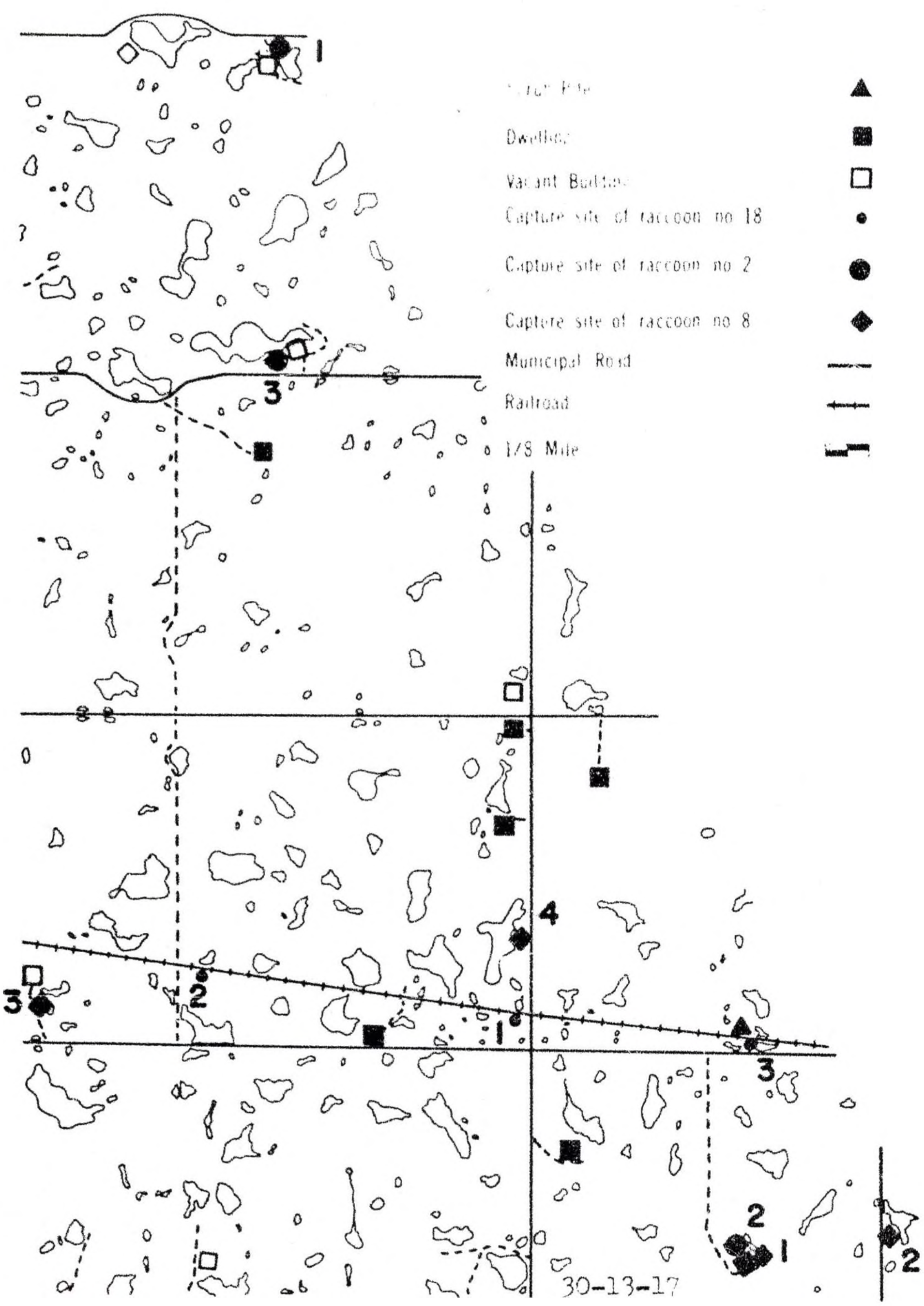

Figure 8.—Movement of adult male raccoons 2, 8 and 18, determined by live trapping and carcass collections in Ohanah District, Manitoba pothole area; 1967, 1968, 1969

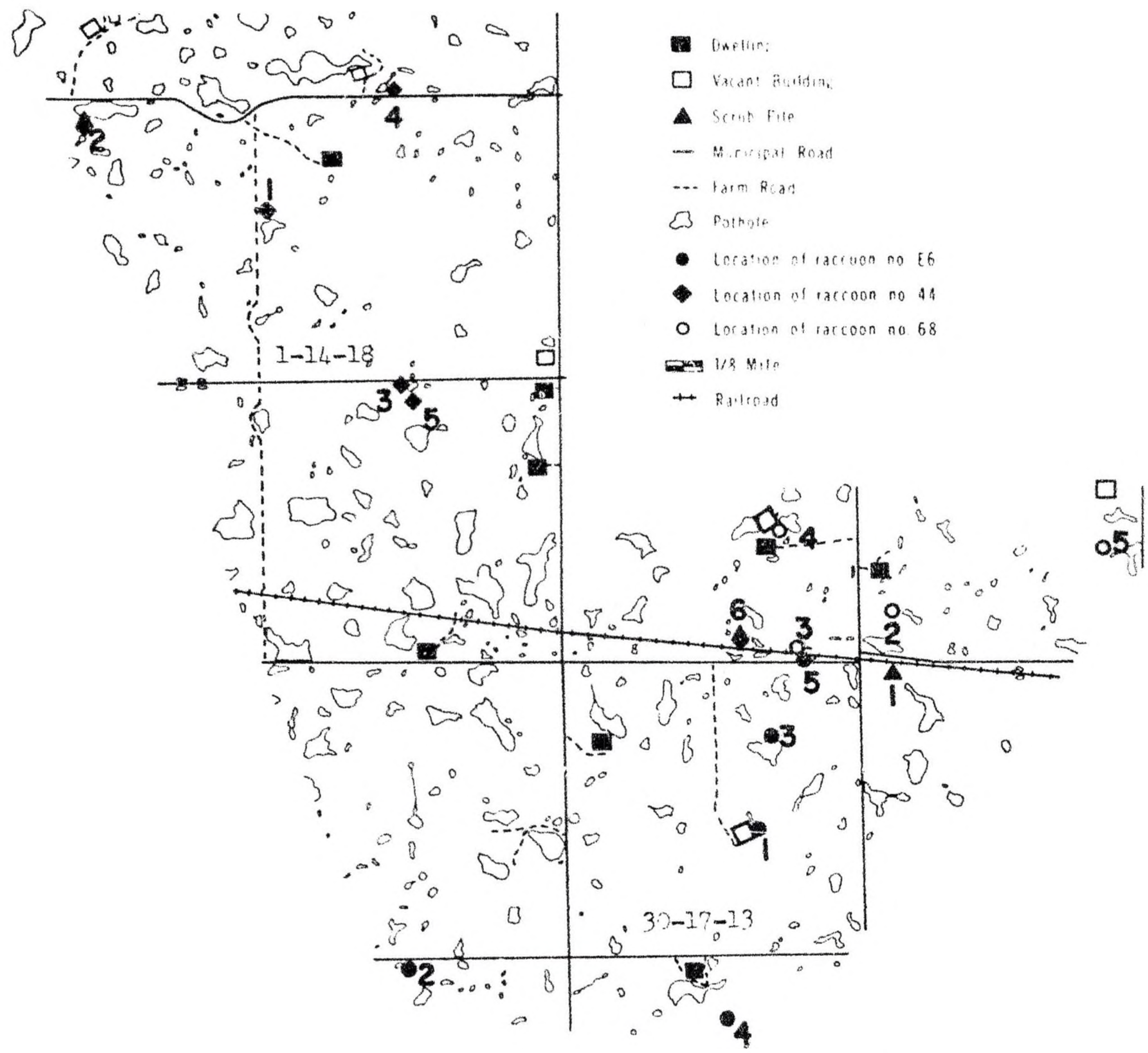

Figure 9.--Movement of adult female raccoons 36, 44, and 68, determined by live trapping, footprint identification, and carcass collection in Odanah District, Manitoba pothole area; 1967, 1968, 1969

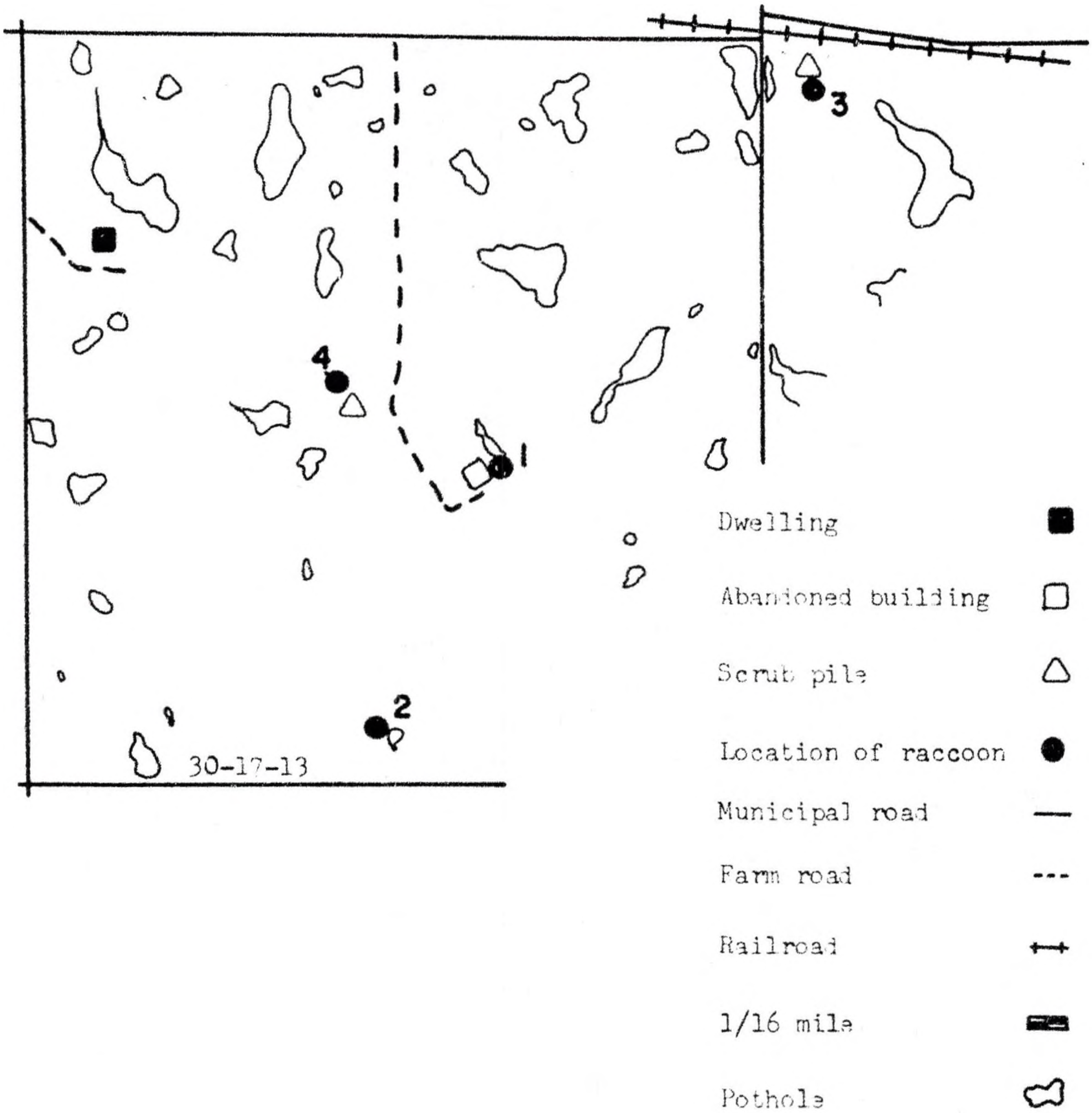

Figure 10.--Movement of juvenile raccoons F37 and F22, determined by live trapping in Olanah District, Manitoba pothole area; 1967 and 1968

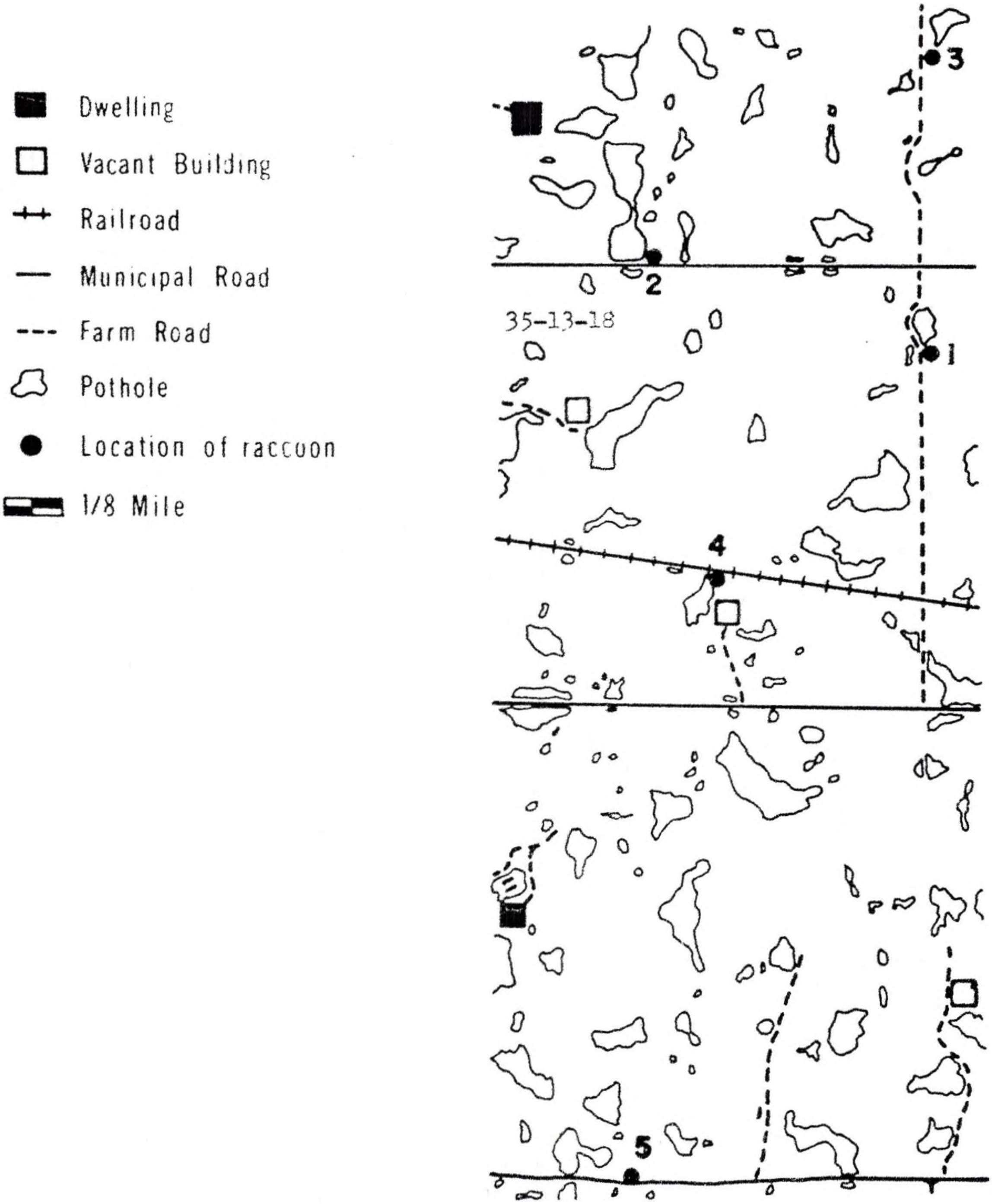

Figure 11.--Movement of juvenile female raccoon 20, determined by live trapping and carcass collection in Odanah District, Manitoba pothole area; 1967, 1968, 1969

the bone protruded; otherwise, it appeared to be in healthy condition. It was trapped twice more in August within 0.6 miles, and again on June 8, 1968. Female 20 was killed by a car 2.0 miles south on June 30, 1968.

The total transmitting time of five radios carried by raccoons in autumn, 1968 was 84 raccoon-days; that of six radios in spring was 166 raccoon-days. Battery life was approximately 17 days in autumn and 29 days in spring.

Home ranges of juveniles, as determined by telemetry, were generally larger than those of yearlings and adults (Table 23). In fall, juvenile males remained within an area of 1.0 square miles and a juvenile female, 0.5 square miles. Two yearling males and an adult male occupied 0.5 square miles each in spring. Adult female 94 with a litter utilized 0.1 square miles. Yearling female 93 travelled over a distance of 10 miles, establishing three temporary areas, each of 0.3 square miles.

Raccoon W78, a juvenile male, was trapped with a female on September 11, 1968; it was recaptured, equipped with a radio transmitter, and released on November 5 in northwest section 6-14-17 (Figure 12). It travelled over northern and western section 6 during the next week, and rested by day in the edge vegetation of frozen potholes. The animal traversed a thin layer of snow to a scrub pile (location 10) where it denned during the day of November 10. It fed on swathed grain in an adjacent field the next day. Four days later, W78 was located 1.0 miles north in a basement den (location 13) from which only two trips to nearby granaries were made. Thermister probes were placed inside the basement on November 21. The radio signal was located inside the den the next morning, but not during subsequent checks. On December 11, 1968, the den was entered and found to be vacant.

Table 23.--Minimum home range of five raccoons in fall, 1968, and of six raccoons in spring, 1969 in the Manitoba pothole area, determined by radio telemetry

Period	Age and Sex	Animal No.	Days Tracked	Min. Home Range (miles^2)
Fall 1968	JM	72	24	1.00
	JM	W78	16	1.00
	JM	85	18	1.00
	JF	86	25	0.50
	AF	87	1	0.25
Spring 1969	YM	89	49	0.50
	YM	90	22	0.50
	YF	93	52	0.30
	AM	91	17	0.50
	AF	45	2	0.25
	AF[a]	94	24	0.10

[a] Nursing a litter

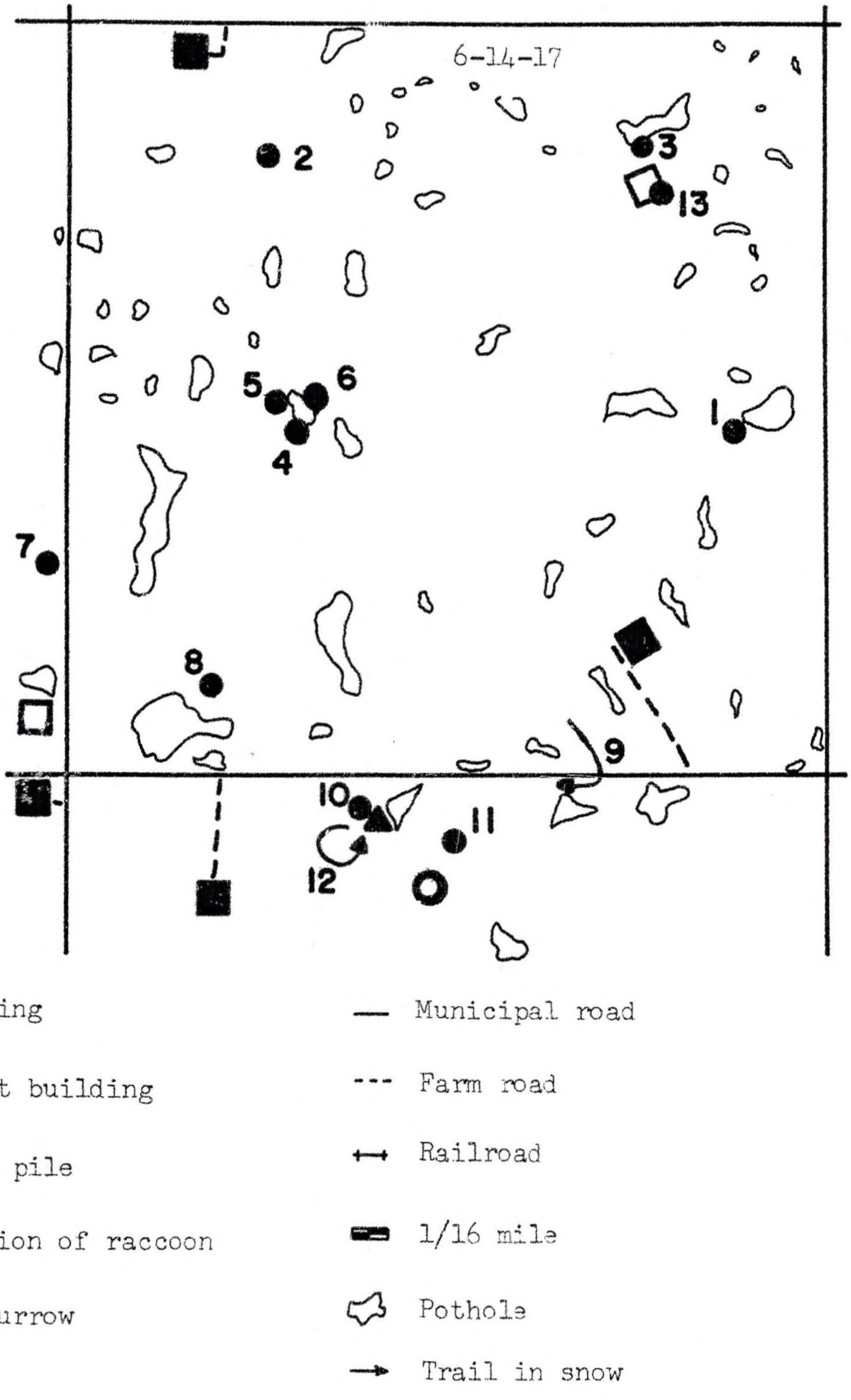

Figure 12.--Movement of juvenile male raccoon W78, determined by live trapping, radio telemetry, and trails in snow in Odanah District, Manitoba pothole area; September 11 to November 21, 1968

Raccoon 85 remained overnight near the abandoned farm in central section 30, where it was released on October 31, 1968 (Figure 13). The following evening, it travelled rapidly eastward until the signal was lost; it was relocated on November 4, 1.5 miles east (location 4). Three days later, the animal moved along a low drainage, eventually entered a scrub pile (location 10), and returned by a similar route to another scrub pile on November 15 (location 12). The radio signal was lost the next day.

Juvenile female raccoon 86 was radio-tagged on October 31, 1968 at a granary in northeast section 6 (Figure 14). It travelled south over the next five days to a fox den (location 5) where it rested through the day. The animal was again located on November 7 in the company of juvenile male raccoon 72.

Raccoon 72 was trapped on August 7, and was recaptured and equipped with a radio transmitter on October 31 at location B, an abandoned farmstead. It travelled throughout central section 6 until it joined with raccoon 86. The two rested in pothole cover (location H7) and moved within a two-acre area for the next two days.

Raccoon 86 moved west into a scrub pile on November 8, thence back to rejoin raccoon 72 at location K10 three days later. They remained together and entered an abandoned fox den on November 24. It was evident from scats deposited at the den entrance and from tracks in the snow that these raccoons had been utilizing this den for the past 10 days, and were feeding on swathed wheat in an adjacent field. Both transmitter signals were lost on November 25, possibly because the animals had moved deeper underground to where the depth of the intervening soil completely blocked out the signals.

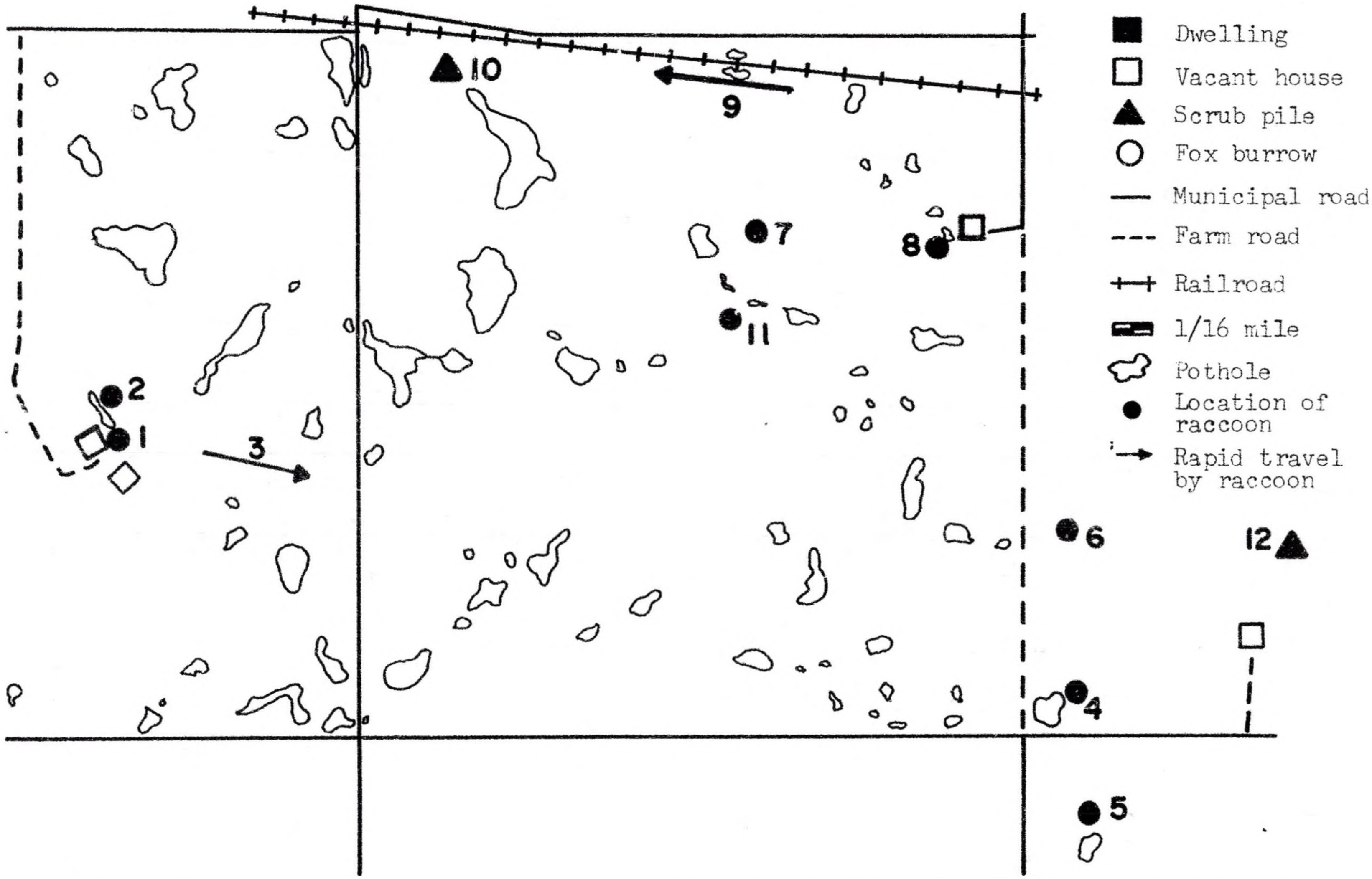

Figure 13.--Movement of juvenile raccoon 85, determined by radio telemetry in Odanah District, Manitoba pothole area; October 31 to November 14, 1969

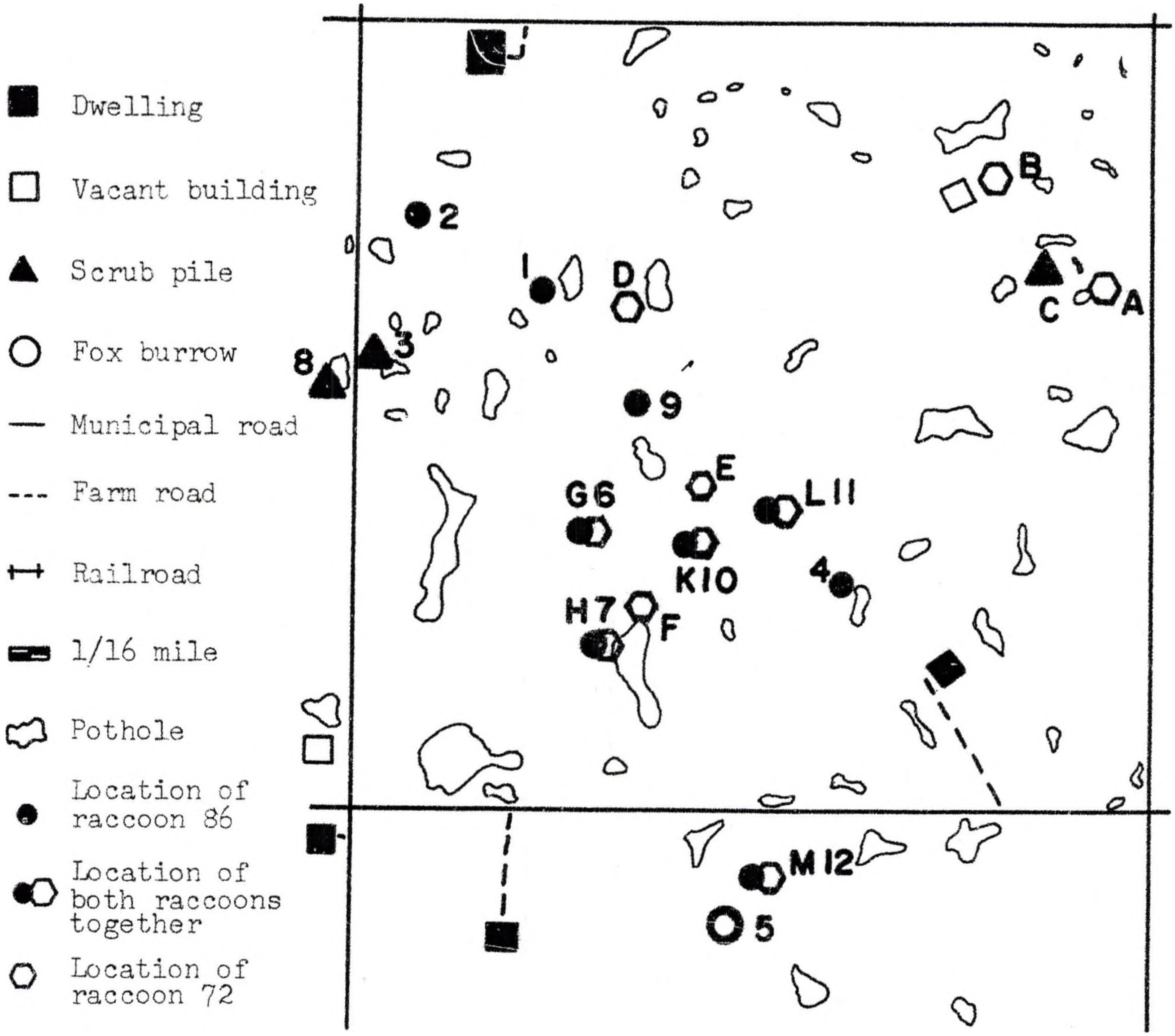

Figure 14.--Movement of juvenile raccoons 86 and 72, determined by live trapping and radio telemetry in Odanah District, Manitoba pothole area; August 7 to November 25, 1968

Yearling female 45 was trapped three times in June, 1968 over a distance of 2.0 miles (Figure 15). On April 4, 1969, Raccoon 45 was fitted with a radio transmitter at an abandoned farmstead (location 4). Radio signal was temporarily lost, was relocated on April 6 inside a granary at an inhabited farm, and was lost again that night. A raccoon bearing a radio crossed the road at location 6 on April 22; signal was not received. This was assumed to be female 45 since the possibility of the presence of other raccoons bearing nonfunctional transmitters in the vicinity was remote. On July 23, 1969, female 45 was collected 100 feet from the previous siting.

Yearling male 89, bearing a radio transmitter, travelled from the point of release to an empty granary in the centre of section 30-13-17 on April 10, 1969 (Figure 16, location 2). It spent the next day in a scrub pile at location 3. A pattern of feeding in potholes and swathed fields, and denning in scrub piles was maintained within a 0.5 square mile area during the next month.

On May 17, raccoon 89 was held at bay in a scrub pile (location 4) by a hound, was captured, fitted with a new transmitter, and released. Movement patterns were similar to those previous to May 17 until May 25 when hounds treed the animal at location 5. The transmitter was operating well and the raccoon was allowed to escape; however, the signal was lost on May 29.

Yearling male raccoon 90 maintained a home range of 0.5 square miles entirely within section 30 from April 17 to May 9, 1969 (Figure 17). The range utilized was identical in time and space to that of raccoon 89, except that raccoon 90 did not enter the abandoned farmstead.

Raccoon 91, an adult male, was released in north central section

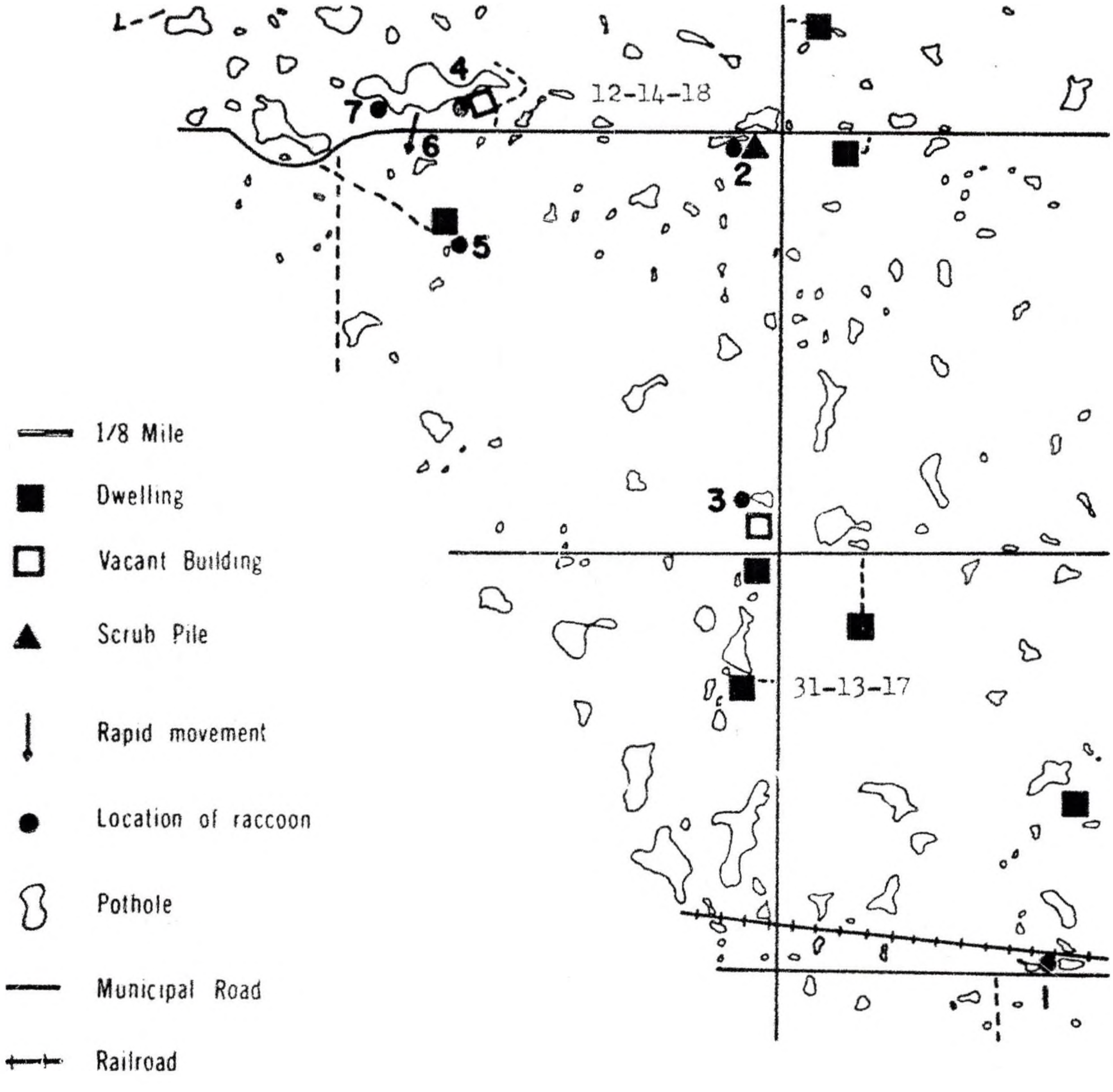

Figure 15.--Movement of adult female raccoon 45, determined by live trapping, radio telemetry and carcass collection in Oianah District, Manitoba pothole area; June 10, 1968 to July 23, 1969

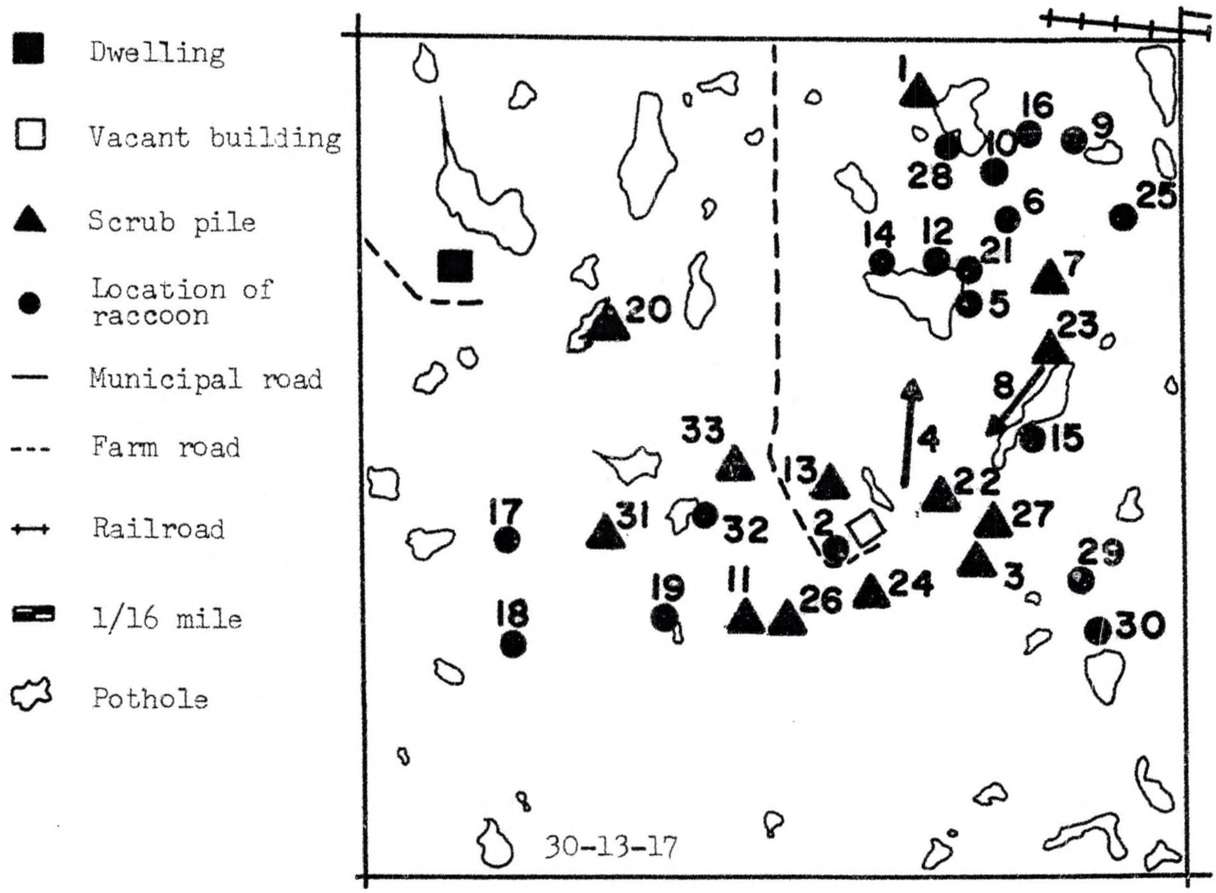

Figure 16.--Movement of yearling male raccoon 89, determined by radio telemetry in Odanah District, Manitoba pothole area; April 10 to May 29, 1969

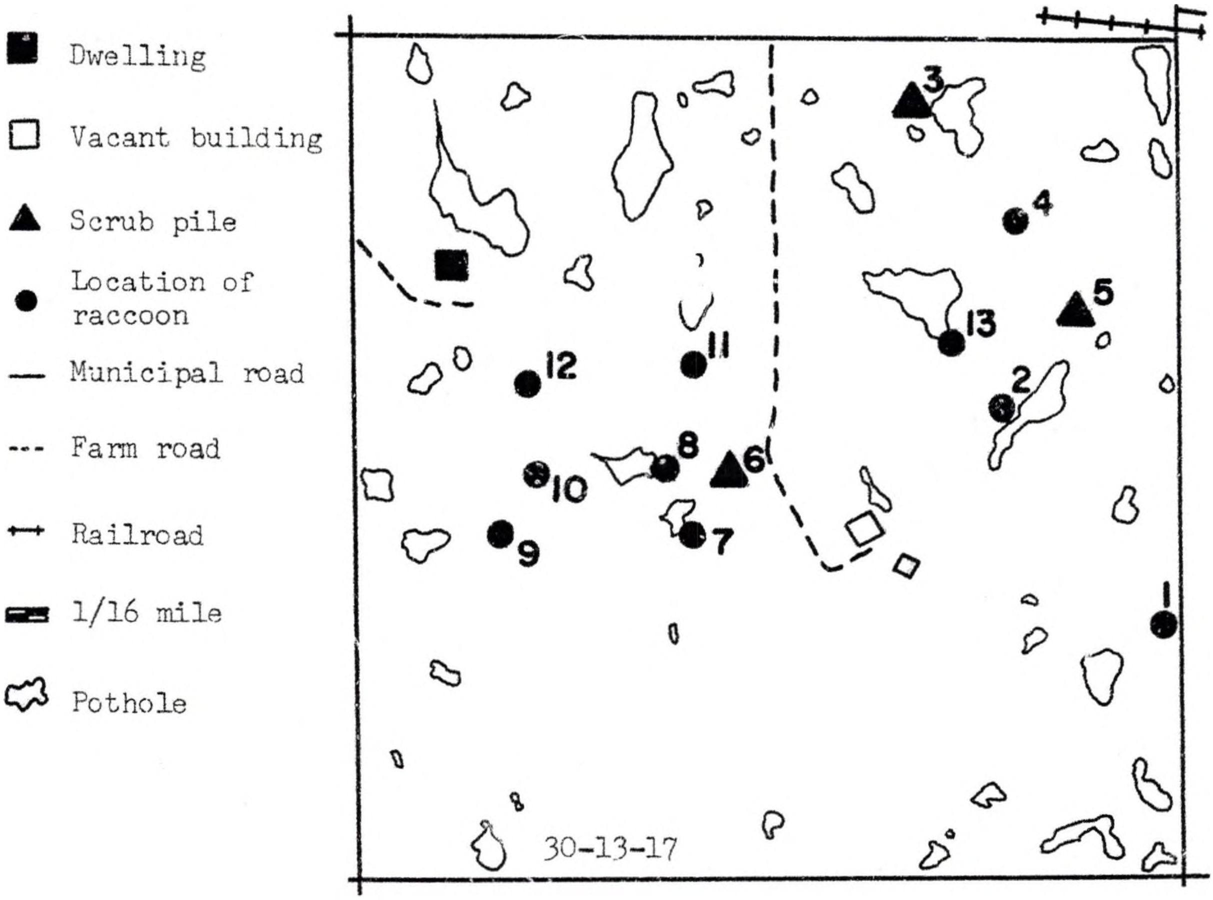

Figure 17.--Movement of yearling male raccoon 90, determined by radio telemetry in Odanah District, Manitoba pothole area; April 17 to May 9, 1969

36-17-18 on April 23, 1969. It entered a scrub pile (Figure 18) and remained inside for eight days while road construction was in progress 50 feet away. On May 4, the animal was at location 5, a small pothole from whence it travelled back to the scrub pile den. Two short trips away from the den precluded a 0.5 mile journey back to location 5 on May 9. Raccoon 91 was sited the next day sleeping in an abandoned crow's nest; the transmitter was not functioning.

Yearling female raccoon 93 was tracked by radio over an area greater than 10 miles long from May 6 to June 27, 1969. It maintained a home range of 0.5 square miles (Figure 19), foraging in potholes and denning on the ground and in an abandoned house (location 5). Radio contact was lost on May 20.

The animal was captured by coon hounds under granaries in the vacant farmstead on May 22. It was in the company of raccoon 94. The transmitter batteries were replaced and raccoon 93 was released. It moved from the farmyard north one mile to a scrub pile den at location 16, and remained in that vicinity until June 5.

On the evening of June 5, raccoon 93 began a journey of six days and 10 air miles (Figure 20). It travelled east in a long drainage basin through four sections of land to location 25; radio contact was lost on June 7. The animal was relocated five air miles away (location 26) on June 11. It remained within a 0.3 square mile area for two days, then confined activities to a pothole 1.0 miles west (location 29) for seven days, then to location 30. On June 27, raccoon 93 travelled rapidly 1.5 miles south; it moved through an aspen bluff (location 33) and the signal stopped abruptly.

Adult raccoon 94 was nursing a litter when captured with raccoon 93

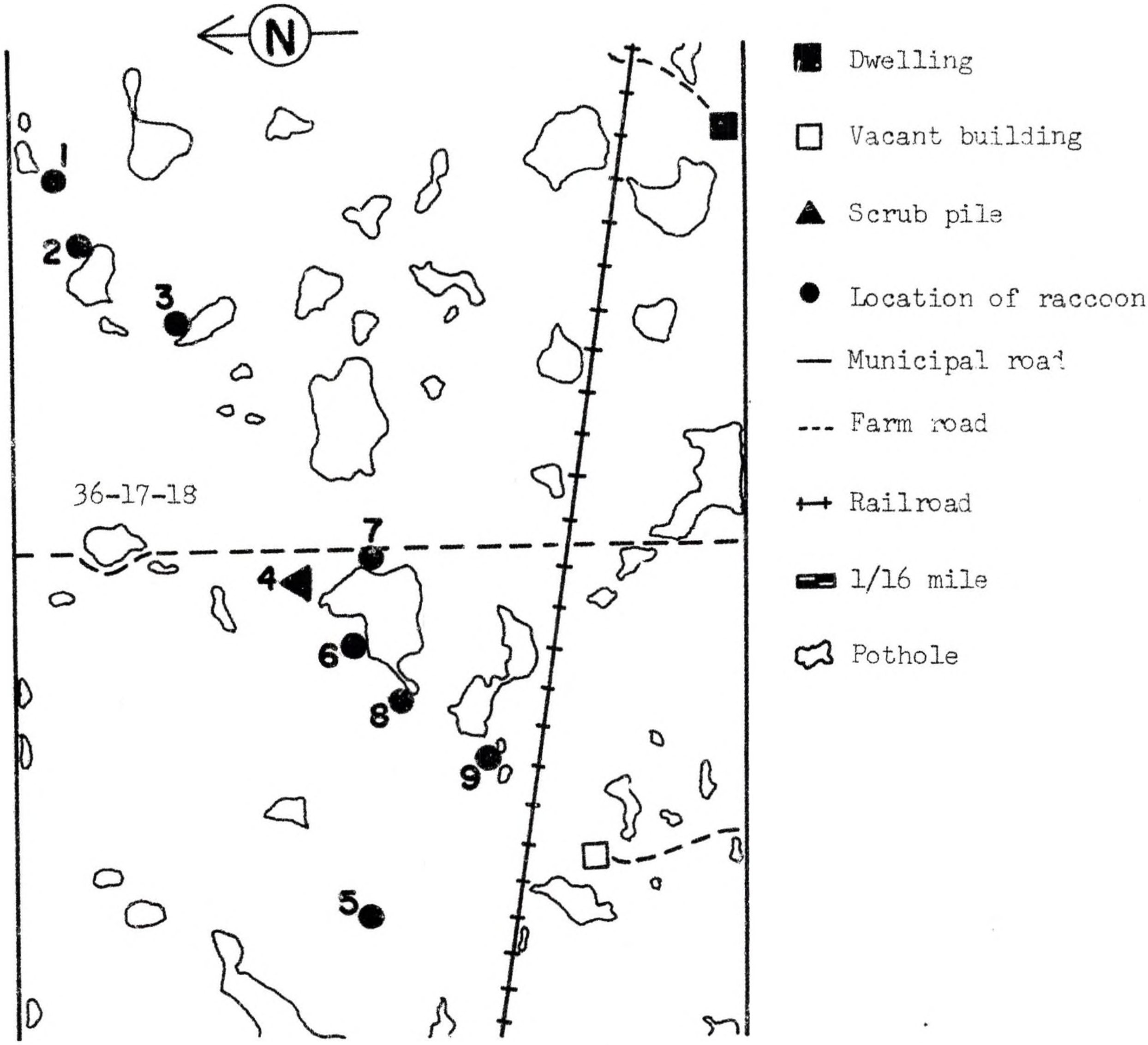

Figure 18.--Movement of adult male raccoon 91, determined by radio telemetry in Odanah District, Manitoba pothole area; April 23 to May 10, 1969

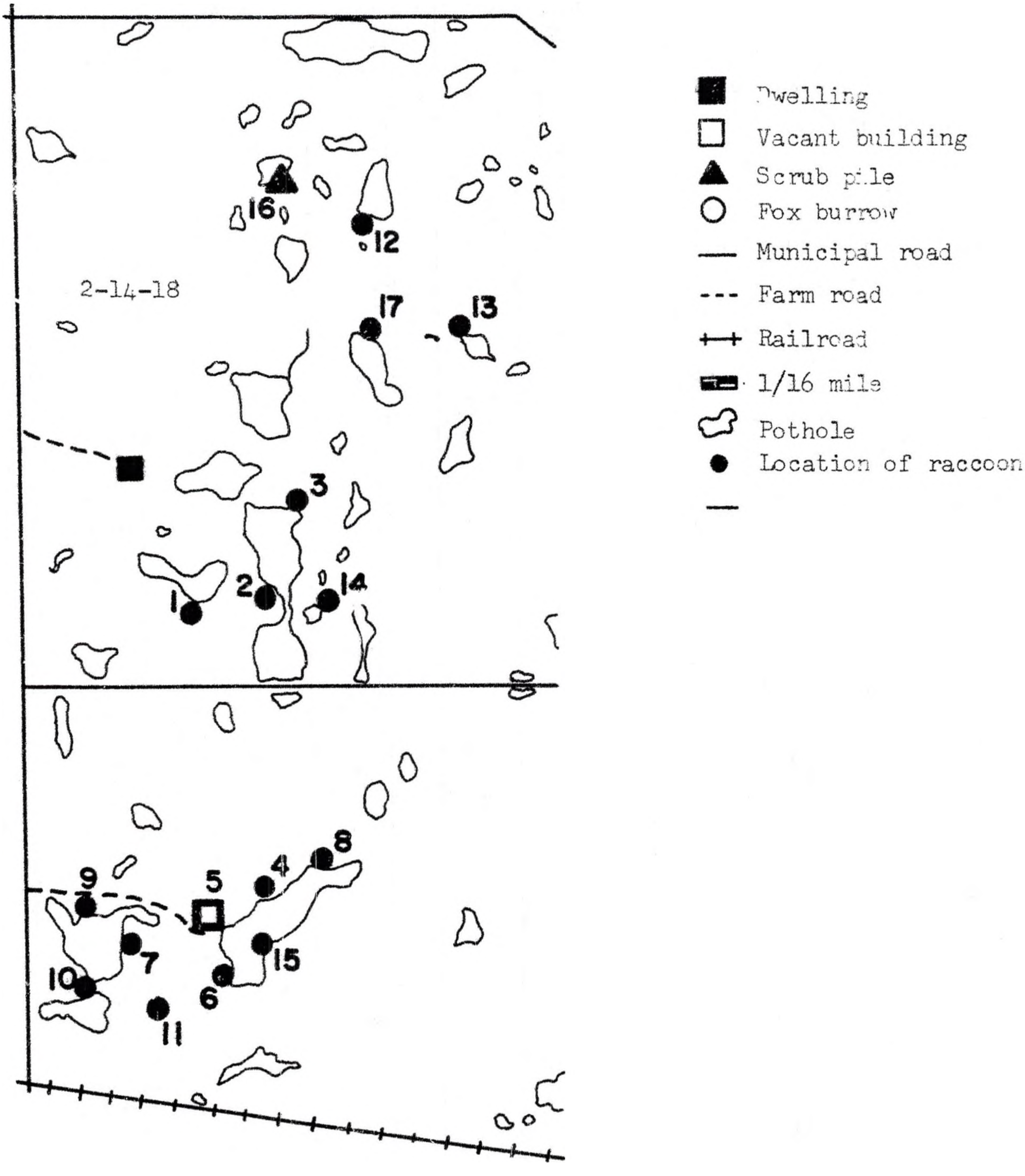

Figure 19.--Movement of yearling female raccoon 93, determined by radio telemetry in Odanah District, Manitoba pothole area; May 6 to June 5, 1969

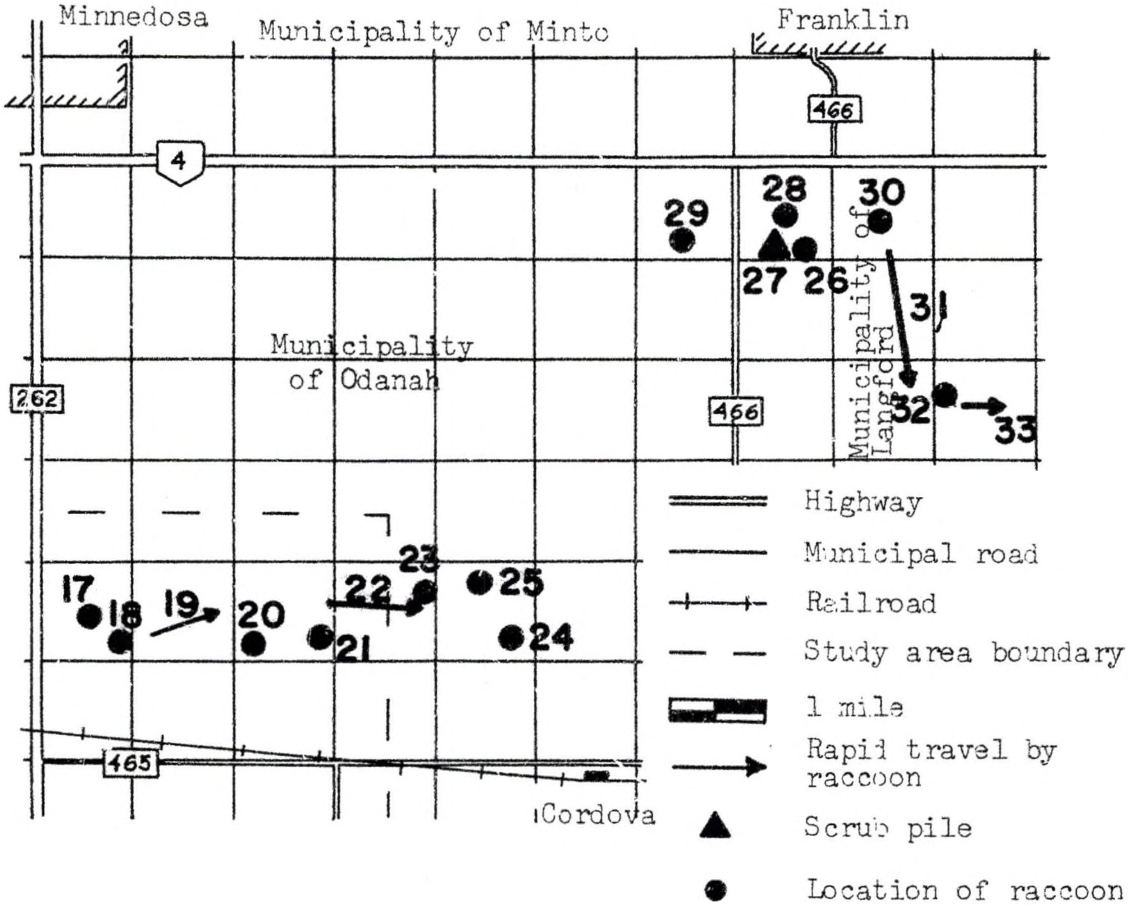

Figure 20.--Movement of yearling female raccoon 93 during dispersal from the home activity area in Odanah District, Manitoba pothole area; June 5 to 27, 1969

on May 31, 1969 at an abandoned farmstead (Figure 21, location 1). It remained in and near the house, foraging in nearby potholes and returning frequently throughout each night. On June 5, it was located 0.5 miles south on a burning stubble field.

Female 94 was radio tracked only during daylight hours from June 7 to 16. It rested in a maple grove adjacent to the house during two afternoons, and foraged potholes (locations 9 to 12) each evening. Transmission was lost on June 25.

A tunnel at least eight feet long was found in the soil of the south basement wall of the house. It was impossible to inspect the excavation thoroughly because the delapidated condition of the building made digging hazardous. However, there was a large pile of fresh raccoon scats deposited at the entrance of the den, and the toe-clipped foot prints in the powdery clay at the entrance indicated that this had been the den of raccoon 94.

Foot prints of four raccoons were found in fresh snow in central section 32-13-17 (Figure 22). The trail ran from a scrub pile (location 1) to an uninhabited farm. A large male moved north to the granaries at location 3; the others returned to the scrub pile. The lone animal moved north to enter the granaries at location 4, thence east to two more granaries and a large scrub pile (location 7). The animal dug into the snow cover and made a temporary den on top of the brush one foot above ground and four feet below the apex of the scrub pile.

The raccoon continued to location 8, the basement of a vacant farm house, investigated two empty granaries, and moved south. A large scrub pile and abandoned fox burrow were examined before the animal travelled to a vacant house at location 10. It continued directly east to the

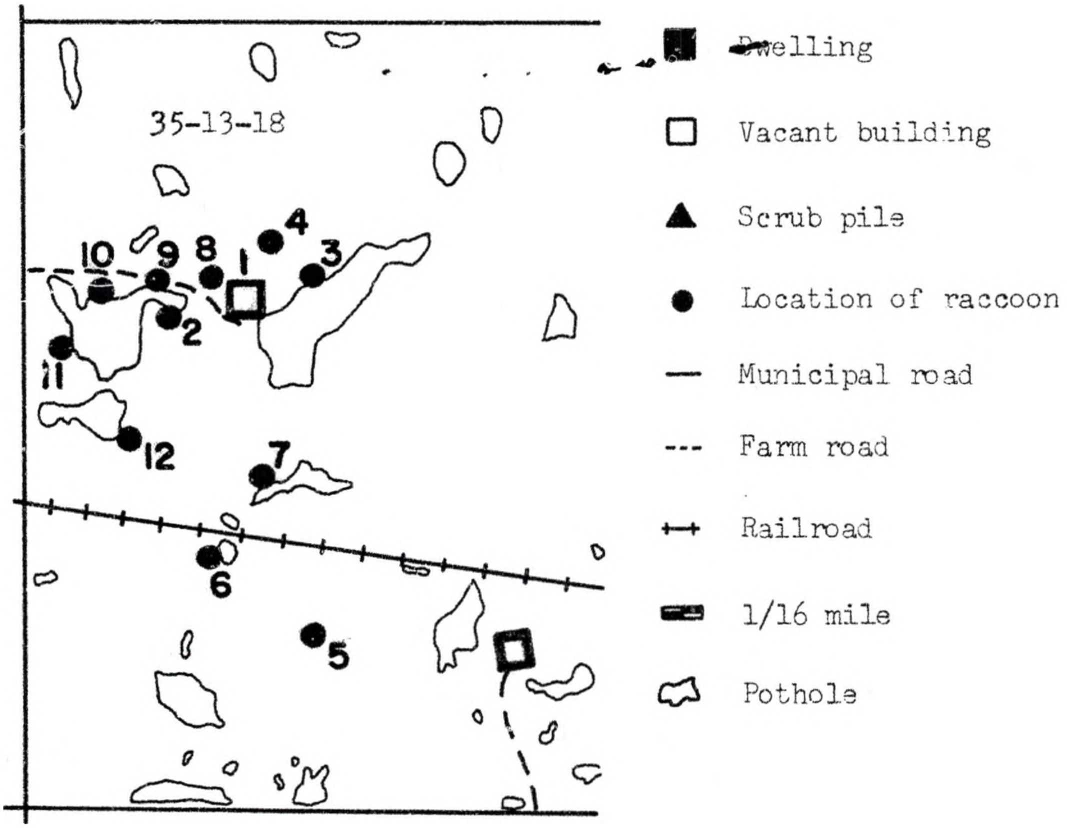

Figure 21.--Movement of lactating adult female raccoon 94, determined by radio telemetry in Odanah District, Manitoba pothole area; May 30 to June 25, 1969

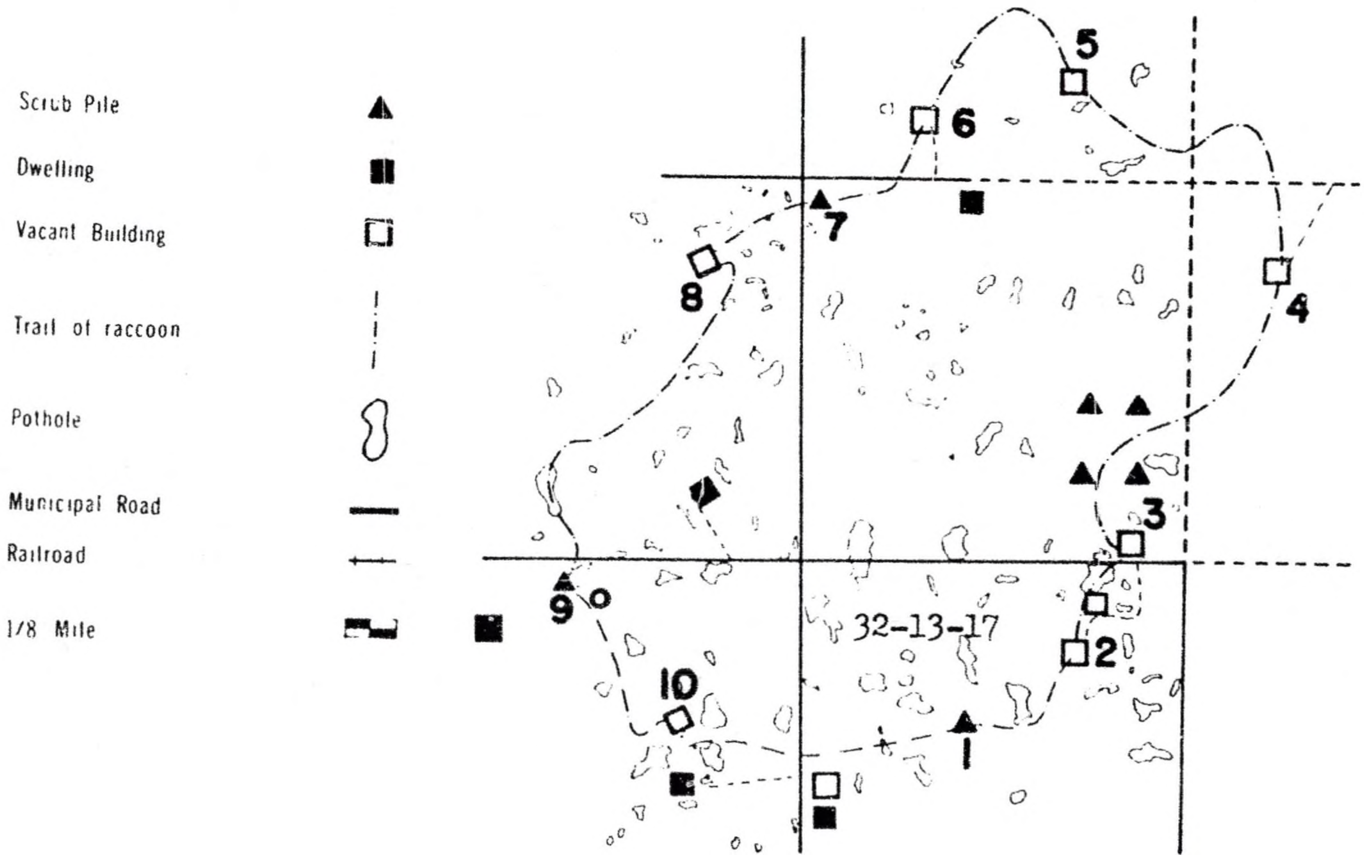

Figure 22.—Movement of an adult male raccoon on snow in Odanah District, Manitoba pothole area during the breeding period; March 17, 1969

starting point, a scrub pile (location 1). The route was 10 miles long and circumscribed an area of 3.0 square miles.

<u>Denning</u>

Scrub piles were the major dens used by raccoons in every season (Table 24). Scrub piles were used 50% of the time in summer, and ground beds and tree limbs less frequently. Burrows of other animals and cellars were important for survival in winter; three of four raccoons found in upper stories of buildings and one in a grain combine were dead. Breeding dens were located in vacant buildings from April to June, however three litters were found in scrub piles.

Average ambient temperatures during days when raccoons were active outside the den (Figure 23) were significantly higher ($t = 4.1$, $P < 0.05$) than those when the animals did not emerge. Mean low temperatures were -2 and -30.5 F, and mean highs were 30.5 and 27.5 F, on days of activity and inactivity, respectively. A change in arousal behaviour with progressively colder weather was apparent. Raccoons travelled in late November when minimum temperature was 11 F and the maximum was 39 F. However, they were active during minima of 0 to -5 F and maxima of 15 and 18 F in December and February. Raccoons emerged only on two occasions between late December and mid-February; these were on unseasonably warm days when temperatures reached 20 F. They moved frequently from February 12 to March 31 when daily maxima were above 10 F.

The effect of snowfall on emergence and travel could not be determined because high temperatures were associated with snowfall. Of the 35 occasions on which raccoons were known to be active outside winter dens, 9 were during or immediately following snowfall; on these

Table 24.—The location of 86 raccoon dens and day beds observed in southwestern Manitoba during spring, summer, fall, and winter in 1967, 1968, and 1969

	Number of Dens								
Season	Scrub Pile	Tree	Pothole	Beaver Lodge	Burrow	Building Upper	Building Beneath	Hay Loft	Farm Implement
Winter-Spring	6			1	2	2[aa]	4	2[a]	1[a]
Spring-Summer	3					8	7	2	
Summer-Fall	23	5	10		2	1	1	1	2
Total	32	5	10	1	4	11	12	8	3

[a] Raccoon carcass found in the den

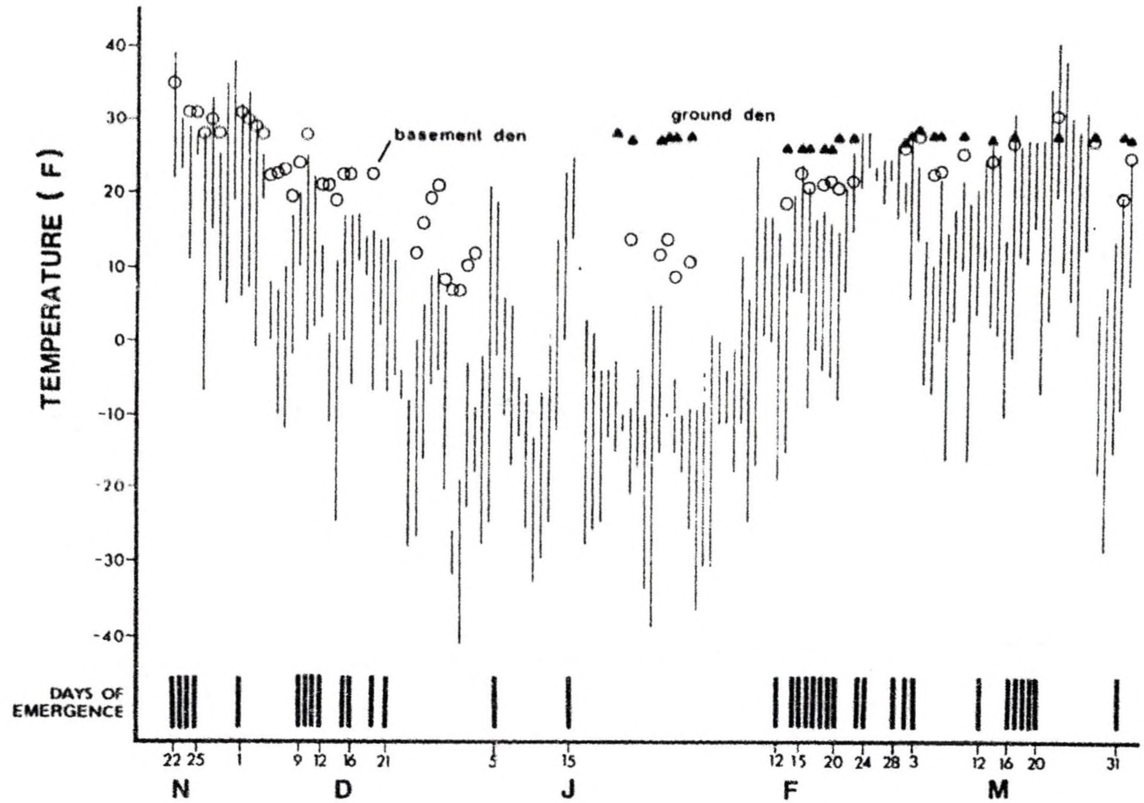

Figure 23.--Comparison of daily activities of raccoons with ambient and interior den temperatures in Odanah District, Manitoba pothole area; November 22, 1968 to March 31, 1969

occasions, maximum and minimum temperatures were between 15 and 29 F, and -19 and 14 F, respectively. These temperature regimes were similar to those when raccoons were active but snow did not fall: maxima of 12 to 39 F and minima of -9 to 25 F.

Snow depth varied locally throughout the study area. Snow accumulated to 25 to 35 inches in protected areas, and remained relatively soft. Open uplands were usually blown clear or the snow was packed so densely by consistently strong winds that raccoons could walk over the surface.

Temperatures in den 1, a basement, were only slightly higher on 54 days when raccoons emerged than when they did not; the difference was significant ($t = 3.38$, $P > 0.05$). This relationship was not significant ($t = 1.10$, $P > 0.05$) in the case of den 2, an abandoned fox burrow. Ambient temperatures had a greater effect on the basement den than on the burrow. Temperatures in den 1 ranged from 7 to 34.5 F, or 27.5 degrees; in den 2, they ranged from 25.5 to 29 F, a range of 3.5 degrees. In den 1, temperatures equalled or exceeded the minimum 26.5 F for den 2 on eight occasions during the periods November 22 to December 10, and March 1 to March 31. The basement den was colder than the burrow during the period early December through February.

Temperatures in den 1 correlated significantly with daily maximum, minimum and mean ambient temperatures, while those of den 2 were not (Table 25). The basement den was influenced to a greater extent by ambient temperatures than the ground den, which provided a stable environment.

Table 25.--Correlation of raccoon winter den temperatures with daily maximum, minimum and mean ambient temperatures in Odanah Municipality, Manitoba pothole area; January 21 to March 31, 1969

	Correlation Values (r)	
	Den	
Temperature	1 (n = 54)	2 (n = 25)
Maximum	0.886*	0.146**
Minimum	0.741*	0.321**
Mean	0.729*	0.176**

* $P<0.05$

** $P>0.05$

Food

Plant materials represented more than 50% of the volume of digestive tract and scat contents in each season (Table 26). Cereal grains, particularly wheat, were of greatest importance, contributing from 37% of the content in summer to 70% in fall. Wild fruits were consumed in quantity when available and comprised 13.3 and 12.3% of the summer and fall diets, respectively. Edible vegetation and undigestible materials occurred in all seasons and accounted for 12.2% in winter and 11.3% in spring.

Invertebrates composed more than half of the animal materials; insects and snails predominated (Table 27). In winter, insects accounted for the bulk of the animal remains. Mammals and birds contributed approximately 18% to the spring and summer diets and were represented by 17 species. Muskrats and meadow voles were the most important mammalian foods in all seasons; waterfowl, unknown birds, and their eggs were the most important avian foods. Coots were taken more than any other bird species. Herptiles and fish were of little importance.

The three raccoon stomachs that contained food in winter had equal portions of wheat, oats and raccoon fur. Raccoon fur occurred in two stomachs and wheat and oats, in one each.

Predation on Waterfowl Nests

Adult birds, embryos, and bird eggs were prevalent in the diet of raccoons during the duck nesting season (Table 28). These occurred in 13.6 and 28.8% of the digestive tracts examined in 1968 and 1969, respectively and comprised 22.7% of the volume in 1969. It was not possible to identify species except in the case of coots, coot embryos and a few duck eggs. Much of the egg material may have been other than waterfowl.

Raccoons were frequently active at night in potholes, and spent 62.3%

Table 26.--Plant food items and indigestible materials in 1109 scats and 298 digestive tracts of raccoons collected in spring, summer, fall and winter in Odanah Municipality, Manitoba pothole area in 1967, 1968, and 1969

	SPRING		SUMMER		FALL		WINTER	
	(775)[a] -69- Percent		(154) -183- Percent		(40) -46- Percent		(140) -00- Percent	
Food Items	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.
Cereal Grains								
Triticum sp.	57.1	35.9	52.6	33.2	43.0	34.7	72.1	60.9
Avena sp.	7.8	5.9	5.3	3.8	21.6	34.7	4.3	3.7
Hordeum sp.	1.2	1.0	0.5	Tr.	1.3	0.3		
Mays sp.		1.1	1.1	4.3	4.3			
Amelanchier alnifolia	0.8	0.5	5.2	3.4	6.5	2.0		
Prunus virginiana	0.1	Tr.	6.7	5.6	1.1	0.2		
P. americana	0.1	Tr.	3.8	2.0	8.4	6.3		
P. pennsylvanica					1.3	0.4		
Rosa sp.	0.6	Tr.	0.6	0.1	1.3	Tr.		
Avena fatua	0.1	Tr.			1.1	Tr.		
Quercus macrocarpa	3.1	1.2	0.3	1.5	2.2	1.8	2.1	1.9
Corylus sp.					1.1	1.1		
Unknown fruit	1.8	0.2	2.4	0.7	2.5	0.5		
Buds	0.3	Tr.					0.7	0.7
Roots	3.0	2.9	1.1	0.9			1.4	0.4
Grass Stalks	2.2	1.2	0.9	0.6	2.2	1.0		
Leafy Greens	3.2	1.6	0.9	0.6	2.2	1.0		
Fungus	0.1	0.1			1.3	Tr.	0.7	0.7
Raccoon Fur	4.7	1.5	5.2	3.2			6.4	1.5
Wood Fibers	2.4	1.9	0.7	0.2			15.0	9.5
Paper	0.3	0.1						
Insulation	0.3	0.4					5.7	4.0
Felt	0.1	Tr.						
Coal	0.1	Tr.						
Soil	2.1	1.4	0.3	0.2	1.1	0.5		
Gravel	0.3	0.1						
Unknown Debris	0.2	0.1	0.3	Tr.	3.3	0.9		

[a] Number of scats ( )
Number of tracts - -

Table 27.--Animal food items in 1109 scats and 298 digestive tracts of raccoons collected in spring, summer, fall, and winter in Odanah Municipality, Manitoba pothole area in 1967, 1968, and 1969

	SPRING (775)[a] -69- Percent		SUMMER (154) -183- Percent		FALL (40) -46- Percent		WINTER (140) -00- Percent	
Food Items	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.
Odocoileus virgin.	0.1	0.1						
Mustela vison	1.5	0.8						
Lepus sp.	0.4	0.3	0.6	0.2			0.7	0.7
Thomomys talpoidea	0.1	Tr.	0.4	0.2				
Tamiasciurus hudson.	0.1	0.1						
Ondatra zibethica	3.7	2.4	2.1	1.7	2.2	1.2	1.4	0.6
Microtus pennsylv.	4.1	2.2	6.6	2.5				
Peromyscus sp.	0.5	0.3	0.9	0.5				
Blarina brvicauda	0.3	0.1						
Unknown Mammal	2.3	1.1	4.4	2.4	1.3	0.4		
Adult Duck	0.3	0.3	1.0	0.9				
Duckling	0.1	0.1	0.4	0.3				
Colymbus auritus	0.1	Tr.						
Fulicia americana	3.0	2.5	1.4	1.1				
Pediocetes phasianellus							1.4	0.1
Agaelius phoenicius	0.2	0.2	0.6	0.3				
Unknown Bird	8.3	4.3	9.1	3.6	3.3	1.8	1.4	0.7
Bird Egg	9.0	3.0	12.9	3.5				
Thamnophis sp.	0.1	Tr.	0.3	Tr.				
Ambystoma tigrinum	1.5	1.2	1.4	0.9				
Rana sp.	0.1	0.1	0.5	0.3				
Unknown Amphibian	1.5	1.1						
Insect	25.9	9.8	26.3	8.7	17.9	6.7	9.6	4.5
Dermacentor sp.	0.1	Tr.						
Crayfish	1.5	0.6	6.1	4.4				
Snail	26.1	13.1	23.1	8.6	6.3	1.0		
Leach			0.8	Tr.				
Unknown Animal	2.2	1.6	0.8	0.8				

[a] Number of scats ( )
Number of tracts - -

Table 28.--Bird food items found in 22 stomachs and 66 colons of raccoons collected during the duck nesting season, May 1 to July 1, 1968 and 1969 in Odanah Municipality, Manitoba pothole area

	1968		1969	
	Percent		Percent	
Food Items	Occ.	Vol.	Occ.	Vol.
Fulicia americana			9.1	7.9
Unknown Bird			3.0	1.9
Bird Egg	13.6	1.6	16.7	12.9
Total	13.6	1.6	28.8	22.7

of their time in that habitat (Table 29). During the remainder of the summer and fall, frequency of use of potholes declined to 48.8%.

Population Dynamics

The determination of an index of the number of raccoons on the study area was not possible because marked and unmarked animals were not equally trappable. Females were trapped as many as seven times, males never more than twice. A total 62 adults and yearlings were marked by the end of the 1968 trapping period and unmarked raccoons were not taken at that time. This indicated that all nonjuveniles had been tagged. Therefore, the minimum breeding raccoon population on the study area was 62 adults and yearlings, or 62/16 = 3.9 per square mile.

The potential productivity (Table 30) was 4.1 young per adult female, and 0.8 per yearling female, or 2.5 young per female of breeding age. Since females comprised 44% of the 62 adults and yearlings on the study area, the total possible annual production was 73 offspring. This increased the summer population to a minimum of 135, or 135/16 = 8.4 per square mile.

Changes in proportions of juveniles, yearlings and adults reflected reproductive and maturation processes and followed an annual cycle (Figure 24). Juveniles comprised the major portion of the population from period I , birth, through period IV; the excessive ratio in fall was believed to be due to a greater susceptibility to traps and hounds. At the age of nine months, raccoons were classified as yearlings, therefore juveniles did not appear in the collection from March to April. Yearlings comprised the major portion of the March-April sample, probably because they were also more susceptible than adults to collection techniques. Adults and yearlings were approximately equally represented during May

Table 29.--Occurrences of raccoons in pothole and other habitats during and post duck nesting in 1967, 1968, and 1969

PERIOD			
Nesting		Post-Nesting	
Percent Occurrence		Percent Occurrence	
Pothole	Other	Pothole	Other
62.3	37.7	48.8	51.2

Table 30.--Potential average annual production of young by adult and yearling raccoons in Odanah Municipality, Manitoba pothole area

	FEMALES		LITTER	
	Proportion			
Age	In Breeding Population	Producing	Average Size	No. Produced Per Female
Adult	.219	.865	4.80	4.1
Yearling	.219	.259	3.25	0.8
Productivity by adults and yearlings			2.5	

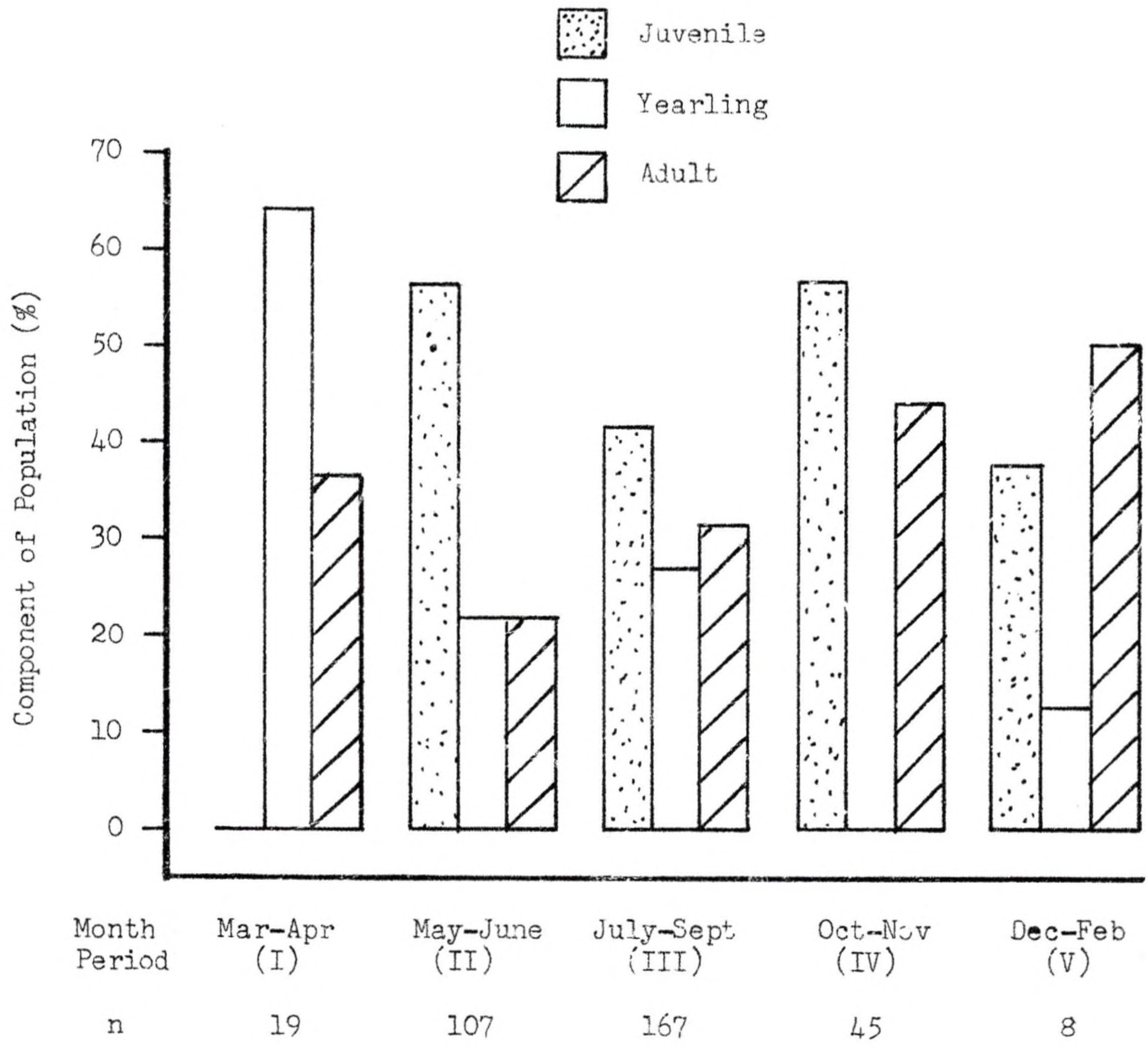

Figure 24.--Seasonal distribution of 89 juvenile, 124 yearling, and 141 adult raccoons in the live trapping, carcass and nestling collections in Odanah Municipality, Manitoba pothole area; 1967, 1968, 1969

through September. Yearlings did not appear in the October-November sample because the majority attained adult physical proportions by this time and were therefore categorized as adults.

The proportion (j) of yearling raccoons in the summer population was 0.491 (Figure 24). Using the method of Petrides (1951), the turnover rate was:

$$T = \frac{\log 0.005}{\log (1-j)} + 1 = 7.6 \text{ years}$$

and the mean life span was calculated as:

$$L = \frac{1}{j} = 1.8 \text{ years}$$

Therefore, raccoons of the Manitoba potholes lived an average 1.8 years and it took 7.6 years for an original population of 1,000 young of the year to be decimated to five individuals.

Survival rate, projected to an initial 1,000 young of the year, for each year group is presented in Table 31 and Figure 25. It was only possible to calculate mortality in two year groups: raccoons between one and two years, and those two to three years. Of six raccoons marked as juveniles (age 0), 3 (age 1) were recaptured in 1968, one of which was killed; 1 (age 2) was recovered in 1969. Thus 50% of the original marked population was recovered at age one year and 20% at age two years. Consequently, 20/50 x 100 = 40% survived between the ages of one and two. This was a mortality rate of 60%. The mortality rate of three year old raccoons was 45%, based on recaptures of 6 and 3, of 11 animals marked as yearlings.

A mortality rate of 60% for juveniles was based on the assumption supported by field observations, that the juvenile death rate was as great as that of yearlings. In the case of adults, it was assumed that raccoons that attained two years of age, or sexual maturity, were well

Table 31.--Theoretical turnover rate of a population of 1,000 raccoons in Odanah Municipality, Manitoba pothole area, based on mortality rates for each year class

Age Group	Mortality Rate	No. Surviving
0	0.000	1000.0
1	0.600	400.0
2	0.600	160.0
3	0.450	88.0
4	0.450	48.4
5	0.450	26.6
6	0.450	14.6
7	0.450	8.0
8	0.450	4.4
9	0.450	2.4
10	0.450	1.3
11	0.450	0.7

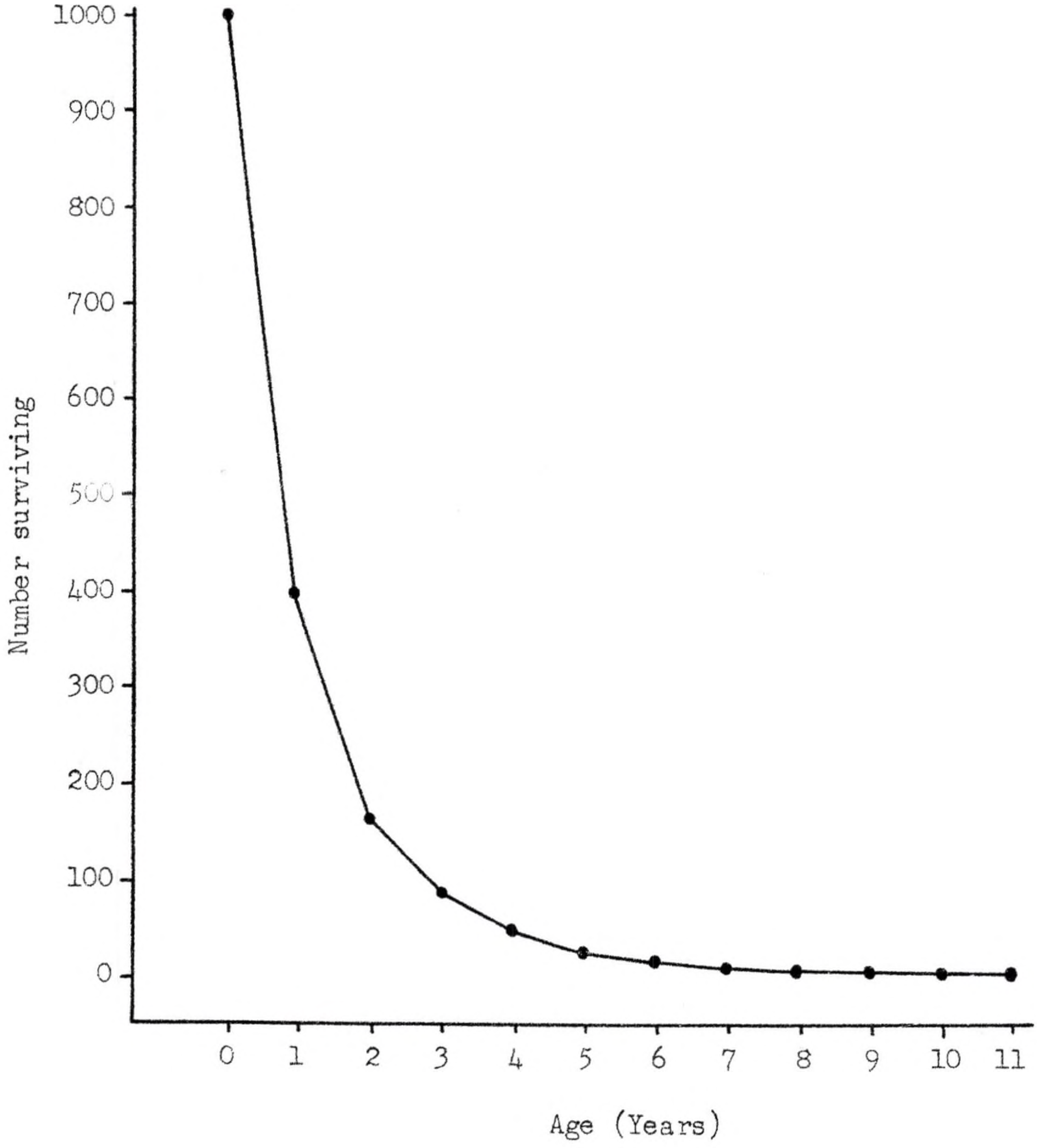

Figure 25.--Calculated survivorship curve of 1,000 newborn raccoons in the Manitoba pothole study area, based on mortality rates for each year class

established in the niche. Mortality would not vary appreciable in adults, and a constant decline in numbers would be expected over subsequent years. Since mortality rate of three year olds was 45%, and data for older animals was lacking, the mortality rate for raccoons from age three years and older was established at 45%. The original population of 1,000 was reduced to 4.4 in 8 years and 0.7 in 11 years.

Determination of the long-range trend in population size (Table 32) was inconclusive. The proportion of juveniles and their mean body weights increased between 1967 and 1968, indicating an increase in population size. However, a decrease in the proportion of females testified to a decrease in the total number of raccoons. Sex ratios and mean body weights indicated a population increase in 1969.

From the determination of a population of 62 adults and yearlings on the study area, and from a potential productivity of 73 young per year, a mortality rate of 73/135 x 100 = 54.1% must occur in order that the population remain static. The mean death rate was 47.8% for all year groups. Therefore, the population was increasing slightly in size or was not changing.

Table 32.--Changes in size of the raccoon population in the Odanah Municipality, Manitoba pothole area during 1967 to 1969, as indicated by annual changes in sex and age ratios and mean body weight

Year	Sex Ratio (M/F)		Proportion of Juveniles		Mean Body Weight (g)	
1967	1.217	(41)[a]	0.410	(30)	5864	(41)
1968	0.911	(108)	0.437	(68)	5649	(108)
1969	1.225	(58)	-----		5577	(58)
Population Trend	questionable		increase		increase	

[a] (n)

DISCUSSION

This was a study of the limiting ecological factors operating on a raccoon population in a severe environment. An attempt was made to discover the characteristics of Manitoba's environment that delimit the size of the population and to describe the ways in which these factors affect reproductive success, growth and maturation, and survival of raccoons. The rapid changes that man has incurred in the ecology of the area since 1940 were outlined. These changes have reduced the effects of factors that limit the raccoon population in Manitoba.

This is a broad study of a complex and dynamic interaction between an adaptable organism and the environment. The greatest value of the analysis is that it points out the major factors involved in this interaction. Hopefully, it may lead to studies that will describe the environmental characteristics that limit the raccoon population in Manitoba.

Survival

The breeding biology of raccoons in Manitoba is in phase with the chronology of the climate. Manitoba raccoons mate from late February to mid-June, the majority in mid-March. This is later than most northern raccoons (Soper, 1946, 1963; Cabalka, 1952; Sanderson, 1961c) and those in subtropical regions (Whitney, 1931; McKeever, 1958; Cunningham, 1962; Doutt et al., 1966; Lehman, 1968). On the study area, extremely cold January and February temperatures and snow depths to 3 feet generally prevented travel in search of mates; emergence was recorded only twice between December 22, 1968 and February 11, 1969. It is inconceivable that coitus was achieved at these times. Mating of Manitoba raccoons is delayed until the extreme cold of mid winter has subsided, and survival is enhanced.

Parturition is generally late enough to avoid extremely cold weather and early enough that young may obtain maximum possible growth before winter. On the study area, the majority of raccoons were born between early May and mid-June, and 13.6% between July and September. Mean November weight was 1,800 g, as compared to 5,200 g for juveniles born in May or June. Late born young are not expected to survive. Fat reserves are depleted by November, and additional body growth in late born young results in starvation and death. Young raccoons born in May or June are weaned by July or August when fruit, invertebrates and vertebrates are abundant. Growth and maturation are enhanced by an extended period of abundant food, and fat is accumulated before November. Therefore, the timing of birth of Manitoba raccoons is such that the major proportion of young have the best opportunity to survive the winter.

The phenomenon of late litters is not unique to Manitoba (Stuewer, 1943b; Sanderson, 1949; Schoonover, 1950; Johnson, 1970), and may be due to environmental stress during the breeding season. Extreme cold and starvation may reduce resistance so that parasite load and disease further contribute to deterioration of physical condition (Whitney and Underwood, 1952; Kellner, 1954; Robinson et al., 1957; Doutt et al., 1966; Mech et al., 1968). Females under such stress may not conceive, may abort or may lose the litter post parturition. The prenatal mortality rate of 31.5% recorded in Manitoba raccoons was greater than the 6.1% (Johnson, 1970) and 4.0% (Sanderson, 1950) reported in temperate climates. Females that lost their first litters or did not mate may undergo a second heat in May or June when their condition has improved because of increased availability of food. In the case of yearlings, mating may be delayed until summer because winter stress may have retarded maturation of the animals and depressed gonadal development. This could be a mechanism of survival in that it relieves females from physical demands of pregnancy during a period of environmental stress.

The occurrence of late litters may be due to the choice of dens in winter. One third of winter dens were in cellars and burrows. Sunlight does not penetrate burrows or cellars banked with drifted snow. Denning raccoons may not be stimulated by increased photoperiod (Bissonnette and Csech, 1938; Whitney and Underwood, 1952) and gonadal development may be retarded. Therefore, sexual urge may be latent and out of synchromy with the majority of the raccoon population, and coitus may not be achieved until late spring or early summer.

In Manitoba, the large mean litter size, 4.8 in adult raccoons, may compensate for the high mortality rate due to a severe environment. Mean life span of raccoons on the study area was 1.8 years and mortality rate was 60% in the first year of life. Only 10% of females attained adulthood; however, adults produced 4.1 young per female as compared to 0.8 for yearlings. Although the maximum age of fecundity is unknown, the contribution to productivity by a minority of adults surviving to 3 years or older would be considerable and may compensate for the high mortality rate in young raccoons.

The most important limiting factors for the raccoon population in Manitoba are lack of winter and early spring foods, and insufficient protection against extreme cold. Natural foods are generally unobtainable from December to April. Many raccoons starve during this period; in juveniles, weight loss was 30%, and mortality rate 60%. This was similar to weight losses in Minnesota raccoons (Mech et al., 1968) and greater than in temperate regions (Sanderson, 1961a; Urban, 1970; Johnson, 1970). Of 15 stomachs collected in December and February, 12 were empty. Materials in scats collected in winter and in scats and stomachs in spring included 16.8 and 11.4% indigestible materials, respectively. Several stomachs contained only balls of raccoon hair which indicates that these animals had attempted to satiate hunger by licking or chewing their own fur.

Survival in winter and early spring is assured raccoons that find granaries or grain swaths. A few accessible granaries on the study area contained wheat, oats or barley, and hibernating insects. Grain comprised more than 50% of the diet during winter and spring and insects, more than 5%. Raccoons living near grain supplies need expend relatively little energy in order to acquire food.

Sexual development and breeding potential may be enhanced in raccoons that have available winter food. A female that travelled frequently to a granary only 150 feet from the den was fat and in apparent good health. It was known to be at least four years old and to have produced a litter in each of three succeeding years. This animal's choice of a winter den near a granary was undoubtedly the prime factor in its survival and reproductive success. Animals that do not have available food must travel extensively in search of it, and a net loss in energy may result in a deterioration of physical condition (Novikov, 1956). This loss of vitality and the demands of reproductive development and sexual activity may decrease productivity. Conversely, that portion of the raccoon population having access to grain throughout winter may accumulate the energy required for reproduction.

Potholes are an important source of protein for Manitoba raccoons from the spring thaw in March or April until the winter freeze-up. The resultant great increase in available protein may assure survival for a portion of the population that otherwise would have starved. Raccoons utilize this habitat intensively: the frequency of occurrence of raccoons foraging in pothole cover increased from 48.8% to 62.3% in the period May to July. The greater availability of prey probably influenced the concentration of raccoon activity: the proportion of animal food items in raccoon scats and stomachs increased from 6.6% in winter to 45.3% in spring. Gestation in raccoons is coordinated with the spring break-up and females nursing litters may depend on the continued provision of pothole foods until as late as September. The highly productive pothole habitat assures survival and reproductive success for raccoons during a period of nutritional stress in spring, and provides energy for females and their litters throughout summer.

Raccoons in Manitoba require efficient dens to survive adverse winter climate. Since tree cavities, the favoured den of raccoons (Preble, 1941; Stuewer, 1943; Gysel, 1961; Johnson, 1970), are rarely found over major portions of the aspen parklands, suitable alternatives are essential. In the study area, winter dens were provided by scrub piles, cellars and abandoned animal burrows. These provided adequate protection in winter. Temperatures in an unoccupied cellar varied directly with external temperature between December and March: 1.0 F for each 2.1 F change in ambient temperature. This was less efficient than the 1:5.4 ratio recorded for den trees (Stains, 1961). Had a raccoon been present, the body heat produced would have greatly enhanced this correlation. A fox burrow provided an exceedingly stable environment in winter. Temperature varied 1.0 F for every 20.7 degree change in ambient temperature. Minimum temperature inside the burrow was 27.5 F and in the unoccupied cellar, 7.0 F when minimum ambient temperature was -42.0 F. Scrub piles probably are intermediate between cellars and burrows in the protection they afford animals. When covered with snow, these provide protection from wind and hold the heat produced by the occupant.

Adequate natural dens are apparently too few to sustain raccoons in the Manitoba pothole area. If not for the dens available in scrub piles and buildings, raccoons probably could not survive winter in Manitoba and the population would be reduced. The continued existence of the species in this severe environment would seem improbable.

Den choice is especially important to survival in winter; four of five raccoons found in upper structures of buildings were dead. Cellars, grain storage bins, hay lofts and scrub piles were accessible to three of these animals, but were not selected as winter dens. Competition among raccoons for prime winter dens is unlikely because suitable sites are abundant throughout the pothole habitat and because raccoons tolerate large numbers of their own species in winter dens (Mech and Turkowski, 1966). It may be that some raccoons freely select dens of inferior protective quality, and these do not survive.

The majority of raccoons that choose dens near stored grain probably survive the winter. Of six raccoons that travelled from the den to nearby grain supplies at least once during the winter, all survived until March. A raccoon lived a minimum of four years in a den located 100 feet from a wheat-filled granary. Heavy use of corn by raccoons from nearby winter dens was noted in Minnesota (Mech and Turkowski, 1966) and South Dakota (Geis, 1966). In Manitoba, raccoons that select winter dens of high insulation value, located near grain supplies, probably experience minimal environmental stress. Little energy is dissipated inside the den or during short trips to feed, and reserves are accumulated during feeding. The portion of the population that utilizes such dens and food supplies is probably very small. However, the great majority of these animals probably survive for many years.

Emergence by raccoons in winter is probably dependent on ambient temperature and on acclimatization by the animal. It may be essential to survival. Raccoons on the study area were generally inactive from late November, concomitant with the first reduction in temperature below 10 F, to mid-February. Emergence was recorded during only 18 of 86 days in this period, and involved no more than four raccoons on any one day. Travel distances did not exceed 0.25 miles. Arousal occurred in November when temperatures of 20 F or more were attained. As winter continued, arousal occurred at progressively lower temperatures, with maxima between 10 and 20 F. Daily minima were rarely below -5 F on these occasions; however, raccoons probably remained inside the den when temperatures were below 0 F (Novikov, 1956).

Emergence at some time during winter may be essential for raccoons to survive in Manitoba. During years in which subzero temperatures persist for several months, raccoons would be restricted to their dens. Those that ventured any distance in search of food would perish; others would die of malnutrition, parasites and disease (Redford, 1962; Novikov, 1956). Manitoba raccoons are capable, due to acclimatization, of utilizing infrequent warm periods in winter to obtain food. Body energy depleted by heat loss during long periods of extreme cold may then be restored. Mortality is probably reduced in such instances.

Mortality may be greatest among Manitoba raccoons during the early breeding season. Travel at this time is in response to sexual urges that override the discomfort and hardship brought about by extreme cold and starvation. In the study area, raccoons emerged during 20 days between February 12 and March 20, 1969 while ambient and den temperatures remained below the freezing point. One movement by a male exceeded 10 miles. Between November 22 and December 28, 1968, ambient and den temperature regimes were similar to those of February and March; however, raccoons emerged from dens during only 13 days. This indicates that a biological response in the animals may have prompted emergence and a resulting exposure to environmental extremes that would not otherwise be tolerated. Winter stress would be compounded by starvation at a time when large expenditures of body energy were necessary for travel and breeding activities. The effect could be critical, especially in yearlings that are already in poor physical condition. An increase in mortality would be expected at this time.

Raccoons in the Minnedosa pothole region frequently change their areas of activity over winter. This is manifested by extensive wandering by yearlings and adult males during the breeding season. Activities were generally confined within 1 square mile of pothole habitat from late spring to fall. However, the mean distances from fall to spring trap locations usually exceeded 1 mile, and the maximum was 10 miles. Adult females restrict their home range to approximately 0.25 square miles, apparently in response to the activities associated with raising young. The breeding den is often in the same location as, or near the winter den. Conversely, adult males do not alter the extent of their travelling due to the seasons; mean trapping distance was consistently about 1.5 miles during and between years.

Shifts occur in home range of raccoons in several other states (Cunningham, 1962; Ellis, 1964; Geis, 1966), and it is postulated that they are a response to breeding and seasonal availability of food. In Manitoba, such movements may be extensive due to a homogeneous habitat and a sparse population. A male travelled 10 miles in two days in March but apparently did not obtain food or contact a mate. Raccoons may enter strange environs during the mating search, may become lost and continue away from their centres of activity. A yearling maintained three successive activity areas of 0.3 square miles during a journey of more than 10 miles. Movement by raccoons across the pothole area is probably random at this time because food and dens are fairly equally distributed and because of a lack of visual keys; there are no streams and few melt channels that might serve as travel lanes. Dispersal and shifts in home range would be natural under these circumstances.

Establishment of the Population

Raccoons became established in Manitoba since 1940 because man altered the ecology of the aspen parklands. This is the result of economic development and intensified agriculture which has continued from the mid-west United States northward into the prairie provinces (Whitney and Underwood, 1952; Geis, 1966). Farmsteads are abandoned and large tracts of land are controlled by few individuals; 6 of 15 farms on 9 square miles of the study area have recently been vacated, and two are occupied by retired farmers.

Man has provided, through land management practices, the solution to the two major ecological factors that limit raccoons in Manitoba: winter foods and den sites. Large quantities of grain are stored in structures accessible to raccoons; these include abandoned houses and deteriorated granaries. In 1968, excess grain was piled on the ground and was exposed to rain and snow. Some grain fermented in granaries and remained accessible to raccoons for several years. Grain is eaten extensively by Manitoba raccoons and forms 61% of the winter diet. Tree clearing provides scrub piles that are used by raccoons as dens.

The attempts to exterminate wolves and coyotes throughout northern U.S.A. and central Canada may have caused alterations in the community structure of the aspen parklands. Foxes, skunks and raccoons have greatly increased since 1940. Raccoons generally are not preyed on by coyotes or wolves (Bond, 1939; Murie, 1945), but removal of these large predators may have opened a niche which has been occupied by raccoons. Ground burrows furnished by an increasing red fox population may assure survival of raccoons in winter. Fox burrows provide a stable environment; the interior temperature may vary only 3.0 F during the winter, and raccoons probably can survive the winter months in these burrows.

Raccoons possess a number of biological characteristics that contribute to extension of the range and establishment of the population in an inhospitable environment. They have a high reproductive rate, are omnivorous, and have a high rate of emigration. The latter is a common characteristic especially in northern raccoon populations (Priewert, 1959; Lynch, 1967). Dispersal through emigration may be an important mechanism to balance raccoon population density in adjacent habitats and to assure an equal utilization of available foods and den sites. When dispersal is great, frequencies of contact and opportunities to mate are conceivably greater in peripheral habitats. The minimum emigration rate of Manitoba raccoons is 9%. This may be great enough to establish a population in new areas. Reports of frequent sitings as far north as The Pas, Manitoba indicate that raccoons are in fact increasing their numbers in northern areas of the province.

Although demographic data are inconclusive concerning trends in the Manitoba raccoon population, field observations indicate population stability. Hunters, trappers and farmers in the Minnedosa area have not noted discernable changes in effort to harvest this species, in frequencies of roadside observations, and in the extent of depredations to grain. A raccoon hound used in the field from 1967 to 1970 located raccoon trails with apparent equal success in every year. Therefore, population stability had probably been reached before 1967 and little change has since occurred. From these observations and from the increase in numbers of raccoons in more northerly areas, it may be concluded that the raccoon population is stable in the southern portion of Manitoba and the range is extending further north throughout the aspen parklands.

Economic Relationships

Raccoons are important to the fur trade in Manitoba. Annual supplies of pelts do not meet market demands and an increased harvest is economically feasible. The Manitoba raccoon population is large enough that a greater annual kill is possible under managed conditions. This would mean increased income for the province and the fur industry.

Hunters have become increasingly interested in the development of raccoon hunting in Manitoba. Coon hounds have been purchased from American stock during the last five years, hunters have enjoyed the sport, and have interested friends in it. The number of potential raccoon hunters in the province has increased correspondingly. Substantial income may be realized from the sale of pelts, particularly since hunting with hounds is exceedingly efficient (Noren, 1941; Atkeson and Hulse, 1953; Johnson, 1970). Legalizing night hunting of raccoons with hounds would be beneficial to the fur industry; however, uncontrolled hunting may have disastrous effects, resulting in the decimation of the raccoon population. In spring of 1971, two hunters with hounds killed all raccoons found in abandoned buildings within a 10 square mile area in Odanah Municipality. If one female and litter per square mile were killed, this would represent a minimum 40 raccoons, or four per square mile. This is approximately one half of the minimum population in a small area. Therefore, it is apparent that any increase in hunting pressure must be carefully regulated to maintain the raccoon population as a renewable resource.

Previous to the influx of raccoons in 1950, over-water nests of waterfowl in Manitoba were susceptible to predation only by crows and magpies. Raccoons are efficient predators, wading and swimming to reach nests, as far as 100 yards from shore (Hammond and Mann, 1956). They concentrate activities in potholes during spring and have become the greatest single predator on diving duck and coot eggs throughout the Manitoba pothole area (Olson, 1964; Stoudt, 1969, personal communication). Olson (1964) and Stoudt (1969, personal communication) showed that raccoons are responsible for up to 58% of canvasback duck nests lost in the Manitoba potholes. Stoudt reported that raccoons were responsible for destruction of the nests of all species of waterfowl that nest in the potholes.

The impact of raccoon predation on ducks in Manitoba has undoubtedly been augmented by current land-use practices. Pothole vegetation is ploughed under as close to the water's edge as possible in order to increase tillable acreage, and the remaining vegetation is often burned off. Forest clearing is extensive and fallowing is practised in spring and summer. An unknown number of waterfowl nests are destroyed directly, however a greater number are probably destroyed by predators due to a decrease in nesting cover. An example of the importance of nesting cover as a deterrent to raccoon predation is that of ruddy ducks, which nest late in the season after extensive growth of emergent cover; they have the greatest nesting success: 59% (Stoudt, 1969, personal communication). Nest predation by raccoons in potholes can be decreased significantly through proper manipulation of habitat, including changes in present techniques of grain farming.

APPENDIX

MANAGEMENT OF RACCOONS IN MANITOBA

Raccoons have existed with man throughout the major portion of the range in Manitoba. They have been valued as game animals, for their fur, and as pets. However, because of their predation on duck eggs, depredations on grain, sweet corn and domestic fowl, and damage to farm buildings, raccoons have attracted public sentiment against them. The species is presently threatened by extinction by unmanaged predator controls, and by overharvesting because of high fur prices.

It would be in the best interest of the Province of Manitoba if raccoons were managed as a game species, utilizing a two-part scheme. They should be protected in areas where waterfowl are not produced; designated the management units. Then the excess population would be utilized as a renewable resource and a source of income from pelt sales. Depredation control could be carried out on a complaint basis. Alternatively, waterfowl production areas should be designated as predator control units within which hunting and trapping of raccoons may occur year round.

The management of raccoons should be organized under the Manitoba Department of Mines, Resources, and Environmental Management. Data concerning raccoon nest predation, depredations, and raccoon population size and structure should be collected. Further research should be encouraged through procurement of grants at universities.

The success of management and control programs may be assessed by comparing live trapping success of adult raccoons in spring, annual pelt take, and rates of predation on waterfowl nests on managed and non-managed areas. Local depredation controls could be evaluated by comparing annual numbers of complaints made, annual takes of problem raccoons, and estimates of depredation losses.

In the management unit, raccoons would be harvested on a seasonal, sustained yield basis with emphasis on perpetuating their numbers for hunting and trapping. A hunting season from August 15 to February 28 would not adversely affect raccoon reproductive success, thus ensuring an annual fur crop. Trapping could be permitted from November 15 to April 30 when pelts are prime. This would have minimal effect on reproduction because yearling raccoons, which constitute most of the trappable population, contribute little to productivity. The bag limit should not exceed one raccoon per hunter per night. A hunting party usually consists of several people, therefore, the night's hunt would not be restricted to only one chase. Bag limits may be adjusted subsequent to several years of research concerning raccoon population trends within the management unit.

Complaints concerning raccoon depredation or damage should be the jurisdiction of the Conservation Department; however, the landowners should be responsible for the removal of problem animals under the direction and advice of a conservation officer. Traps or other equipment could be loaned to the landowner and instruction provided for their use. Pamphlets describing raccoon hunting and trapping techniques should be prepared and the layman educated concerning problem raccoons.

Depredations on stored grain occur during the late winter and spring when natural foods are scarce or unavailable and raccoons have emerged from winter dens. Fur is prime during the period of February through April and should be harvested.

It is desirable that a raccoon pelt industry be established in Manitoba. Fur dealers complain of the small annual raccoon harvest, and report that they have a greater demand than they can satisfy. This necessitates a province-wide organization of regulated hunting and trapping seasons, management, research, and cooperation between government and the people of Manitoba.

Raccoons must be given game animal status. This would entail changing statutes to include night hunting with lights. The existing law prohibits the use of lights while hunting at night, but does not include restrictions on carrying firearms at night. It is proposed that hunters be permitted to carry flashlights of any size while night hunting and that a .410 shotgun with #4 shot maximum pellet size, or a .22 calibre rifle with short rimfire cartridges, be legallized for this sport. The gun should be carried breached or encased until the raccoon is located in the light and can be shot with maximum safety to the hunting party. A Conservation Officer checking night hunters to ensure against jacklighting for deer need only examine the firearms in use, and could confiscate any other than those permitted by law.

Raccoon hunting cannot be successful, nor enjoyable, without hounds. Hunting with hounds is an established sport in a large part of the United States and is superior to trapping for taking substantial numbers of animals. Hounds have also been used effectively to regulate raccoon populations in restricted areas. In order to introduce this sport into the province, it is necessary to organize local houndsmen's clubs with the aid of established organizations such as the Manitoba Wildlife Federation, Ducks Unlimited, Manitoba Fur Buyers, management and research groups. These organizations could be vehicles for the collection and distribution of literature and films concerning raccoon ecology, management, problems and solutions, harvesting, hunting and trapping techniques, and maintenance and training of hounds. Hunters could increase their skills by pooling experiences and could develop a profitable business of raccoon hound breeding, training, and trading.

The province could direct organization of houndsmen's clubs as well as provide information and advertising. The many groups involved including the Manitoba Department of Mines, Resources and Environmental Management, and the fur industry, could publicize the need for organized raccoon hunters' groups. The cooperative efforts of all would result in proper raccoon management in Manitoba.

Farmers could enhance their incomes through the sale of pelts, and by checking grain storage structures and outlying buildings to remove problem animals. Raccoon damage to sweet corn is restricted to gardens during late August and September. Brochures concerning prevention of damage to corn should be made available and instructions given on the media prior to and during corn ripening.

The Conservation Department should have power to permit hunting and trapping on lands of the complaintee, with his consent, and until depredations cease. This would remove problem animals at minimum cost to the province, permit hunters to use their hounds throughout the year, and satisfy landowners.

In waterfowl management and production areas, raccoon hunting and trapping should be conducted year round in an effort to have maximum control of the raccoon population, and thus minimize nest predation. Hunters could be recruited from areas with restricted seasons in order to concentrate hunting. Competitive hound trials could be organized by refuge personnel prior to and during duck nesting seasons to decrease raccoon numbers and thus improve duck production. Raccoon den hunts conducted under supervision of experienced field personnel during May and June, would ensure the capture of reproductive females and their litters. These may be transported to management unit areas to increase depleted indigenous populations.

Intensive control of raccoons may only be temporary until a more permanent system of habitat management can be instigated. The rate of raccoon predation on waterfowl nests is a reflection of land management practices that are not condusive to high yields of waterfowl. Agricultural overproduction with little consideration for existing habitat is the cause; high predation rates on duck nests is the effect. If waterfowl are to exist as a harvestable resource, breeding habitat must be managed. Raccoon control will bring only temporary relief and a little more time to adopt more permanent and effective duck management programs. Raccoon control areas may then be converted to raccoon management units.

In summary, the overall aims of raccoon management should be (1) to ensure that the species is not extirpated, and that a substantial population be maintained where they do not conflict with man's activities, (2) to increase the monetary gain from the raccoon fur harvest, (3) to alleviate nest predation in waterfowl production areas, and (4) to eliminate depredations in agricultural areas. Raccoons can be protected by a well managed hunting season and a change in the status of the species to that of game animal. The raccoon pelt harvest can be increased with possible financial aid from the fur industry, by publicizing the need for a greater annual harvest, and the organization of raccoon hunting on a province-wide scale. Waterfowl nest predation can be controlled temporarily on production areas by year round hunting and trapping. Farmers reporting depredations on grain and building damage could be instructed by Conservation Officers, and be permitted to use Department equipment to remove problem animals for personal profit and at minimal cost to the province.

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