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The Development and Evaluation of a Predator
Population Monitoring System
for Agricultural Manitoba

by
Graham P. Latonas

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THE DEVELOPMENT AND EVALUATION OF A PREDATOR
POPULATION MONITORING SYSTEM
FOR AGRICULTURAL MANITOBA

by

GRAHAM P. LATONAS

A practicum submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the
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ABSTRACT

The response to predator-inflicted loss and current high fur prices is contributing to increased trapping and hunting pressure upon predator populations. A red fox population monitoring study was conducted over six townships in the cropland habitat region of agricultural Manitoba during the spring and summer of 1976. Aerial surveys, colour infra-red imagery analysis, landowner questionnaire surveys, and personal interviews were conducted and evaluated as possible red fox population monitoring techniques. The relative spring red fox population in the study area (based upon den counts) was estimated at 0.31 fox per square kilometer. The aerial survey technique was the single most reliable method, but, increased reliability was achieved by combining techniques. Questionnaire and interview response did not yield reliable population estimates but these methods did provide information regarding predator-inflicted loss, fox harvest, and attitudes towards fox population control. Predator-inflicted loss, over a three township sample area, was estimated at 2.50 dollars per square kilometer. Estimated landowner income derived from the harvest of foxes was 8.85 dollars per square kilometer. The harvest of fox populations accounted for a net economic gain of 6.35 dollars per square kilometer in the sample area. An economic supply model, based upon historical data for which

prices were adjusted according to the price index, can, in conjunction with a reliable population monitoring system, provide a valuable management tool, making it theoretically possible to predict the impact of coming trapping seasons upon fox populations. The harvest of foxes as predators is unwarranted under present economic conditions. Adequate control of foxes can occur pursuant to The Wildlife Act alleviating the necessity to classify foxes as predators under The Predator Control Act. The aerial survey monitoring technique and the economic supply model should be refined and incorporated as part of a predator management program to manage fox populations more efficiently in response to fluctuating economic conditions and population levels.

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I. INTRODUCTION

1.1 The Statement of the Problem

Between 1944 and 1965, the Province of Manitoba and Rural Municipalities have paid out a total of 1,188,125.50 dollars in bounty payments for predator control (Emberley 1968). This represents an average yearly expenditure of approximately 90,000.00 dollars. The results of this attempt at predator control were largely negative. In 1965, a new Predator Control Act was passed, placing the administration of predators under the Department of Mines, Resources and Environmental Management. Bounties were discontinued in favour of the use of poison baits, primarily aimed at controlling coyote populations in agricultural areas of Manitoba (refer to Appendix I). The Act provided for cost-sharing agreements between the Province and Rural Municipalities to implement the following control programs:

- 1) 1080 Poison Bait Program for controlling coyotes and foxes.

- 2) \$10.00 Program whereby the Province assessed the municipality \$10.00 for each complaint investigated by field officers.

- 3) Special Trapper Programs to deal with special problems within a municipality (usually directed towards wolf control). The program included a trapper education series

and some landowner participation in fur schools.

4) Vehicle Hunter Program. This regionally administered program made available special permits allowing aircraft, snow plane and snowmobile hunting to control predator populations. These special programs are no longer in effect.

Between 1968 and 1974, in the Western Region of Manitoba alone, 39,180.12 dollars was spent on predator control. No predator population monitoring studies were conducted, consequently the effect of these programs upon predator species or other wildlife populations is unknown.

The red fox is classified as a predator (in predator control areas of the Province) and is subject to the regulations set forth in The Predator Control Act. In the past, fox populations have undoubtedly been overharvested in areas as a result of predator control programs.

Fox populations are an economically valuable resource and the species is classified as a fur bearer subject to the regulations set forth in The Wildlife Act. Several inconsistencies and jurisdictional questions arise because of the fur bearer-predator classification of the red fox. The species is currently being harvested as both a predator and as a fur bearer. Recent high fur prices and the subsequent increased trapping pressure, in conjunction with predator harvest, may adversely affect red fox populations density in the Province.

At present, there is no program in the Province to monitor red fox or other predator populations. There is also

no method by which trapping pressure on fur bearing species can be predicted in response to fluctuating raw fur prices.

1.2 The Objectives

1) to delineate specific red fox habitat regions within agricultural areas of Manitoba.

2) to delineate specific census townships within the habitat region chosen for the study.

3) to determine population density and distribution of red fox within the census townships chosen for the study.

4) to evaluate aerial survey techniques and infrared imagery as population monitoring systems.

5) to survey local landowners to determine predation levels, predator densities, and landowner attitudes towards predators within the census townships.

6) to determine the economic feasibility and the reliability of these monitoring systems in determining predator population levels throughout agricultural areas of Manitoba.

7) to investigate the inconsistencies and jurisdictional problems arising from the legal classification of the red fox as a fur bearer-predator.

8) to investigate and apply economic theory to Manitoba's fox population and to demonstrate the value of economic models in wildlife management.

1.3 The Hypotheses

The first hypothesis is that the aerial census technique, using den counts as an indicator of total fox families,

will yield reliable estimates of population densities in open agricultural areas.

The second hypothesis is that infrared imagery analysis will successfully delineate active fox den sites on an economical scale.

The third hypothesis is that landowner information acquired through questionnaire sampling and interviews will yield a reliable estimate of fox population density in the study area.

The fourth hypothesis is that economic evaluation of historical red fox harvest data will provide a valuable management tool for predicting the harvest response to fluctuating market conditions.

1.4 The Delimitations

As a result of time, manpower, and budget constraints, the study did not attempt to monitor more than one census region. Therefore, no correlation of predator population levels in different habitat regions is possible.

1.5 The Assumptions

The first assumption is that a predator problem will continue to exist in Manitoba in areas where proper animal husbandry techniques are not implemented. Development and implementation of a reliable monitoring system as part of a predator management program will aid in predicting potential problem situations by delineating areas of high fox populations.

The second assumption is that the aerial census technique will provide the most reliable estimates of predator population levels in open agricultural areas.

The third assumption is that the number of active red fox den sites is the best indicator of the number of total families and that the number of foxes per family in the study area do not differ significantly from numbers recorded in other studies.

1.6 The Importance of the Study

The lack of consistent and quantitative data makes it difficult to assess the magnitude of the predator problem. The effect of predator inflicted losses upon the economy of a region may be evaluated by combining the following:

- a) livestock losses directly attributed to predation.
- b) cost of predator control programs.
- c) non-marketed fur values (i.e. value lost by not selling the furs of predators taken under control programs).

The data from the Western Region of Manitoba represents the most complete and accurate information available for analysis. Tables I through V outline the sources and values of the various components comprising the total economic loss resulting from predation and control programs in the Western Region during the period 1968 to 1974.

During this period a total economic loss of 245,518.06 dollars (Table V) can be attributed to the predator problem within the region. The greatest proportion of this loss

Table I Expenditures for predator control in the Western Region of Manitoba.

Year	Total Number of Complaints	Total Cost for Control Program
1973-74	89	\$ 13,180.12
1971-73	148	7,097.00
1970-71	125	9,091.00
1969-70	54	5,130.00
1968-69	79	4,682.00

(I. McKay, pers. comm.)

Table II Value of livestock losses experiences in the Western Region of Manitoba

Year	Total Value Reported Lost
1973-74	\$ 10,805.00
1968-69	2,460.00

(I. McKay, pers. comm.)

Table III Average fur value of predators taken under Predator Control Programs*
in the Western Region of Manitoba.

Year	Bear	Badger	Coyote	Fox	Lynx	Raccoon	Timberwolf	Total Value
1973-74	--	2	538	438	11	4	-	\$ 29,522.91
1971-73	28	1	836	433	--	-	6	20,120.78
1970-71	29	1	293	174	--	64	1	6,271.30
1969-70	--	-	385	696	--	6	-	12,193.00
1968-69	63	-	754	1670	--	3	-	36,731.50

*Also includes all special control programs, i.e., aircraft and snow vehicle permits and special snaring programs.

Table IV Average fur value of fox taken under Predator Control Programs in the Western Region of Manitoba.

Year	Value	Present Value (\$1976)*
1973-74	\$ 17,169.60	20,776.38
1971-73	9,645.08	14,121.64
1970-71	2,157.60	3,474.96
1969-70	6,960.00	12,329.50
1968-69	24,215.00	47,184.33
TOTAL	\$ 60,147.28	97,886.81

Table V Economic loss experienced in the Western Region of Manitoba as a result of predation, predator control programs and non-marketed furs.

Year	Total Economic Loss	Present Value (\$1976)*
1973-74	\$ 53,508.03	64,748.34
1971-73	27,217.78**	39,850.34
1970-71	15,362.30**	24,741.99
1969-70	17,323.00**	30,687.33
1968-69	43,873.50	85,490.06
TOTAL	\$ 157,284.61	\$ 245,518.06

(R. Stardom, Pers. Comm.)

- * present value calculated using a 10% discount rate
- ** exclude estimates of livestock loss resulting from predation

(66.7 percent) results from not marketing pelts, and subsequently losing the value of all predators taken under the various control programs. Nearly forty percent of the total economic loss (i.e. 97,886.81 dollars) represents the loss due to not marketing fox pelts harvested through the various control programs. Although the actual predation problem attributable to foxes is not as great as that due to coyotes, the number of foxes taken as predators, and the subsequent economic loss, is substantial. It is assumed that the total economic loss experienced by all of agricultural Manitoba during this same period was substantially greater than the loss incurred in the Western Region alone. Livestock loss, in the past, has acted as the impetus for bringing political pressure to bear on the predator problem. As a result, several extensive, costly, and ineffective control programs were implemented.

The need for a complete predator management program is evident. Students of the Natural Resources Institute conducted a survey regarding predators and predator control problems. Government personnel currently involved in control programs and several other interest groups were surveyed. Overall, 83.8 percent of the respondents felt that a predator management program should be developed for the province and 89.0 percent of the respondents agreed that such a program should include a predator population monitoring system. Although these results are in no way conclusive of public attitudes, they nevertheless strongly indicate the need for

both a management program and a population monitoring system.

A sound management program would require the following:

- 1) an efficient and reliable predator population monitoring system.
- 2) a central data collection agency.
- 3) a landowner education program.
- 4) effective control techniques.

The ultimate objective of this study is to develop phase one (an efficient and reliable predator population monitoring system) and pave the way for the development of a complete predator management program.

1.7 Literature Review

Knowledge of red fox and coyote densities is essential for the development of a management program and for assessing their impact on prey. Scott and Selko (1939) conducted spring ground searches in Iowa to locate red fox dens. The number of fox families identified from den counts was used to estimate density. This method was then modified by Scott (1941) into a fall inventory of fox sign, mainly to reduce the number of man hours required by the original study. Richards and Hine (1953) checked fox sign at scent stations along trails about 30 miles (48 km) long in Wisconsin. In the rabies control project in New York (McKeon 1952), fox populations were estimated by averaging the number of tracks per road mile after a fresh snowfall. This method was not considered to be valid as no correlation with actual populations could be determined.

Sheldon (1950) and others have conducted tagging studies, but these were used more to determine the extent of movement than to estimate population density. Many researchers in the past have employed bounty records and fur catches in estimating populations. Wood (1959) utilized a series of standardized traplines, with traps set at 0.2 mile (0.32 km) intervals. Comparisons between areas were based upon the proportion of successful trap stations. A scent post method, based upon the proportion of stations visited, was used to corroborate the results of the trapping method. This system appeared quite adequate, and was used to evaluate the effects of fox control programs.

The scent post technique has been elaborated upon by Linhart and Knowlton (1975) in an attempt to determine the relative abundance of coyotes. This extensive survey utilized several hundred standardized scent station lines and was conducted in 17 western states. Animal visits, based upon track counts, were used to provide an index by which coyote population trends may be compared between states, regions, and years. Lemke and Thompson (1960) evaluated the use of questionnaires in determining a fox population index. The percentage of positive reports of foxes was evaluated as a population index by comparing it with existing fox bounty claims. Significant relationships between reports and claims were noted, suggesting that questionnaire results may provide an inexpensive means of arriving at a population index.

The methods previously outlined have produced only

indices for monitoring population trends. The relationship of these indices to actual population densities is largely conjectural. MacPherson (1969) used den counts of Arctic foxes to study and determine the cause of population fluctuations. The study lasted 5 years (ending in 1963) and utilized questionnaire information, trapper information, dog sled, canoe and foot searches to locate and map den locations. In 1959, the use of low altitude flying in light, single engined aircraft was tested as a method for surveying fox dens in the Northwest Territories (McPherson, 1969). Sargeant et al. (1975) utilized systematic aerial searches to locate red fox and red fox rearing dens. The survey covered six townships (559.4 km²) that contained no villages or well travelled highways. Systematic searches were conducted during mid-April, mid-May and mid-June. Each township was flown in transects spaced 0.40 kilometers apart in 1969, and 0.32 kilometers apart during 1970 through 1973. The combined sighting of fox dens and individual adults was used to determine the number of fox families in the census region. The number of fox families was used in measuring population density. Dens, highly visible during the mid-May searches, were found to be the most reliable family indicator. Adult foxes and pup sightings were less reliable as family indicators. Rural mail carriers (RMC's) were employed by Allen and Sargeant (1975) to obtain an index of fox populations for comparison with data acquired by the aerial census techniques. The study was conducted concurrent to the aerial searches during mid-April, -July, and

-September of 1969-73. The mid-April RMC index reflected the annual fox density changes recorded on the 6 townships (correlation coefficient=0.958). Indices often reveal population trends at considerably less expense than census data, and may prove adequate for management requirements.

McKay (I. McKay, pers. comm.) used an aerial sampling technique in an attempt to obtain a spring coyote population index for predator problem areas in the Western Region of Manitoba. Sample plots representative of each habitat type were flown at altitudes ranging from 35 to 70 metres and at airspeeds ranging from 88.5 to 112.7 kilometers per hour. The need for ground verification of aerial sightings became evident in distinguishing between coyote, red fox and badger dens.

To date, the aerial survey technique, based on den counts, appears to be the most reliable method in estimating population density for red fox. The main drawbacks involved are the expense associated with aerial censusing and the short time period over which data may be collected.

1.8 Ecology of the Red Fox

The red fox is common throughout Manitoba. The geographic range of this species, and its various sub-species, is illustrated in Figure 1.

All three colour variations, red, cross, and silver, occur in Manitoba. The variation of colour is thought to be caused by the action of a single pair of gene alleles. The homozygous dominant produces red foxes, the homozygous

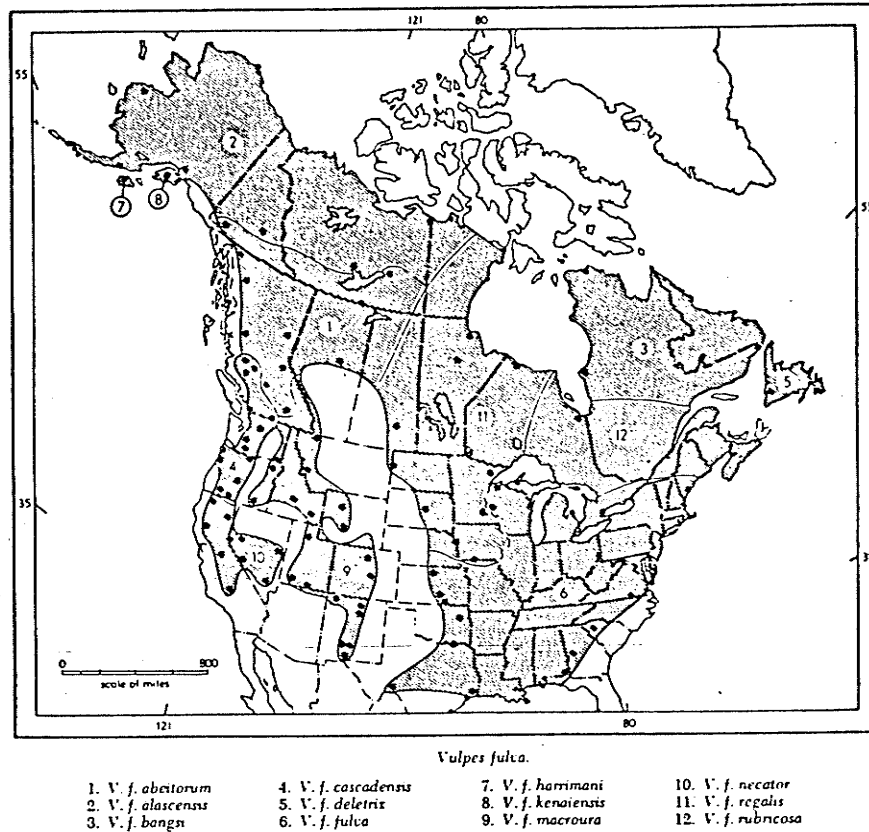


Figure 1 Geographic range of the red fox (Banfield, 1974).

recessive produces silver or blue foxes, and the heterozygous form produces cross foxes (Banfield, 1974). The cross and silver colour variations are more common in the northern portions of their range.

Red foxes are adaptable, and inhabit a variety of terrain and vegetation types. The red fox prefers a habitat type composed of a mixture of vegetative components, avoiding large homogeneous tracts of any single habitat (Fox, 1975). Storm (1965), however, could discern no habitat preference

between cropland or woodlands during a radio tracking study. Foxes, according to Banfield (1974) prefer semi-open areas and are seldom found in dense forest. The determining factors in habitat selection are food and cover availability.

The vixens are monoestrous and exhibit estrus between December and the end of March. The estrus period lasts 1 to 6 days with a period of sexual receptivity of 2 to 4 days. The young are capable of breeding at an age of 10 months and generally breed later in the same estrus period than adults (Fox, 1975).

The pups are born between March and May after a gestation period of 51 to 53 days (Banfield, 1974). Observation of pups during the study suggest that parturition occurred during mid-April in southern Manitoba. Litter sizes may vary considerably (from 1 to 13) but generally, the average number of young per litter between studied populations, is relatively constant (Fox, 1975). Average litter sizes of 4.6 and 5.5 pups were recorded in Michigan (Schofield, 1958), 5.37 and 5.4 in New York (Sheldon, 1949) and 5.1 and 5.4 in Wisconsin (Richards and Hine, 1953). Banfield (1974) recorded an average litter size of 5.1 pups.

Dens are prepared in late winter. Foxes may excavate their own or enlarge the dens of other burrowing mammals. Location preference will vary with habitat type and topography. Well-drained sites with loose soils located near vegetative cover are preferred (Fox, 1975). Dens generally have two or more entrances, with older, well-established den sites often

having a large number of interconnected openings. MacPherson (1969), categorized arctic fox dens by age:

1. Youthful - no development of characteristic vegetation; few burrows; sand heaps the most conspicuous feature of the den.
2. Mature - well-developed; good mat of vegetation; no extensive area of collapsed burrows.
3. Old - large den site; many burrows; vegetation rich; extensive area of collapsed burrows.
4. Senile - no longer active; burrows collapsed, producing a distinctive hammocky appearance; covered with tall grasses.

The same age transition in den type occurs in red fox dens.

Adult foxes tend to remain in the same area for life, though the range area will vary with habitat and food availability (Fox, 1975). Most fox activity occurs within a 1.6 kilometer radius of the den site (Scott, 1943, 1947; Richards and Hine, 1953; Storm, 1965). This home range area was used to approximate red fox home ranges in this study.

During fall and winter the family unit breaks down and the young move to new areas. The male pups tend to disperse earlier and move farther away from the home area than do the female pups (Fox, 1975).

Red foxes are opportunistic feeders, eating any acceptable abundant food. Major food items include small rodents, rabbits, ground nesting birds, wild fruits, berries, and insects. Foxes will eat carrion and have been known to hunt along highways

taking advantage of road kills. Fox commonly cache uneaten food items. On excavating a non-active den site, the author found the cached remains of 2 whitetail jackrabbits, 5 meadow voles and 4 thirteen-line ground squirrels.

Few foxes live beyond the age of 3 to 4 years. Coyotes, bobcats, and to a lesser degree wolves, prey upon red foxes. Man has exerted the greatest pressure upon fox populations through hunting and trapping. In a Wisconsin study (Schofield, 1958) man caused a 30 percent mortality for the first year of life and 53 percent during the life span of foxes.

Red fox populations fluctuate according to a 10 year cycle (Cross, 1940; Calhoun, 1950; Butler, 1951; and Keith, 1963). Calhoun (1950), Cross (1940) and Butler (1951) based their population estimates on the annual harvest of fox pelts. Table VI and Figure 2 illustrate the fluctuations in red fox harvest experienced in Manitoba since 1919. Populations (based on harvest) appear to follow a 10 year cycle. However, annual harvests were probably related more to fur prices, bounty payments, and the associated fluctuations in hunting and trapping pressure than to natural population cycles.

1.9 Legal Status of Red Fox in Manitoba

The red fox, legally classified as a "fur bearing animal" in Division 2 of Schedule A of The Wildlife Act, is subject to administration under the following Sections, Subsections and Regulations cited from the Act (Province of Manitoba, 1970).

Table VI Harvest and value of red fox in Manitoba (1919-1974)

Fur Year	Pelts Taken	Average Value	Value to Trapper
1919/20	* 3.070	* 27.22	83,565.40
1920/21	* 1.250	* 13.80	17,250.00
1921/22	* 2.234	* 12.71	28,391.14
1922/23	* 4.159	* 15.11	62,842.49
1923/24	* 9.310	* 14.22	132,388.20
1924/25	11.046	* 15.60	172,317.60
1925/26	11.089	* 15.00	166,335.00
1926/27	4.919	* 19.00	93,461.00
1927/28	3.590	* 29.06	104,325.40
1928/29	2.413	31.25	75,406.25
1929/30	3.161	24.00	75,864.00
1930/31	3.313	13.15	43,565.95
1931/32	5.492	7.42	40,750.64
1932/33	10.363	7.75	80,313.25
1933/34	19.406	7.50	145,545.00
1934/35	18.033	7.00	126,231.00
1935/36	9.461	8.30	78,526.30
1936/37	8.412	8.67	72,932.04
1937/38	8.479	7.38	62,575.02
1938/39	4.935	5.33	26,303.55
1939/40	5.588	5.80	32,410.40
1940/41	10.137	7.00	70,959.00
1941/42	22.852	9.15	209,095.80
1942/43	24.043	13.14	315,925.02
1943/44	24.717	13.00	321,321.00
1944/45	14.533	8.00	116,264.00
1945/46	10.241	2.50	76,807.50
1946/47	6.271	4.30	26,965.30
1947/48	3.173	3.00	9,519.00
1948/49	2.836	2.00	5,672.00
1949/50	1.926	2.00	3,852.00
1950/51	4.060	2.50	10,150.00
1951/52	1.699	2.00	3,398.00
1952/53	1.626	1.75	2,845.50
1953/54	1.164	1.12	1,303.68
1954/55	1.182	1.38	1,631.16
1955/56	.970	1.00	970.00
1956/57	.356	.82	291.92
1957/58	1.221	1.42	1,733.82
1958/59	.745	2.50	1,862.50
1959/60	2.423	4.33	10,491.59
1960/61	1.862	3.42	6,368.04
1961/62	2.118	4.08	8,641.44
1962/63	1.706	5.50	9,383.00
1963/64	3.546	4.75	16,843.00
1964/65	4.345	5.92	25,722.00
1965/66	5.593	12.00	67,116.00
1966/67	7.071	5.42	38,324.82
1967/68	4.866	8.08	39,317.28
1968/69	8.538	14.50	123,801.00
1969/70	9.363	10.00	93,630.00
1970/71	7.183	12.40	89,106.40
1971/72	11.047	15.15	167,362.05
1972/73	14.337	29.40	421,507.80
1973/74	14.838	39.20	581,649.60
1974/75			
1975/76			

* D.B.S. Figures All Other Figures Province of Manitoba

(Manitoba Department of Renewable Resources and Transportation Services 1977)

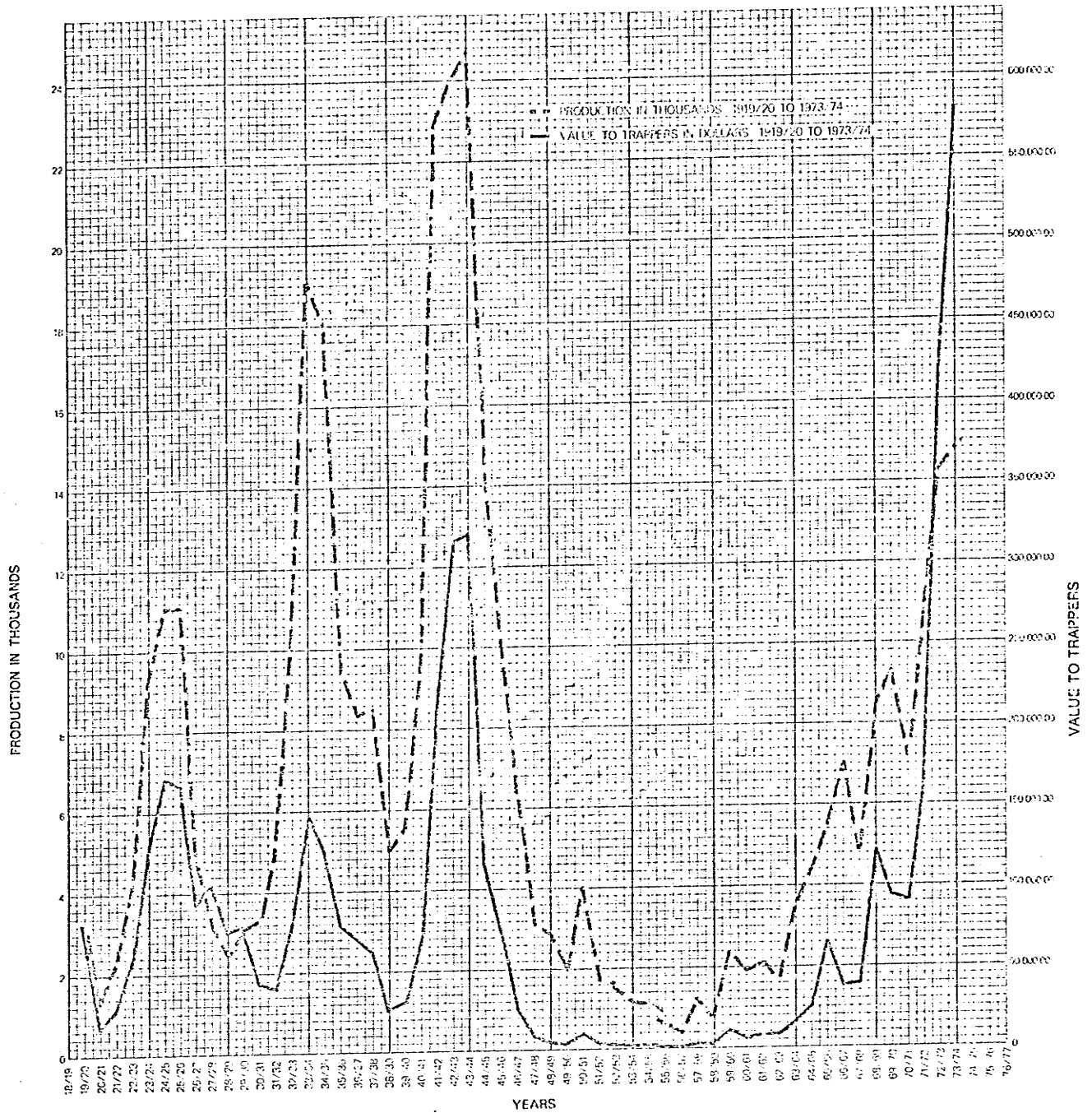


Figure 2 Red fox: production and value to trappers.

(Manitoba Department of Renewable Resources and Transportation Services 1977)

Definitions

2 (a) (g) "Fur bearing animal" means an animal of a species type mentioned in Division 2 of Schedule A to this Act or in the regulations and includes the carcass or pelt thereof and any part of the carcass or pelt thereof"

Division 2 Fur Bearing Animals

Beaver

Fisher

Fox

Lynx

Marten

Mink

Muskrat

Otter

Red Squirrel

Weasel

Wolverine

Black Bear

Trading in furs

30 A person who, by himself or by any servant, employee or agent, engages in, or carries on, or is concerned in, the trading, buying, or selling of the pelts, skins or hides of any animal on which a royalty is payable, or solicits trade therein, and who does not have a valid subsisting licence to carry on trade in such pelts, skins or hides is guilty of an offence ...

Buying pelts from unlicenced persons

31 (1) A person who either by himself or by any servant, employee, or agent, buys, or acquires a pelt, skin or hide of an animal on which a royalty is payable from a person who does not have a valid subsisting licence or permit that authorizes him to sell or trade in the pelt, skin or hide, is guilty of an offence ...

Record of Purchase of Pelts

- 31 (2) Where a person, either by himself or by a servant, employee or agent, buys, acquires, receives, or accepts, a pelt, skin, or hide of an animal on which a royalty is payable from another person, he shall at that time ascertain and make a written record of such information as may be prescribed in the regulations, and any person who fails to comply with this subsection is guilty of an offence ...

Tanning, dressing, etc., pelts

- 32 A person other than an Indian, who either by himself or by his servant, employee, or agent, tans, dresses, plucks, or dyes, a pelt, skin or hide of an animal on which a royalty is payable, or who in any way undertakes, contacts, or agrees to tan, dress, pluck, or dye, such a pelt, skin, or hide and who does not have a valid subsisting licence to dress and tan pelts, skins, or hides of animals is guilty of an offence ...

Possession of fur bearing animals or pelts

- 33 A person who has possession of a fur bearing animal or the raw pelt thereof and who is not the holder of a valid subsisting licence or permit that authorizes possession of the animal or pelt, as the case may be, is guilty of an offence ...

Destroying den of fur bearing animals

- 35 (3) Subject to subsections (4) and (5), a person who molests or destroys the den, lair, or nest of a fur bearing animal without the written authorization of a conservation officer, is guilty of an offence ...

Authority to destroy dens, lairs, etc.

- 35 (5) A conservation officer may, in writing, authorize a person to destroy a muskrat house, beaver lodge, or beaver dam, or the den, lair, or nest of a fur bearing animal subject to such terms and conditions as the director or the conservation officer may prescribe.

There are several other sections and subsections of The Wildlife Act which pertain to the payment of royalties etc. ...

These sections and subsections are not considered important

for discussion in this study but are listed for further reference. These sections of The Wildlife Act are: 36(1), 36(2), 35(3), 36(4), 37, 38, 39(1), 39(2), 39(3), 39(4), 48(1), 48(2).

Other specific sections and subsections of The Wildlife Act of interest to the discussion of the legal status of red fox in the province are:

Use of poison

- 12 A person who uses poison to kill, take, or capture any wildlife or exotic animal listed in the Schedules to this Act or in the regulations, except with the written permission and under the direction of the minister is guilty of an offence ...

Hunting without licence or permit

- 13 (1) Subject to the Predator Control Act, a person who hunts, takes, kills, or captures, any wildlife or exotic animal and who has not previously thereto obtained a licence or permit to hunt, take, kill, or capture, as the case may be, any wildlife or exotic animal of that species or type that would have been valid and subsisting at the time, is guilty of an offence ...

Trapping on Sundays

- 15 (2) Subsection (1) does not prohibit a person who holds a valid subsisting licence to trap fur bearing animals of any species or type from trapping fur bearing animals of that species or type on a Sunday during a period of the year when, and in an area where, the trapping of that species or type of fur bearing animal is permitted under this Act or the regulations.

Exception

- 15 (3) Subsection (1) does not apply to any person hunting and killing a predator in a predator control area.

Hunting out of season

- 16 (1) Subject to the Predator Control Act, a person who hunts, takes, kills, or traps any wildlife or exotic animal at a time of the year when hunting, taking, killing or trapping, or wildlife or exotic animals of that species, type, or class is prohibited under the regulations is guilty of an offence ...

Permission to hunt wolves, etc., from vehicles

- 18 (3) A person who has a permit to hunt and kill wolves, foxes, and coyotes from a vehicle or aircraft may hunt and kill wolves, foxes and coyotes from an aircraft or vehicle and, for that purpose may have loaded firearms in and discharge firearms from a vehicle or aircraft.

Killing animals in defence of property

- 42 (1) Notwithstanding any other provision of this Act, a person may kill or take any wildlife or exotic animal, other than a beaver, a big game animal, a game bird, or a migratory bird on his own land for the purpose of defending or preserving his property.

Report

- 42 (2) A person who kills any species of wildlife or exotic animal listed in schedule A or B of this act or in the regulations in defence of his property as provided in subsection (1), and who does not report the killing or taking to a conservation officer, or the branch within ten days thereof, is guilty of an offence ...

Abandoning wild animals

- 53 (1) A person who has killed or taken a predator or any species of wildlife or exotic animal listed in Schedule A or B to this Act or in the regulations, and who abandons it, or discards it, or fails to make a reasonable effort to retrieve it, is guilty of an offence ...

Exception

- 53 (2) Subsection (1) does not apply in respect of the meat of a fur bearing animal, a predator or a bird listed in Schedule B to this Act or in the regulations, legally taken under a licence to trap fur bearing animals, or taken in defence or preservation of property.

The fox is afforded legal protection subject to The Wildlife Act as a fur bearer as cited. Persons in possession of a valid trapping permit are legally allowed to hunt, trap or otherwise take fox. Section 42 (1) also makes allowance

for landowners to hunt, trap or otherwise take fox on their property for the purpose of defending or preserving their property.

The red fox has the dubious distinction of also qualifying as a predator. In the past, individual municipalities were authorized under The Predator Control Act to pass a by-law providing bounty payments for the taking of predators or nuisance animals within a predator control area. The bounty system is no longer in effect (as of 1968) and administration of The Predator Control Act has been undertaken through the minister of the Department of Renewable Resources and Transportation Services according to the regulations outlined in the Act (Province of Manitoba 1970).

Regulations

- 13 For the purpose of carrying out the provisions of this Act according to their intent, the minister may make such regulations as are ancillary thereto and are not inconsistent therewith; and every regulation made under, and in accordance with the authority granted by, this section has the force of law; and, without restricting the generality of the foregoing, the minister may make regulations not inconsistent with any other provision of this Act.
- (a) Prescribing the manner in which a predator control programme shall be carried out;
 - (b) Prescribing the period during which a predator control programme shall be carried out;
 - (c) Designating species or types of animals as predators;
 - (d) Designating an area within a municipality or a local government district as a predator control area;
 - (e) Prohibiting or restricting the hunting and killing of predators or nuisance animals, or any of them, in all or part of the province during any period.

Under this regulation all Municipalities and Local Government Districts, south of the 53rd parallel, have been designated as predator control areas. This delineation of predator control areas excludes forest reserves, wildlife management areas, parks and recreation lands and unorganized crown land. Predators, as defined for the control areas, include fox, bear, timber wolf, and coyote (Vic McNabb, pers. comm.).

The extremely large Predator Control Area defined under The Predator Control Act includes nearly all of agricultural Manitoba (Figure 3). Consequently, the fox is classified as a predator in addition to its fur bearer status throughout this entire area. The impact of this double classification is, perhaps, not fully realized.

In contradiction to The Wildlife Act, The Predator Control Act allows the legal trapping, shooting, or otherwise taking of fox during any season (including Sunday hunting) by any person not in possession of a legal subsisting licence. As man is the major fox predator, it is important to understand the legal implications of harvesting fox under the dual status classification of a "predator-fur bearer."

The Wildlife Act forms the legal basis for the protection and regulation of fur bearer harvest. The Predator Control Act was designed to alleviate predator problems. The latter, however, makes it legally possible to declare open season on fox populations within the control areas. Some of the possible effects on fox populations resulting from The

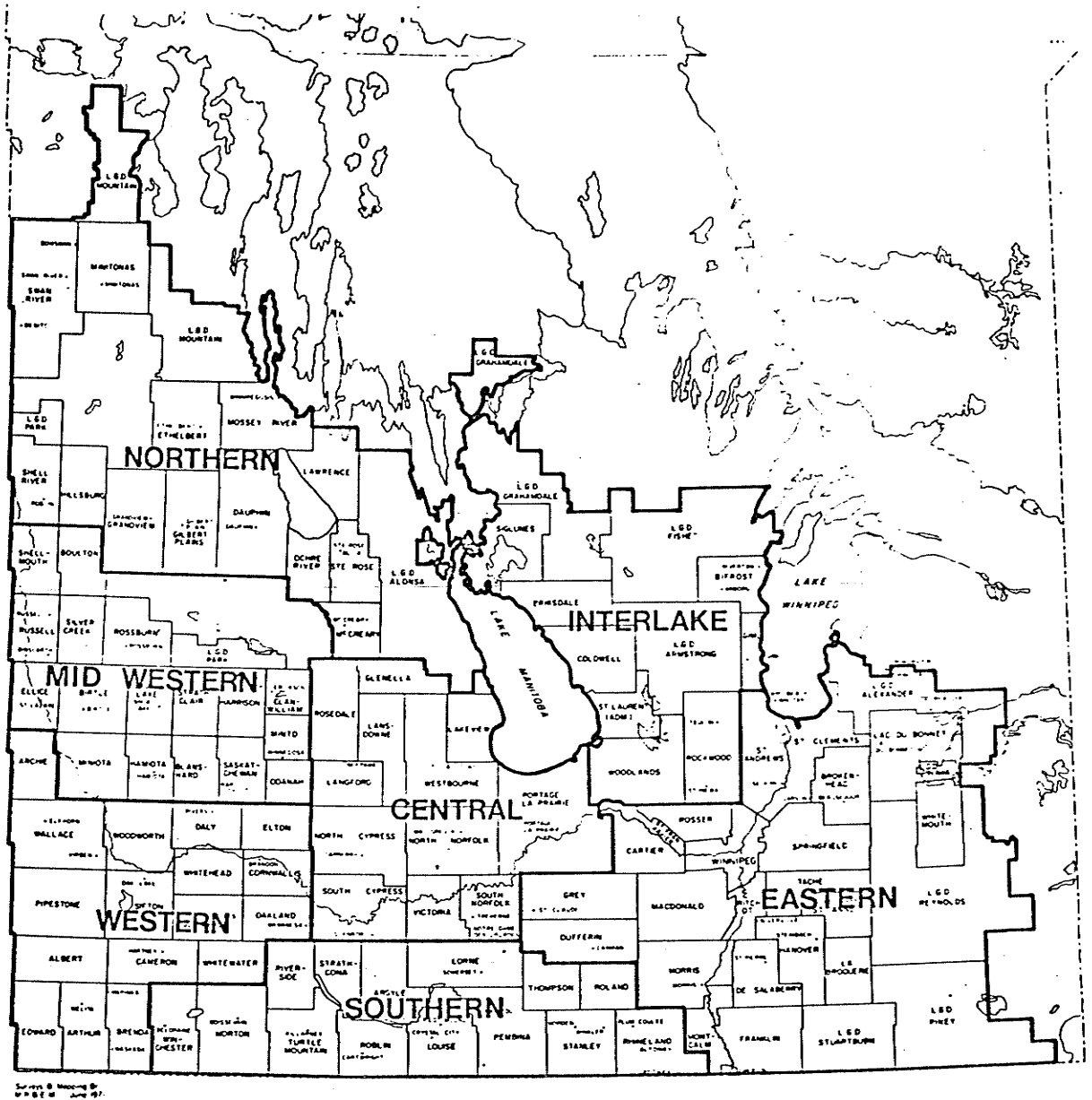


Figure 3 Municipalities and Local Government Districts comprising the Predator Control Area of Manitoba.

(Manitoba Department of Municipal Affairs, 1977)

Predator Control Act are:

- (a) indiscriminate harvest of fox in predator control areas
- (b) harvest of fox out of season
- (c) extension of the trapping season
- (d) effective elimination of any protection that the fox may have been afforded as a fur bearer under The Wildlife Act (except for those regulations pertaining to the transfer, handling, or sale of pelts).

The Predator Control Act allows the indiscriminate harvest of fox populations by (a) allowing harvest by persons not in possession of a valid and subsisting licence, (b) allowing the harvest of the species to occur out of season, (c) allowing the use of vehicle hunting programs to control the species, and (d) allowing the use of poison baits to control the species.

The Predator Control Act, by allowing foxes to be harvested out of season, overpowered The Wildlife Act which had designated specific fox trapping seasons prior to 1964. Consequently, the pelts can be harvested during periods when they are practically worthless. In unorganized territory south of the 53rd parallel a fox trapping season still exists (from November 1 to January 31). In the adjacent Rural Municipalities and Local Government Districts, where no restriction exists, trapping continues during the period prior to November 1 and after January 31 when the pelts are of poor quality. The Predator Control Act in essence allows for an intensified and extended trapping season which, in years when

fur prices are high, may result in an over-exploitation of the species.

1.10 The Economics of Manitoba's Red Fox Population

Fur bearers differ from many other wildlife resources in that they represent a marketable commodity. Alan Loughrey adequately portrayed the fur industry in his discussion of the economics of the Canadian fur industry at the Resources for Tomorrow Conference (1961).

. . . it (fur) is an article of commerce subject to the usual laws of supply and demand, the ills of a luxury trade, fierce competition on world markets, world economic conditions, the vagaries of fashion, rising costs of production and manufacture, and for wild furs particularly, decreasing raw fur prices. ¹

This statement remains true today except for the comment regarding decreasing raw fur prices. The auction value of fox furs rose remarkably in the early 1970's and have currently stabilized at an average of approximately 45 dollars. It is difficult to assess the impact of fluctuating fur prices on fox populations. High fur values increase trapping and hunting pressure but, the effects of this on fox populations have never been quantified.

Resource economists often attempt to estimate the value of wildlife resources by placing a monetary value on individual animals. The initial response, in the particular case of fur bearing species, is to quote the market value of the raw fur.

¹Malaher, G. W. 1962. In Resources for Tomorrow, Proceedings of the Conference, Volume III, Queen's Printer, Ottawa.

This practice undoubtedly oversimplified and underestimates the social value of fox populations. Theoretically the social value of fox populations should take into consideration benefits derived from both marketable and non-marketable sources.

Provincial marketable benefits derived from fox populations would include gross return to trappers, royalties paid to the Province, all Provincial incomes derived from the buying, grading, processing, and marketing of furs and all Provincial incomes derived from the sale, manufacture, and maintenance of trapping equipment. This estimate, of course, would not include any intangible benefits (i.e. recreation value, psychological well-being, research value, rodent control) or costs (i.e. predation impact on commercial and game species). These non-marketable benefits and costs should be taken into consideration to accurately evaluate the social value of fox populations.

A demand curve, from which the social value of foxes could be derived, is of interest but of little practical use to wildlife managers. A supply curve, however, depicting the harvest response to fluctuating market conditions, can provide a useful management tool. Sufficient Provincial historical data are available to permit the development of a theoretical supply curve for raw fox furs.

Average raw fur prices for the period 1960 to 1974 are adjusted to a common value base using the appropriate price index (Table VII). The adjusted fur prices reflect the real value of fox pelts and allows for the comparison of these

Table VII Adjusted average raw fox fur prices (1960-1974)

Year	Index*	Average Price	Adjusted Value	# Pelts Harvested
1960	209.6	4.33	2.07	2,423
1961	212.6	3.42	1.61	1,862
1962	223.8	4.08	1.82	2,118
1963	226.9	5.50	2.42	1,706
1964	225.7	4.75	2.10	3,546
1965	231.2	5.92	2.56	4,345
1966	242.7	12.00	4.94	5,593
1967	246.1	5.42	2.20	7,071
1968	249.1	8.08	3.24	4,866
1969	265.0	14.50	5.47	8,538
1970	256.9	10.00	3.89	9,363
1971	255.5	12.40	4.85	7,186
1972	298.2	15.15	5.08	11,047
1973	418.5	29.40	7.03	14,337
1974	486.1	39.20	8.06	14,838

*Based on Statistics Canada wholesale index for raw and partly manufactured goods (1935-1939 = 100).

values over the 15 year period. The resultant supply curve is illustrated in Figure 4. The price-quantity relationship is linear as determined through linear regression and correlation analysis (at a .05 level of significance). The elasticity of supply can be calculated from this curve.

$$\text{Elasticity} = \frac{Q}{P} \cdot \frac{P}{Q} = \underline{1.178}$$

where Q = quantity supplied
P = supply price

The response to changing fur prices is elastic (i.e. the percentage change in quantity supplied exceeds the percentage change in price (Ferguson and Maurice, 1974). For example, a 10 percent increase (decrease) in raw fur prices would elicit a 12 percent increase (decrease) in the number of pelts supplied.

Economic analysis illustrates the effect of markets on trapping pressure. Foxes, a marketable commodity, will (within limits) adhere to the theoretical supply and demand laws. These limits are inherent in attempting to harvest a natural population in response to market demand. Fluctuating population levels, and harvest timing are important considerations when attempting to manage and maximize returns from the resource (Barlowe, 1972). If we assume that the supply curve reflects harvest response to market price (taking into consideration the constraints involved in harvesting a natural population) then we should be able to predict the response to fluctuating raw fur values independent of population levels.

During late summer, fur auction companies generally

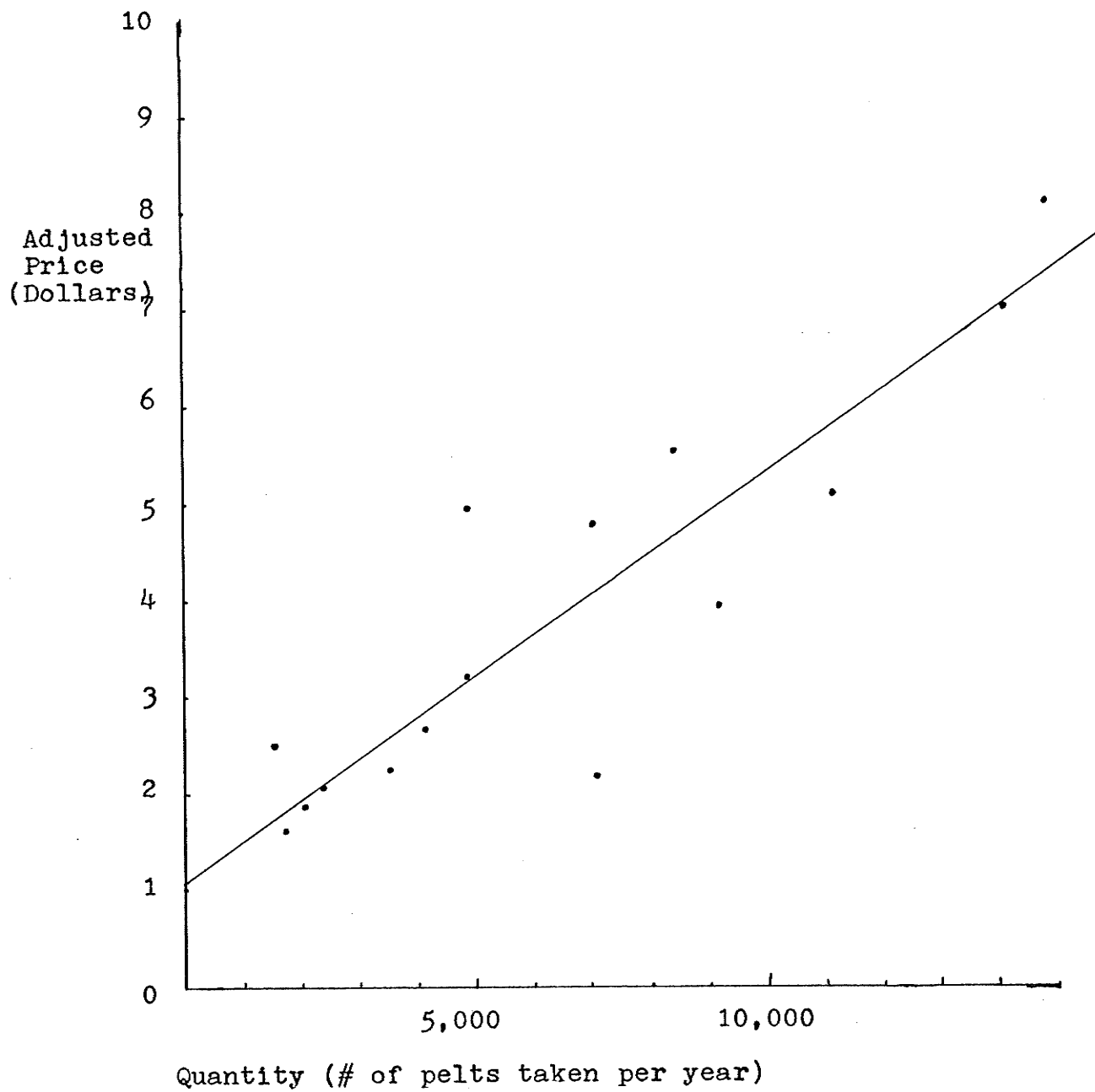


Figure 4 Red fox supply curve (1960-1974).

disclose the expected fur prices for the coming trapping season. If these values are adjusted (according to the price index for raw and partly manufactured goods for the current year) then, an expected level of harvest could be determined from the supply model. The management implications of this model are significant when used in conjunction with a reliable population monitoring system. The expected price-induced trapping pressure could be compared with estimated population densities to predict the impact of the coming trapping season on target populations. This analysis could be applied to all marketable animal species for which reliable population monitoring systems and adequate supply models are available.

Current fur prices suggest that the economic value of the fox as a fur bearer exceeds the economic damage they inflict as predators. Therefore, from an economic efficient point of view, foxes should be harvested as fur bearers. Harvesting of fox populations as predators should occur only when the economic loss inflicted exceeds their economic value.

The optimum degree of utilization of any fur bearer can be defined as that which maximizes the net economic yield. Both total cost and total production can be expressed as a function of trapping or hunting effort and consequently, a simple maximization solution is possible. The total cost curve will be a linear function if we assume no trapping-induced effects on factor prices. The production function (the relationship between effort and total value produced) will be assumed to decrease as effort increases due to the reduction

of population rather than the law of diminishing returns. Therefore, the average product (AP) and marginal product (MP) can be assumed to be linear. The curves AP and MP (Figure 5) illustrate the average productivity and marginal productivity of trapping effort. (These curves represent the same relationship as average revenue and marginal revenue in imperfect competition theory.) Costs are assumed to be unaffected by the intensity of trapping, therefore average cost and marginal cost are constant and equal (Gorden, 1954). These relationships are illustrated below.

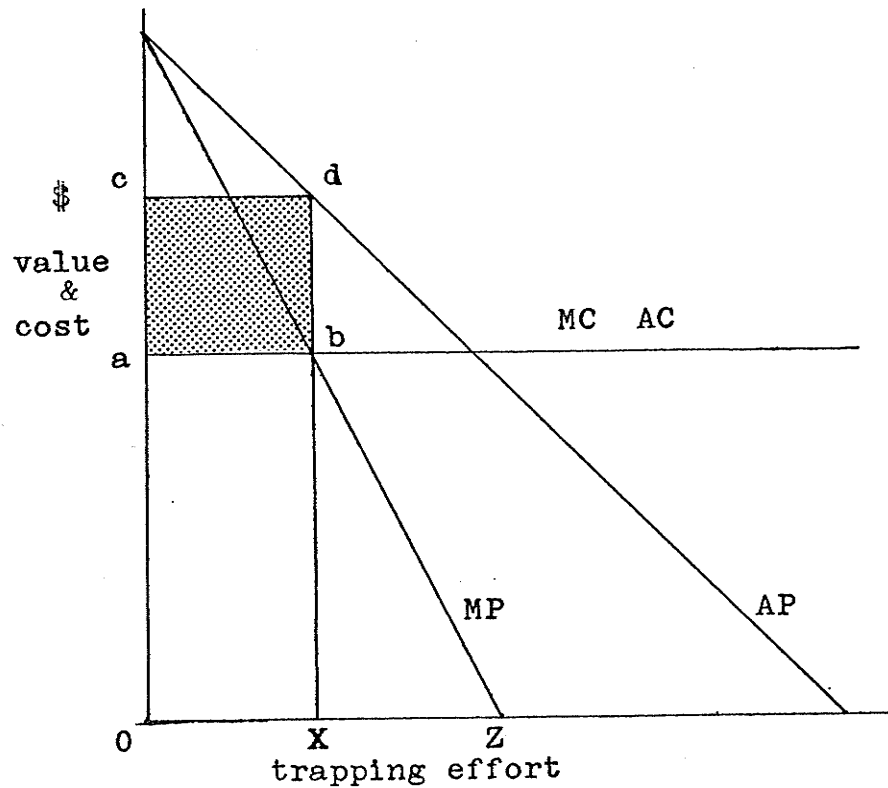


Figure 5 Optimal trapping effort

(Gorden, 1954)

The costs are assumed to include an opportunity cost for trappers (i.e. the income that could be earned in other comparable employments). Level OX represents the optimum trapping intensity on this particular trapping ground. At this level the resource will yield the maximum net economic yield indicated by the shaded area *cdba*. The maximum sustained physical yield, referred to by biologists, will occur when the marginal product of trapping effort equals zero (OZ effort). Therefore the optimum economic trapping intensity is less than that which would produce the maximum sustained physical yield (Gorden, 1954).

The area *cdba* in Figure 5 can be regarded as rent derived from the trapping resource. Level OX represents the optimum rate of exploitation under the given assumptions and the rent derived, reflects the productivity of that trapping ground.

Crutchfield and Zellner (1962) developed a more realistic model which can be applied to trapping harvest. If it is assumed that the price received by trappers does not vary with the size of the harvest and that additional trapping effort only requires more units of the same type (i.e. traps) attainable at the same cost, then Figure 6 illustrates the long term relationship between trapping effort and yield.

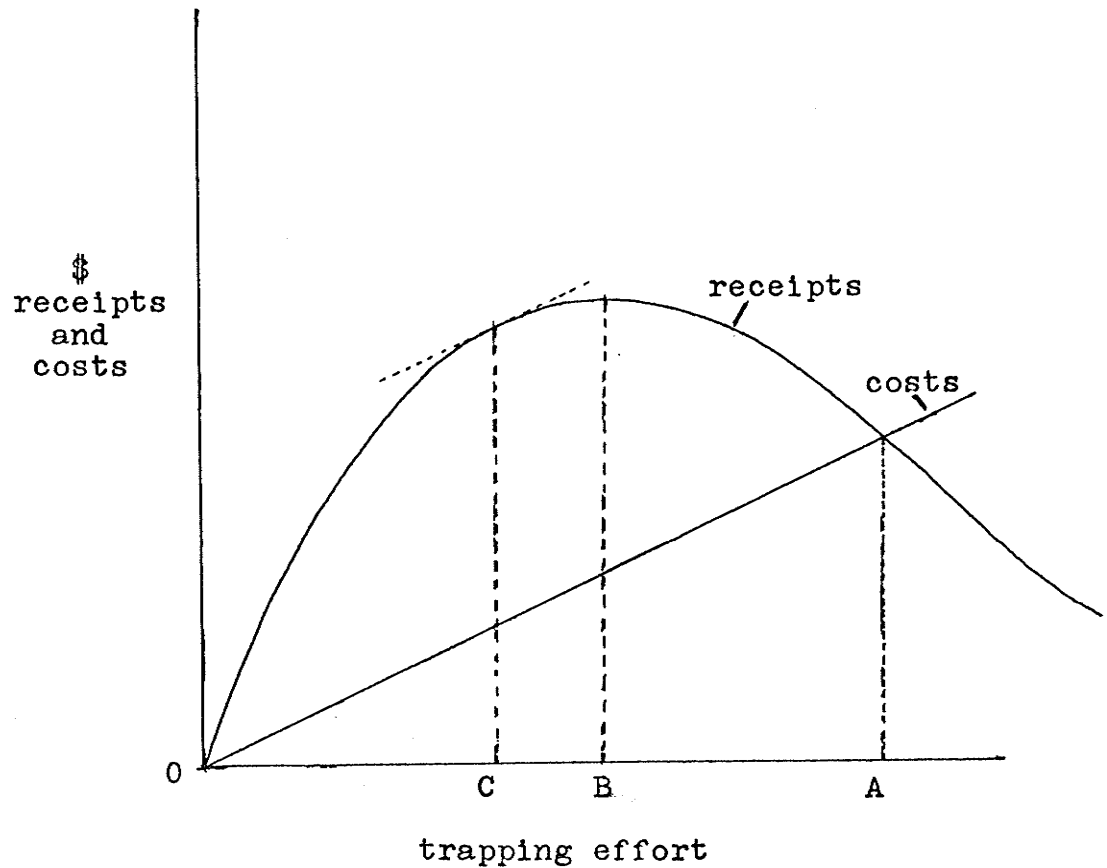


Figure 6 Total money receipts and costs versus trapping effort (Crutchfield and Zellner, 1962).

The total receipt curve approximates the production curve (receipts = harvest x pelt value) and can be used in this analysis. If the fur resource is regarded as a public good with unrestricted entry, then the level of trapping effort will tend toward OA. At this point total receipts cover total costs (including a minimum necessary return to the trapper). The biological sustained yield will occur at trapping effort OB whereas the most economically efficient harvest will occur at a trapping effort of OC. At this point the marginal cost of trapping (slope of the total cost curve)

equals the marginal revenue received (slope of the total receipts curve). The economic rent (distance between these two curves) is maximized at this point.

Wildlife resources are not private property and consequently, the rent yielded is not capable of being appropriated by anyone. The resultant pattern of competition for the common property resource results in the dissipation of the rent (Gorden, 1954). This is the case in the open trapping areas of the Province. In the Registered Trap Line (RTL) Districts the fur bearers essentially become the private resources of the registered trapper. In these districts the individual trappers can realize the rents attributed to the wildlife resources. Therefore, from an economic efficiency perspective, the RTL system is superior to the open trapping area. Individual trappers will be made better off, and populations will be harvested, theoretically, at the optimum level and not at the maximum sustained physical yield. Therefore, in RTL areas, the trapping impact on target populations will not be as great as that experienced in the open trapping areas of the Province.

Historical trends indicate that foxes are becoming a more economically important resource. The contribution of fox harvest to total fur value for the Province has increased from a negligible amount in 1953-54 to over 20 percent in 1973-74, (Figure 7). This results from current fashion trends towards long-hair fur and the corresponding increase in raw fox fur value.

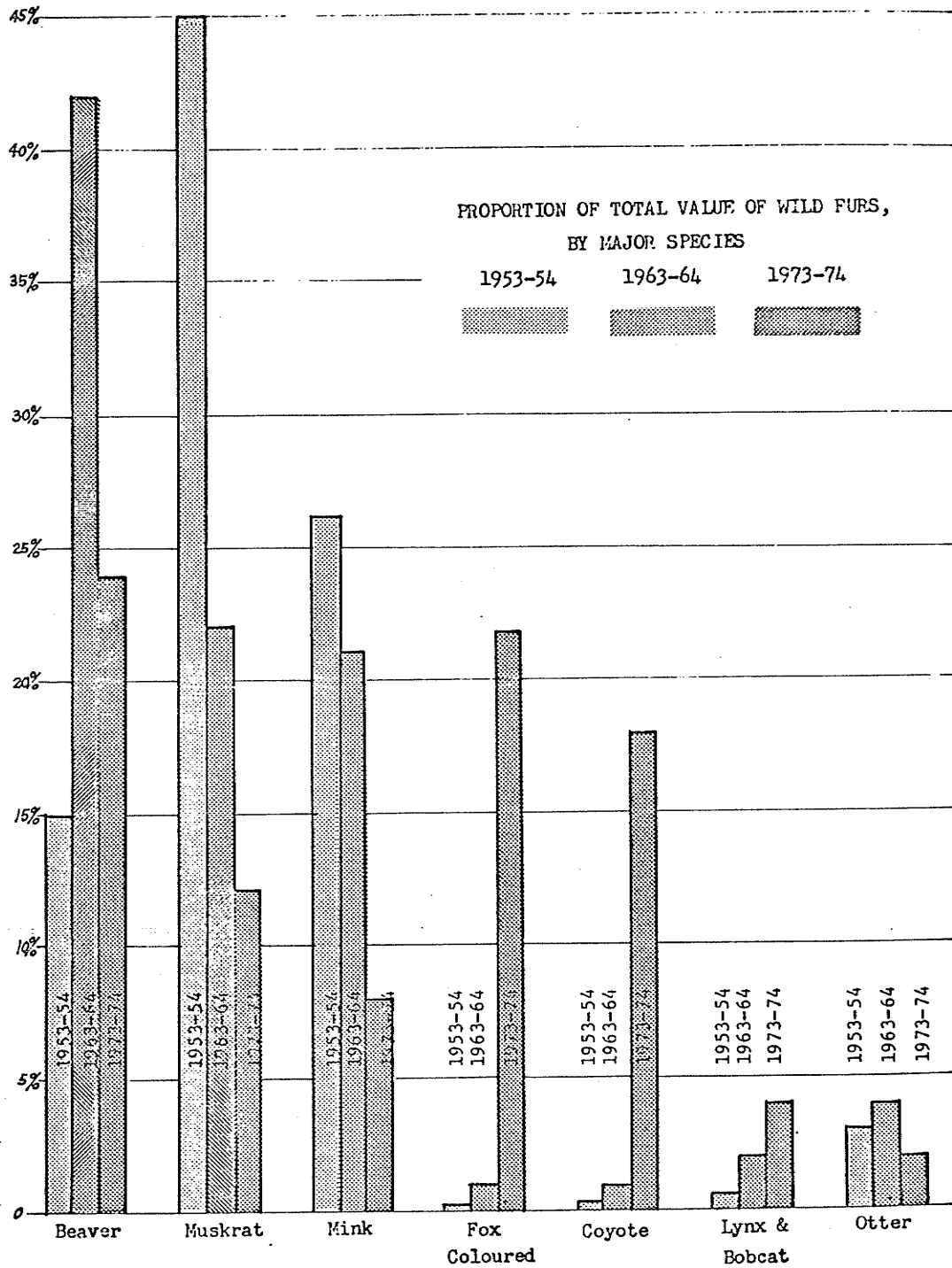


Figure 7 Proportion of total value of wild furs by major species.

(Manitoba Department of Renewable Resources and Transportation Services, 1977)

The demand for fox pelts is largely dependent on fashion. As demand fluctuates the price of pelts and trapping effort will likewise fluctuate. Fox populations are consequently affected by changing market conditions, though these effects are difficult to quantify. Populations are also affected by the non-market harvest of foxes as predators. Therefore, in species like the red fox, where both social benefits and costs accrue from their existence, it is essential to evaluate economic considerations in wildlife management programs.

II. STUDY AREA

Selection of the study area was based on a habitat zonation for Manitoba (Manitoba Department of Mines, Resources and Environmental Management, 1972). The placement of habitat boundaries was based largely on the interpretation of available Canada Land Inventory: Current Land Use Maps for southern Manitoba. The habitat regions outlined are assumed to represent different red fox habitat regions (Figure 8). It is not known how the density or distribution of red fox varies between the different habitat regions. This study initiates research into the determination of population densities based on this provincial habitat breakdown. Table VIII lists the habitat regions, briefly outlining the characteristic shrub and tree cover of each.

The habitat region of agricultural Manitoba designated as cropland, was selected because the open, flat topography was suited for evaluation of the proposed monitoring systems. The cropland region covers an estimated 20,200 square kilometers and is described as an area of intensive agricultural use where 96 to 100 percent of the land area has been converted to crops or pasture.

The study was undertaken in that portion of the cropland region adjacent to the City of Winnipeg (Figure 8). This area represents approximately 11,700 square kilometers or

Table VIII Habitat regions of Manitoba and associated vegetative cover

Habitat Region	Shrubs	Trees	Map Reference No.
Northern Coniferous Forest	Red Osier Dogwood Willow Dwarf Birch Alder Saskatoon Labrador Tea	Black Spruce Jack Pine Tamarack White Birch White Spruce Balsam Fir Aspen Balsam Poplar	9
Mixed Woods	Hazel Dwarf Birch Alder Red Osier Dogwood Saskatoon	Aspen Balsam Poplar White Birch White Spruce Balsam Fir	1
Southeastern Coniferous Forest	Willow Alder	Jack Pine Black Spruce Tamarack White Cedar	3
Aspen-Oak Forest	High Bush Cranberry Hazel Choke cherry Pin cherry Red Osier Dogwood Buffaloberry	Forest cover of 51 to 100%: Aspen Bur Oak Balsam Poplar	2
Riparian Habitat	Coke cherry Rose Saskatoon Snowberry	Aspen Bur Oak White Elm Eastern Cottonwood Manitoba Maple Basswood Black Ash	7
Wooded Grassland	Analogous to wooded cropland except that untreed areas are primarily grassland (i.e. Rough Grasing Lands) rather than cropland.		5



Table 8-Continued

Habitat Region	Shrubs	Trees	Map Reference No.
Grassland	Saskatoon Silverberry Snowberry Red Osier Dogwood	Aspen Bur Oak	4
Cropland	Areas under intensive agricultural use 96 to 100 percent of the land area has been converted to crops or pasture.		6
Wooded Cropland	Contains 5 to 50 percent wooded cover, the tree and shrub species present are identical to those inhabiting the Aspen-Oak or Mixed Woods Forest types depending on location.		8

(Manitoba Departments of Mines, Resources and Environmental Management, 1972)

approximately 70 percent of the total cropland region of Manitoba.

All townships within the study area (Figure 9) (excluding townships Tp. 6, Rge. 2, Mer. W, and those containing portions of other habitat regions i.e. riparian habitat) were numbered. A random sample of five townships was selected from a total of 52 suitable townships by using a table of random numbers. Township 6, Rge. 2, Mer. W was preselected on the basis of available knowledge regarding fox populations. The following townships (Table IX) were selected as the sample area for this study.

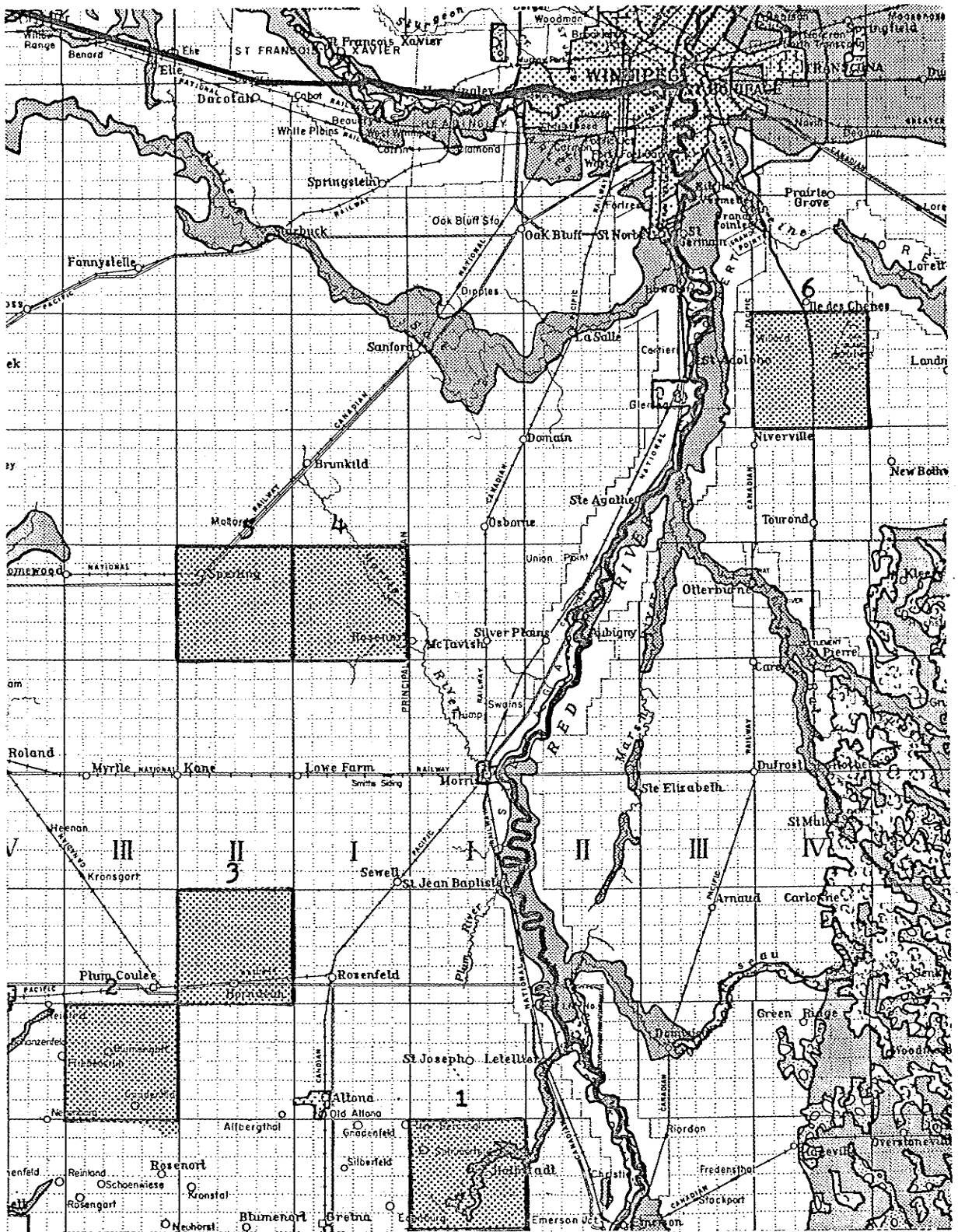


Figure 9 Location of census townships.

Table IX Study area

Study No.	Township	Range	Meridian	Municipality
1	1	1	E	Rhineland
2	2	3	W	Rhineland
3	3	2	W	Rhineland
4	6	1	W	Morris
5	6	2	W	Morris
6	8	4	E	Richot/Tache

(Refer to Figure 9 for locations)

All townships met the criteria for designation as crop-land habitat regions. The townships differed slightly in their land use patterns and overall habitat availability.

Study township 1 (Tp. 1, Rge. 1, Mer. E) has a portion of the Riviere Aux Marais within its boundary. Much of the stream bed has been drained and cultivated and therefore cannot be considered as being riparian habitat. A few treed areas exist mainly in farmyards along the old river channel. Few of the roads are all-weather roads. The township is sparsely inhabited with only one small community located within its boundaries.

Study township 2 (Tp. 2, Rge. 3, Mer W) has a larger rural population than the other study townships. One town and one large Hutterite colony are located in the township. The township has many all-weather roads and numerous treed shelter belts (more than any other township in the study). Treed areas are associated with shelter-belts, and occupied and deserted farmsteads.

Study township 3 (Tp. 3, Rge. 2, Mer W) has one large

community (Horndean) present. The township is bisected by a major highway (Highway #14) and an associated railway line. Much of the township lies north of the highway. There are several major east-west drainage canals also located in the township. Most of the section roads are all-weather roads and most treed areas are associated with either occupied or deserted farmsteads.

Study township 4 (Tp. 6, Rge. 1, Mer. W) has two minor stream beds present providing some cover along their banks. Few treed areas exist other than occupied and deserted farmsteads and portions of the stream banks. Few of the roads are all-weather roads and only one short portion of a drainage canal runs through the township. The rural population is quite low in relation to other townships in the study.

Study township 5 (Tp. 6, Rge. 2, Mer. W) has one large town (Sperling) present and is traversed by a major highway (Highway #3) and an associated railway line. A major drainage canal forms the southern boundary of the township. Rural population is moderate. There are few shelterbelts and all-weather roads. Treed areas are almost exclusively associated with occupied and deserted farmsteads.

Study township 6 (Tp. 8, Rge. 4, Mer. E) is characterized by a high rural population and intensive land use. A major highway (Highway #59) bisects the township into east and west halves. A rail line forms the western boundary of the township and two major drainage canals across the township. Most treed areas are associated with occupied or

deserted farmsteads.

All six townships were characterized by an extremely flat topography. All of the land (except for treed or low lying areas and cultural features) was either cultivated, left fallow, or used as pasture.

III. METHODOLOGY

The study was conducted from mid-April to mid-September 1976. Three distinct monitoring methods were undertaken. These consisted of:

1. Aerial survey and ground verification
2. Infrared imagery analysis
3. Questionnaire and interview sampling of land-owners.

Location of active den sites in an area was assumed to provide the most reliable indication of the total number of fox families. Consequently, all three monitoring techniques were designed primarily to locate active red fox den sites.

Spring field work consisted of aerial and ground searches for active fox dens in each of the six townships. A light four place, high wing aircraft (Cessna 172) was used for the aerial surveys. Each township was surveyed at 0.4 kilometer transect intervals though the starting point and direction of flights were left to the discretion of the pilot. Each township was surveyed at low altitudes (30 to 150 m) and at air speeds ranging from 110 to 140 kilometers per hour. Most of the township was surveyed at the lowest altitude possible but a 150 meter ceiling had to be maintained over certain agricultural and residential areas. At least two spotters were used on

each survey flight. The locations of possible fox denning sites were individually recorded on township aerial photos during the flights. All sites plotted on the aerial photos were transferred to a single map sheet and were subsequently visited to determine den type and verify activity.

Color infrared aerial photographs were taken of selected den sites in order to evaluate this remote sensing technique for locating active fox dens. Kodak Ektachrome Infrared film (35 mm format) was used. This film is equivalent to Ektachrome Infrared Aero type 8443 (Appendix II).

Sites were flown at altitudes of 450 metres, 900 metres, and 1500 metres above ground level. Two 35 mm format cameras and two photographers were required. Each camera was fitted with a standard 50 mm lens. One camera was fitted with a yellow (Y_2) filter and the other with a red (R_2) filter.

Locations were pre-selected from known active fox dens and represented three different denning habitats identified in the study (i.e. woodlot edge, dugout banks and grassed roadsides). Photographs were taken through an open window while the aircraft was sharply banked. This made it possible to obtain low level oblique shots (i.e. near vertical).

The infrared imagery results were visually analysed to determine the potential of this method in recording active fox den sites. The infrared slides were further analysed on a density slicer to determine if the active den sites were recording as a specific signature. The largest scale slides of each site were density sliced, the results of which were

recorded on film.

The third monitoring system involved the use of mail-out questionnaires and landowner interviews. Three townships were chosen from the study area for this portion of the study. Townships 4 and 5 were selected as the questionnaire sample area because of their adjacent locations and homogeneity. Township 3 was randomly selected from the remaining townships as the interview sample area.

The development of questionnaire sampling techniques has been pioneered in social research studies. Questionnaire sampling represents an economical method of acquiring large quantities of information from large, scattered populations. In the study area, nearly all of the land area is occupied or extensively used by the landowners. Consequently, landowners should have a better than average knowledge of fox populations and fox den locations. Individual adult foxes are secretive and rarely seen, but den activity in the study area is quite conspicuous. Peak den activity coincides with spring seeding therefore, most den locations should be known.

The major problem encountered in conducting mail-out questionnaires is obtaining a high response rate (Crapo and Chubb, 1969). The proportion of potential responses depends directly upon:

- 1) the population being surveyed
- 2) the subject of the survey
- 3) the sponsorship of the survey
- 4) questionnaire length

- 5) attractiveness of the questionnaire
- 6) the ease with which the questionnaire can be completed and returned

These factors were taken into consideration during the questionnaire development. The response time was minimized by incorporating only 10 concise questions, all of which could be answered by checking the appropriate answer. A cover letter was employed to explain the objectives of the study and to identify the sponsoring agencies. A follow-up mailing was used, incorporating a different cover letter to help increase the response rate. The questionnaire was printed on coloured paper (yellow) to improve the attractiveness of the questionnaire and consequently, increase response rates (Oppenheim, 1966). A self-addressed, pre-stamped envelope was included to simplify the questionnaire return procedure. Respondents were offered a summary of the questionnaire results after completion of the study. This has been found to increase response rates in most cases (Selltitz et al., 1959). (A copy of the questionnaire and cover letters is included in Appendix III.) Landowner addresses were obtained from the municipal tax roles and the same questionnaire was mailed to each landowner in the two townships surveyed.

Personal interviews of landowners were conducted in one township in late-July 1976. Those landowners not home during the interviews were left a copy of the questionnaire, cover letter and a stamped return envelope. The problems often associated with interviews were partially alleviated by

restricting the questions to the same ones used in the mail-out questionnaire. Interviews were conducted in late July and early August when landowner's time constraints were not critical. The interviews rarely exceeded 20 minutes and most landowners were interested in the study and eager to respond.

IV. RESULTS AND DISCUSSION

4.1 Aerial Surveys

The flat, open nature of the study area was ideally suited for aerial censusing of fox populations. Low altitudes and slow speeds could be achieved with little difficulty over most of the study area. The requirement to maintain a 150 meter ceiling over communities, poultry, hog and dairy operations made the observation of dens more difficult.

Initially, a 0.32 kilometer transect width was flown. As most fox denning activity was concentrated along roadsides and half mile lines, it became apparent that a 0.40 kilometer transect width was adequate and subsequent surveys were flown with observation concentrated along these features. Figure 10 illustrates the flight path used in surveying the townships. A 0.40 kilometer transect width allowed adequate visibility

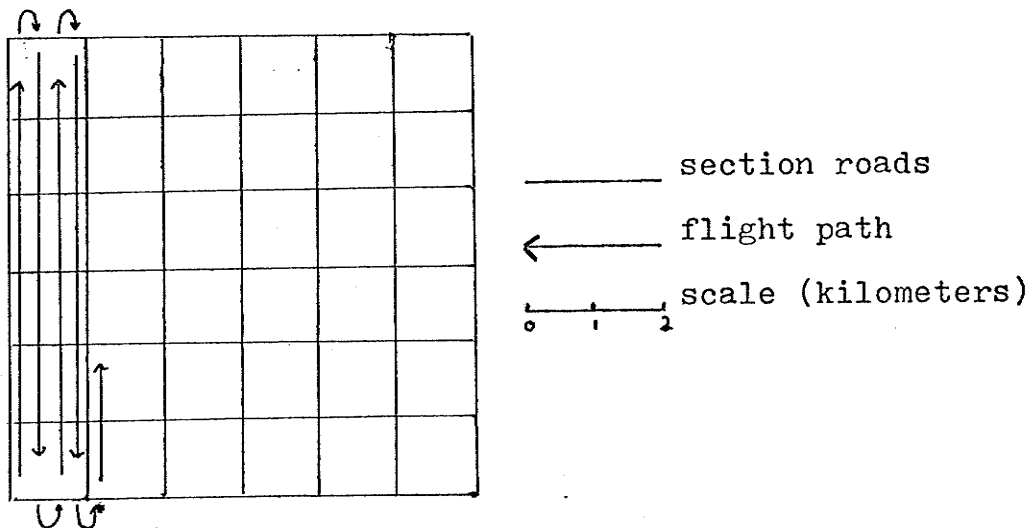


Figure 10 Flight path used for aerial surveys

along section roads and half-mile lines intersecting the flight path at right angles. The reduction in flight time required to survey each township resulted in (a) a reduction in the estimated survey costs and (b) a decrease in observer fatigue. Caughley et al. (1976) in analyzing aerial survey techniques found that observability decreased as transect width increased. However, because of the very organized, uniform and open nature of the agricultural areas surveyed, it was not expected that increasing transect width from 0.32 to 0.40 kilometers would seriously affect the reliability of the results.

The aerial surveys were conducted during May 1976 (Table X).

Table X Aerial survey of study townships

Township	Town- ship #	Date of Survey	Time	Flight Time
Tp 1, Rge 1, Mer E	1	May 12	9:15 am	2.8 hr.
Tp 2, Rge 3, Mer W	2	May 13	9:00 am	2.4 hr.
Tp 3, Rge 2, Mer W	3	May 13	1:45 pm	2.3 hr.
Tp 6, Rge 1, Mer W	4	May 29	9:30 am	3.7 hr.
Tp 6, Rge 2, Mer W	5	May 30	9:15 am	3.6 hr.
Tp 8, Rge 3, Mer E	6	May 30	1:30 pm	2.9 hr.

The initial searches (during mid-May) were conducted over study townships 1, 2 and 3 (i.e. townships characterized by the greatest proportion of treed cover. These surveys were conducted early to facilitate the location of fox dens before foliage matured. The dens were not at peak activity during this time and it was difficult to judge den type and activity

in the majority of cases. Peak fox den activity occurred in late May and increased the observability of active den sites. All possible fox den locations were recorded on aerial photos of the individual townships.

The major difficulties encountered in the aerial identification of active fox dens were a) differentiation between badger and fox dens, and b) differentiation between non-active and active fox dens. Badger dens and diggings were numerous in the study area and could often be identified by their location (often excavated in open fields) and characteristic den entrance (often only one entrance characterized by a distinct mound on sloped surfaces, or a partially excavated sloped entrance on level surfaces). Foxes will use abandoned badger dens, a fact which complicates the identification of den type from the air. Consequently, all dens showing signs of recent activity were recorded and subsequently visited by the author to verify den type and activity.

The aerial identification of active fox dens was largely dependent upon den activity. A rarely used, or recently inhabited den is practically indistinguishable from a non-active site from the air. It was during the pre-emergent period (i.e., before the fox pups venture out of the dens) that non-active fox dens were most frequently mistaken for active ones.

Foxes will generally move the pups to alternate den sites if disturbed. Several dens are excavated by a single breeding pair (usually in close proximity to one another)

for escape purposes (Banfield, 1974). The peak in den activity (late-May) coincides with increased human activity in the study area. Spring seeding practices undoubtedly disturb and consequently displace many fox families, especially those denning in or adjacent to agricultural fields. The numerous inactive fox dens visited during this study substantiates the fact that foxes will excavate and alternate occupancy between den sites if disturbed. Positive identification of active sites generally required ground verification.

Aerial surveys of townships 4, 5 and 6 corresponded with peak den activity. Den entrances were well trampled and littered during this period, and often encompassed a relatively large area (up to 6 metres in diameter). Active den sites were quite distinct and easily identified from the air during this period.

A total of 23 active fox dens (an average of 3.83 active fox dens per township) were located in the six township study area (Table XI).

Table XI Number of active den sites located by the aerial census method

Study Township #	# Active Fox Dens
1	2
2	6
3	5
4	3
5	4
6	3
Total	23

The greatest proportion (48 percent) of active dens were located in the grassed, sloped roadsides, generally along rarely-travelled section roads. Four of the dens (17 percent) were located in dugout banks associated with deserted farmsteads. Half-mile lines provided suitable denning cover and three dens were located in these level, non-cultivated strips of native grasses separating agricultural fields. Two dens were associated with a major drainage canal; one was excavated into the canal bank and the other was excavated on an abandoned road atop the drainage canal bank. Only one den was found associated directly with treed cover. This den was an old, well-established site excavated on level ground at the edge of a woodlot. One den was located in the middle of a large cultivated field and one was located in a rarely used pasture.

The fox population in the study are preferred a sloped surface for den locations (i.e. 70 percent of the identified dens were located on dug-out banks, sloped roadsides and drainage canals). Nearby cover was not a necessary criterion in den site selection as over half of the located dens were situated at least 0.5 kilometers away from the nearest treed cover (Table XII).

Figures 11 through 16 illustrate the den locations and theoretical home ranges thought to be occupied, during the study period, by the associated fox families. Very little overlap of home ranges occurs and only in one case (Study Township 3, Sec. 35 and 36) were two dens in close proximity

Table XII Den locations and distance from nearest treed cover

Township #	# Active Sites	Location	Distance from treed cover
1	2	Roadside W side Sec 31	7.5 km
		Roadside E side S.E. $\frac{1}{4}$ Sec 32	7.5 km
2	6	Roadside S side S.E. $\frac{1}{4}$ Sec 33	7.5 km
		Roadside S.W. $\frac{1}{4}$ Sec 2	<.5 km
		Roadside W side Sec. 8	<.5 km
		Roadside S side S.W. $\frac{1}{4}$ Sec 5	<.5 km
		Pasture S.E. corner SE $\frac{1}{4}$ Sec 16	<.5 km
		Woodlot E. Side N.W. $\frac{1}{4}$ Sec. 20	<10 m
3	5	Roadside S side S.W. $\frac{1}{4}$ sec 31	7.5 km
		Dugout Bank E side Sec 35	<100 m
		Dugout Bank E side S.E. $\frac{1}{4}$ Sec 36	<100 m
		Dugout Bank Mid-Sec 24	7.5 km
		Dugout Bank W Side Sec 5	7.5 km
4	3	Roadside N side N.E. $\frac{1}{4}$ Sec 25	>.5 km
		Roadside W side Sec 5	>.5 km
		$\frac{1}{2}$ Mile line mid-Sec. 18	>.5 km
5	4	Drainage ditch S side Sec 6	<.5 km
		Road (abandoned) S side S.E. $\frac{1}{4}$ Sec. 4	7.5 km
		Roadside E Side Sec. 17	7.5 km
		Roadside E side Sec. 27	7.5 km
6	3	Grainfield mid-Sec 7	>.5 km
		$\frac{1}{2}$ mile line mid-Sec 2	>.5 km
		$\frac{1}{2}$ Mile line mid-Sec 4	>.5 km

Study Township 1

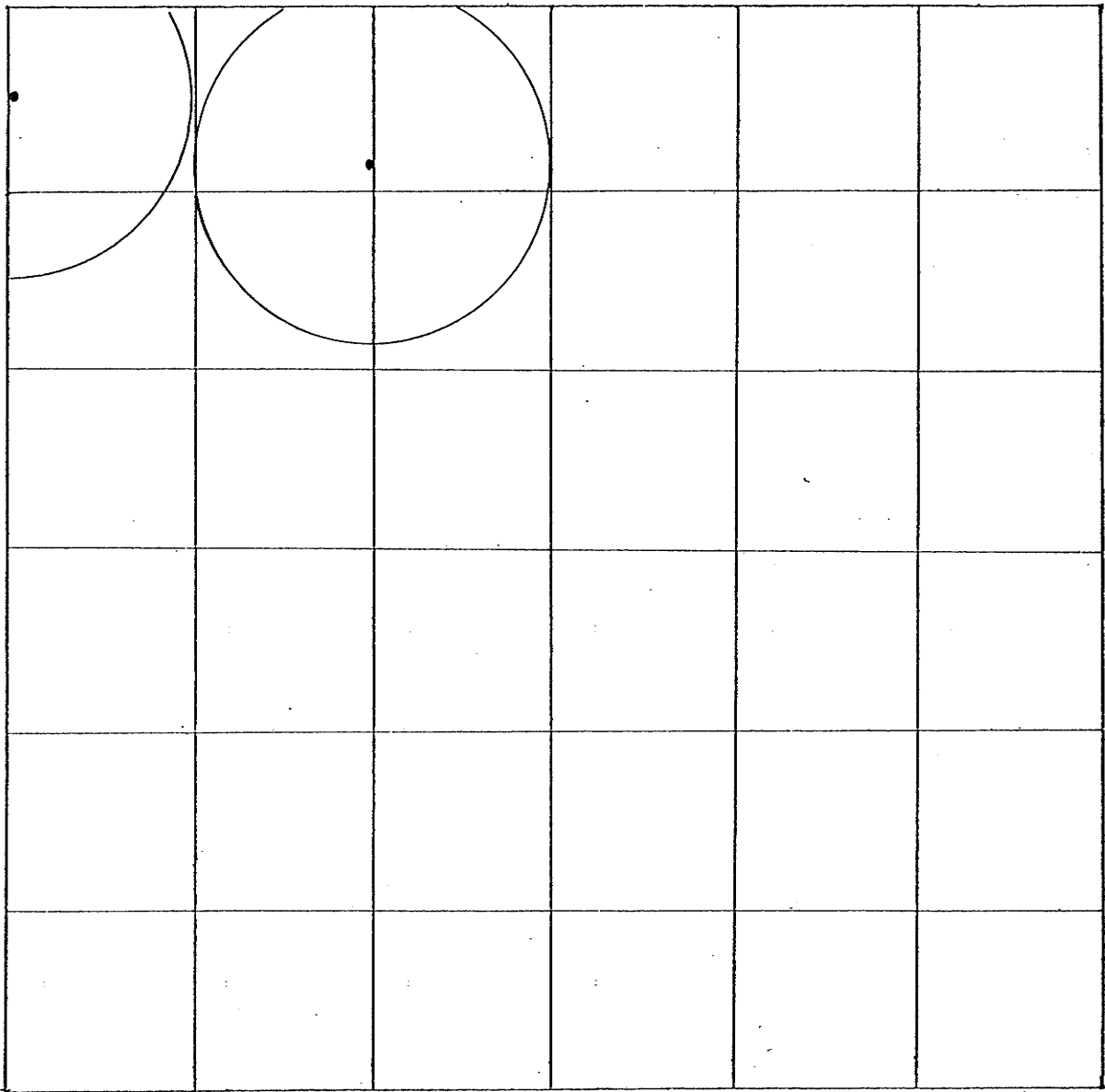
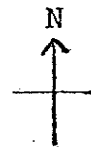


Figure 11 Location of den sites and home ranges.

Scale 0 1 2
kilometers



Study Township 2

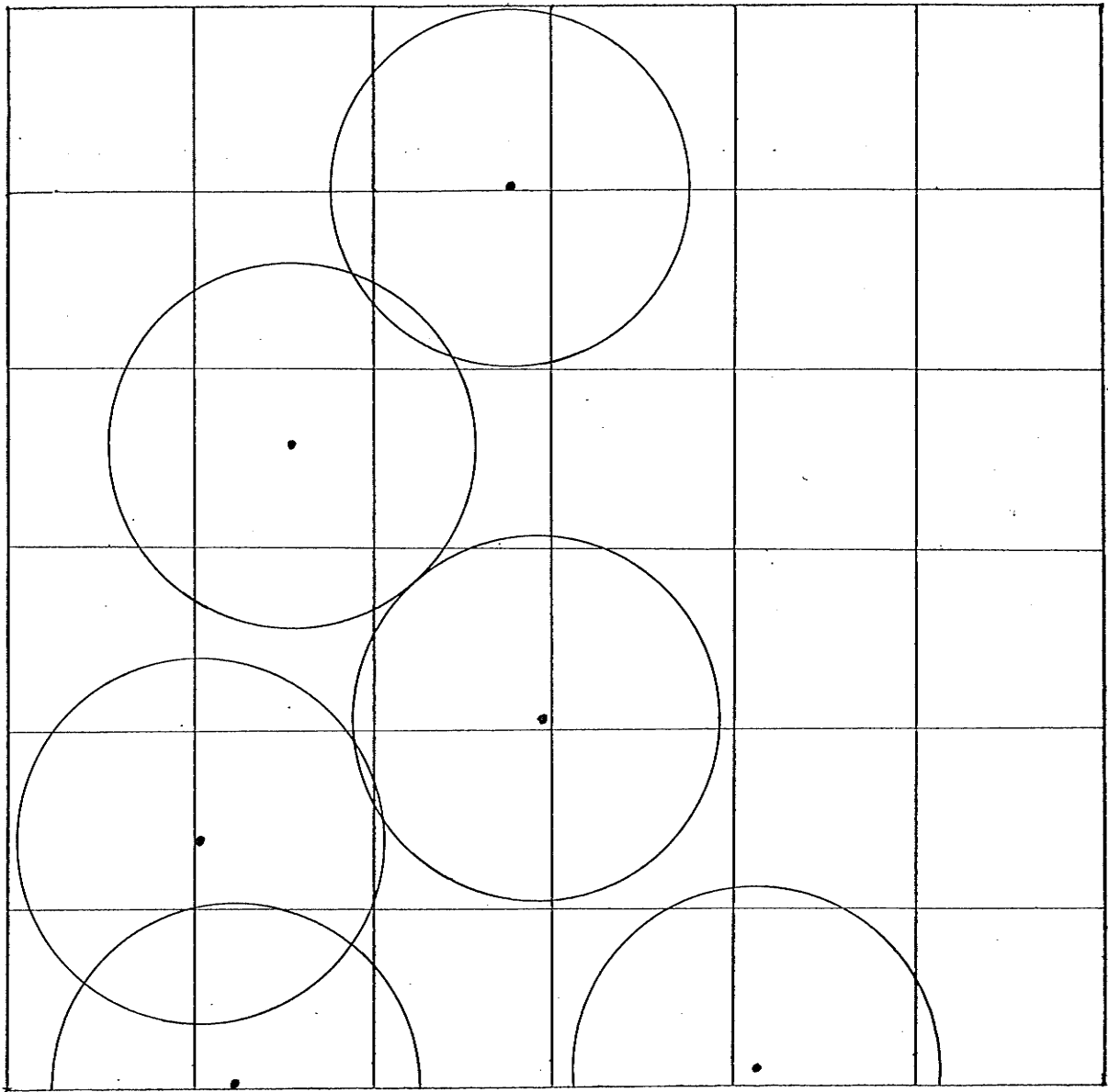


Figure 12 Location of den sites and home ranges.

Scale 0 1 2
kilometers



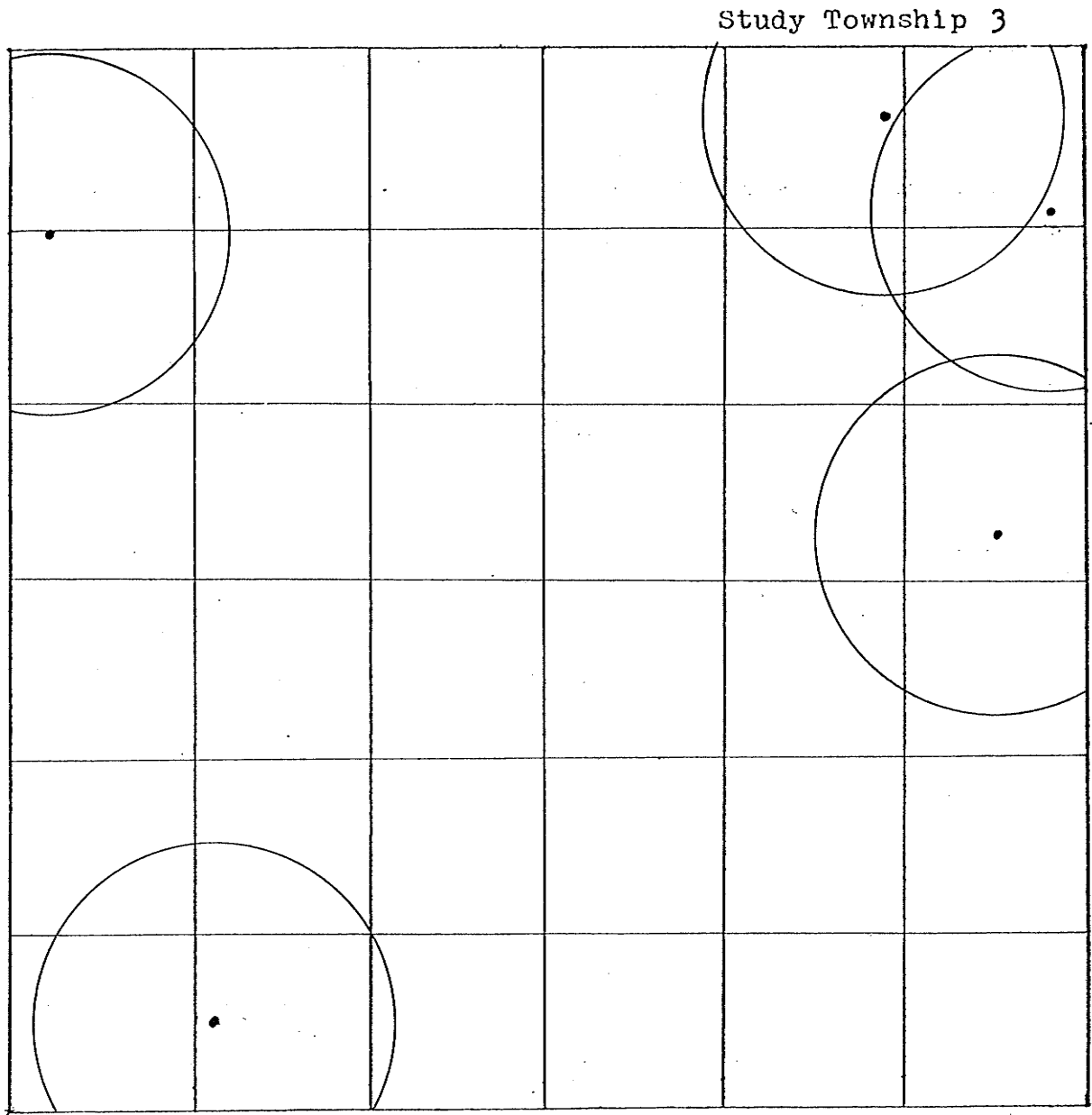


Figure 13 Location of den sites and home ranges.

Scale 0 1 2
kilometers



Study Township 4

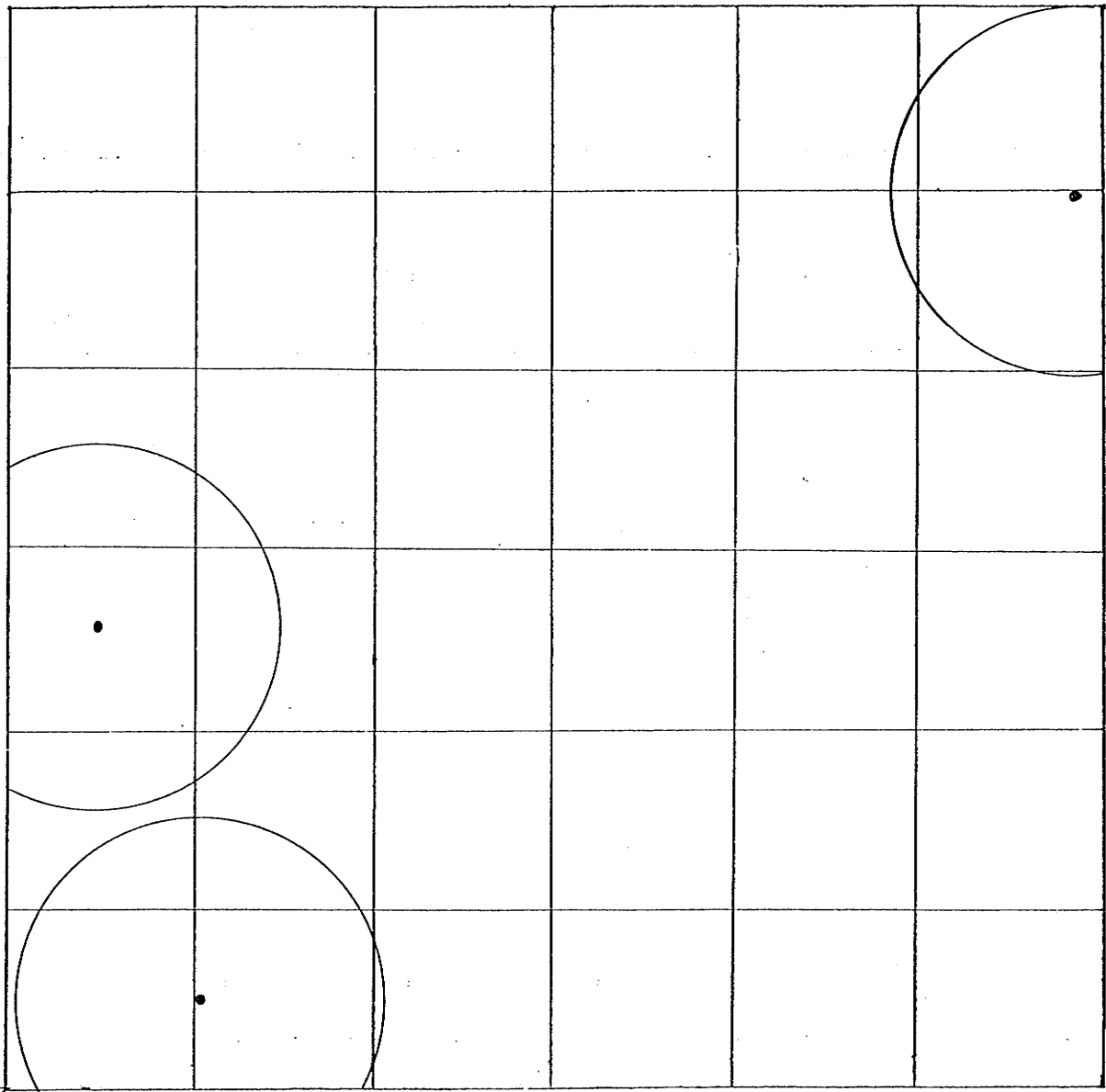


Figure 14 Location of den sites and home ranges.

Scale 0 1 2
kilometers



Study Township 5

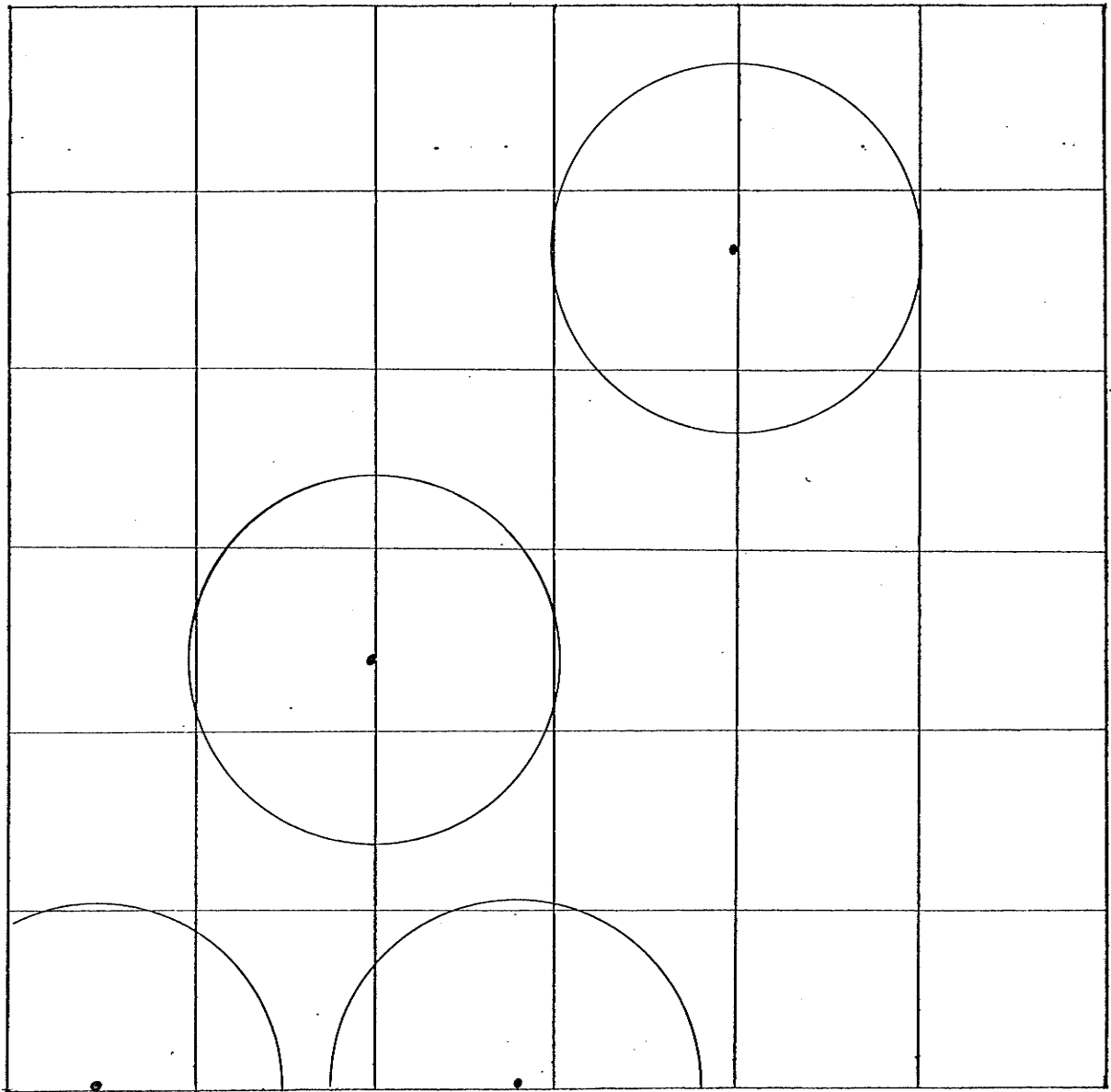


Figure 15 Location of den sites and home ranges.

Scale 0 1 2
kilometers



Study Township 6

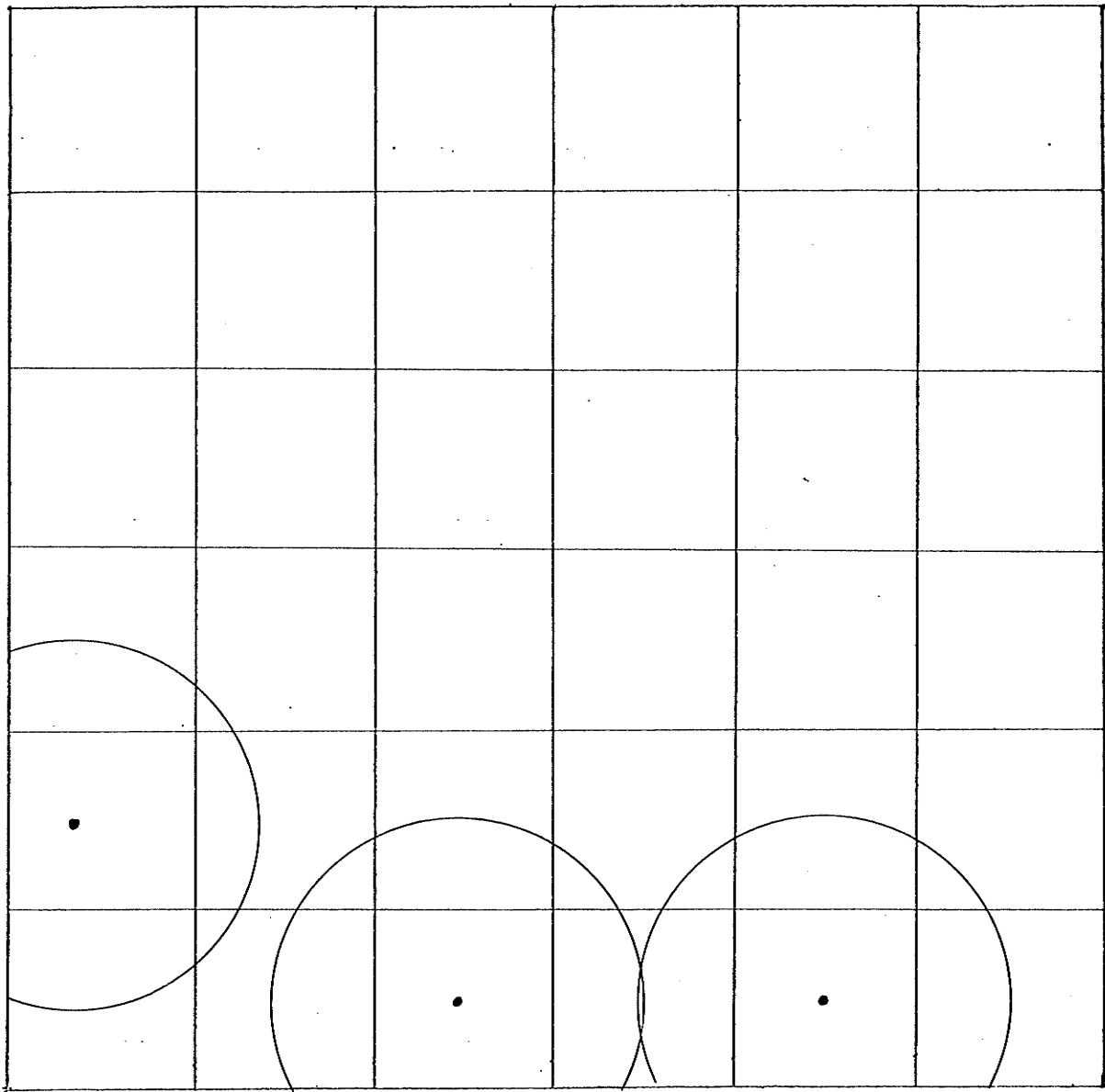


Figure 16 Location of den sites and home ranges.

Scale 0 1 2
kilometers



thought to be occupied by different families (Figure 13). Therefore the 1.6 kilometer circular home range area appears to be a good approximation to actual fox home range areas for southern Manitoba. If this home range area is a territorial necessity (which does not seem to be the case) then one township could only theoretically support a maximum of 9 fox families.

Population densities (Table XIII) are based on the number of active fox dens and the estimated number of foxes per family (2 adults and 5 pups (Banfield, 1974)).

Table XIII Spring fox population density estimated by the aerial survey method

Township #	# Active Den Sites	Total # Fox	Density/ km ²
1	2	14	0.15
2	6	42	0.45
3	5	35	0.38
4	3	21	0.23
5	4	28	0.30
6	3	21	0.23
Total:	23	Total: 161	Total: 0.29

At the time of the survey, there were approximately 161 foxes located within the study townships. This represents an average of 26.8 foxes per township of 0.29 fox per square kilometer.

The study area represented 11,700 square kilometers of the total cropland region of Manitoba. Based on a density of 0.29 fox per square kilometer the total fox population of the study area is approximately 3,400. The total fox population

inhabiting the cropland region of Manitoba (based on an area of 20,200 km²) is estimated at approximately 5,860. These figures approximate the total number of foxes in the cropland region of Manitoba during the denning period. Mortality studies have never been conducted in the Province consequently, the adjusted population level during the trapping season could only be speculated upon. If we assume a 50 percent sex ratio, uniform mortality rates between sexes and that all foxes within the study area (including the previous year's young) mate, then the number of foxes inhabiting the study region prior to parturition is based on 2 foxes per den site (Table XIV).

Table XIV Red fox mating population density based on the aerial survey method

Town-ship #	# Active Den Sites	Total # Fox	Density/km ²
1	2	4	0.043
2	6	12	0.13
3	5	10	0.11
4	3	6	0.064
5	4	8	0.086
6	<u>3</u>	<u>6</u>	<u>0.064</u>
Total:	23	Total: 46	Average: 0.083

A total of 46 foxes represents an average mating population density of 0.083 fox per square kilometer. Therefore, it can be assumed that some 1,677 foxes mated during 1976 over the entire cropland area of Manitoba. This analysis is based on many assumptions but can be useful as a baseline for further research into mortality rates and trapping pressure.

Caughley et al. (1976) evaluated the reliability of aerial surveys in determining population densities. The data suggest that aerial surveys provide underestimates of actual animal densities. Quantitative data suggest the following:

- 1) ability to observe dens decreases with increased altitude
- 2) observed density decreases as the transect is broadened
- 3) fatigue does not affect the efficiency of observation over a 3 hour survey
- 4) observers differ in their ability to locate dens

These factors should be taken into consideration when developing and evaluating aerial surveys.

4.2 Infrared Imagery

Colour infrared aerial photographs were taken of selected den sites in order to evaluate this remote sensing technique for locating active fox den sites.

A yellow (Y2) filter (equivalent to a Kodak Wratten #12) must be used with Ektachrome Infrared Aero type 8443 to retain a biological colour balance necessary for consistent results (Kodak, 1968). This filter absorbs the violet and blue wavelengths to which the emulsion is sensitive. A red (R2) filter (equivalent to a Kodak Wratten #25A) was also used in this study. This filter eliminates electromagnetic wavelengths less than approximately 580 microns (i.e. filtering out the violet, blue and blue-green wavelengths (Appendix IV) and is generally used for black and white infrared applications. However, it was felt that better vegetation definition could be obtained

and that den sites would show up more distinctly than in the Y2 filtered results by combining the use of this filter with infrared colour film.

Flights were withheld until weather conditions were adequate and the aerial infrared photography was conducted between 1:00 p.m. and 2:00 p.m. when the sun's angle was near vertical. Haze was minimal, but patch clouds made it necessary to circle some sites allowing cloud shadows to pass.

Three sites were chosen to represent different denning habitats in order to assess the results of infrared imagery in a variety of situations. The sites were ground-verified before the flights to ensure that they were active. Site #1 (Township 2, E. Side N.W. $\frac{1}{4}$ Sec. 20) was a well-established den site, dug into a relatively flat, triangular grassed section immediately adjacent to a small woodlot. Site #2 (Township 3, E. side Sec. 35) was a conspicuous den excavated in both banks of a dugout on a deserted farmstead. A small woodlot was located about 50 metres from this dugout (Township 4, W. side Sec. 5) was typical of many den sites in the area. It was situated on a sloped, grassed roadside with no tree cover within 0.5 kilometers. These three sites are representative of most den habitats encountered during the course of this study.

As infrared exposures cannot be determined in the conventional fashion and because the film has such a narrow latitude, bracketing was necessary to ensure proper exposure. Kodak suggests an exposure of 1/500 second at f.5.6 based on an aerial exposure index of 10 for Infrared Aero film type 8443

(Kodak 1968). The exposure, site number, frame number, altitude, and filter used for data collection are listed in Appendix V.

Because of the special properties of infrared colour film, healthy foliage records bright red whereas foliage under stress records in other colours (Kodak 1968). Black fertile top soil records green whereas less fertile subsoil records in lighter shades (grey to white) (Jack McKinnon, pers. comm.). The best indication of den location, when photographed from high altitudes using infrared film, results from the stressed vegetation near the den entrances. Heavy use by both adults and pups flattens and kills much of the vegetation near the den entrance. This "stress area" generally covers a radius of 1.5 to 3 metres from the den entrance, depending on the age of the site. Old, well-established den sites, characterized by numerous entrances, show up readily as the excavated sub-soil produces a distinctive light spot on the infrared image.

The determination of scale is accomplished through use of the following equation:

$$\text{Scale} = \frac{\text{Lens Focal Length}}{\text{Altitude (above ground level)}}$$

(Kodak, 1971)

Photographs were taken at altitudes of 450, 900, and 1500 metres. The aircraft was banked steeply and photographs were taken through an open window to ensure a nearly vertical shot. Table XV lists the appropriate scale and approximate ground coverage of the photographs taken.

Table XV Scale determination

Altitude (metres)*	Scale	Approximate Ground Area Covered*
450	1:9000	200 m x 325 m
900	1:18000	400 m x 650 m
1500	1:30000	700 m x 1000 m

*These figures can only be considered approximate as actual values will vary according to the altitude and the angle at which the photograph was taken.

Figures 17 through 22 illustrate active fox den signatures recorded on the infrared imagery. The photographs were taken at the lowest altitude (450 m) and include the results for both filter combinations (Y2 and R2).

Site #1 (Figures 17 and 18)

The den is characterized by a disruption of the natural vegetation pattern. Faint trails are discernable at the site but the den does not appear as a distinct signature. Some recent digging activity is apparent in the adjacent vegetated half-mile line. The photo taken with the Y2 filter (Figure 17) demonstrates the best clarity and potential for den identification. Tall grass partially concealed fox trails and den entrances, making it difficult to identify the den site with infrared imagery.

Site #2 (Figures 19 and 20)

This particular site had dens excavated in both dug-out banks. The dens are quite conspicuous and are characterized

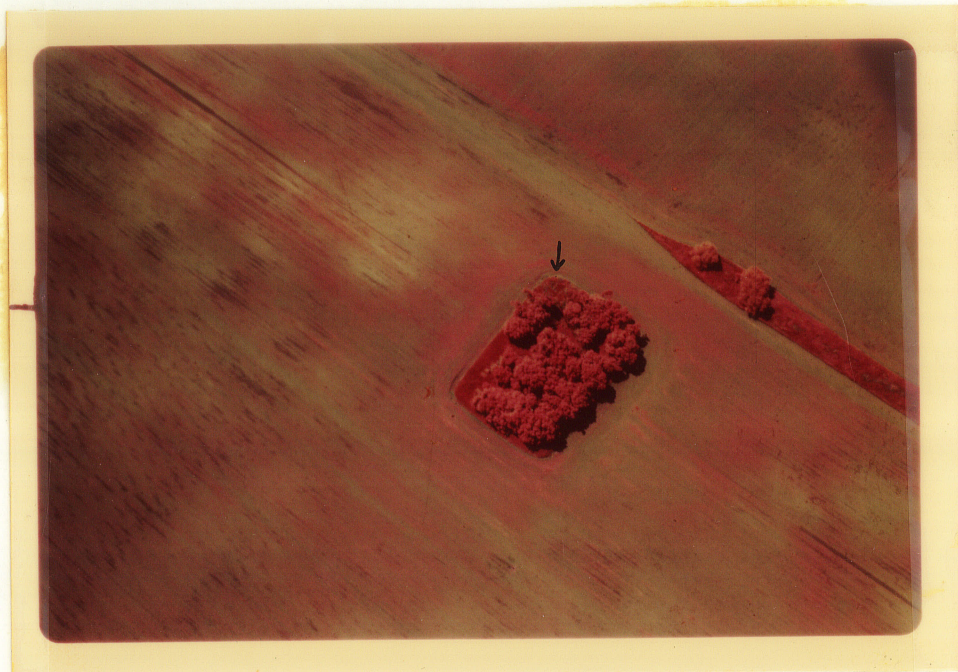


Figure 17 Infrared imagery: Site #1 (Y2 filter)

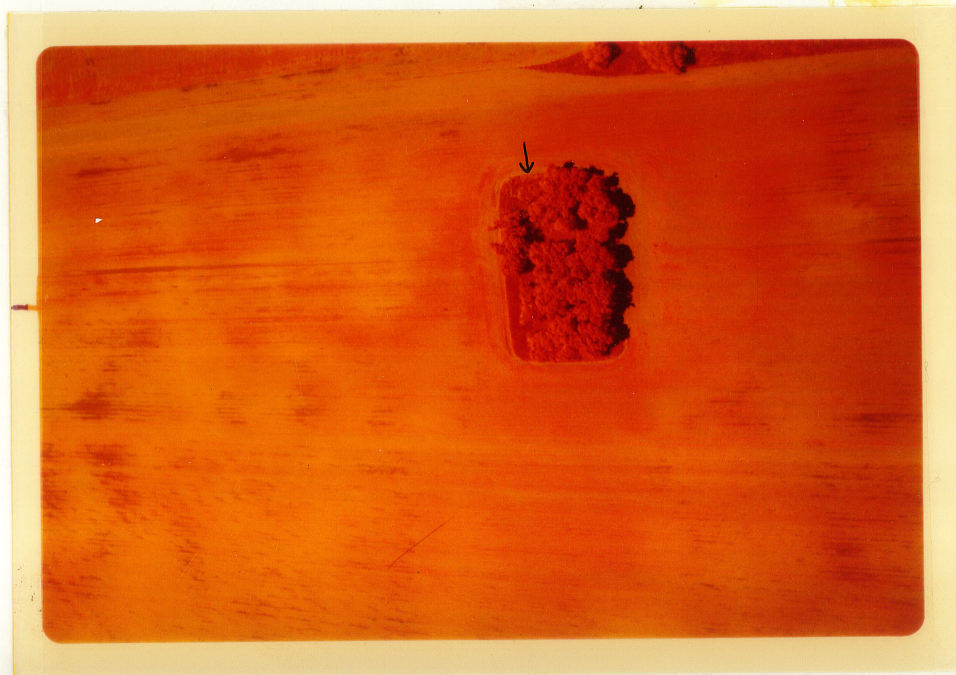


Figure 18 Infrared imagery: Site #1 (R2 filter)

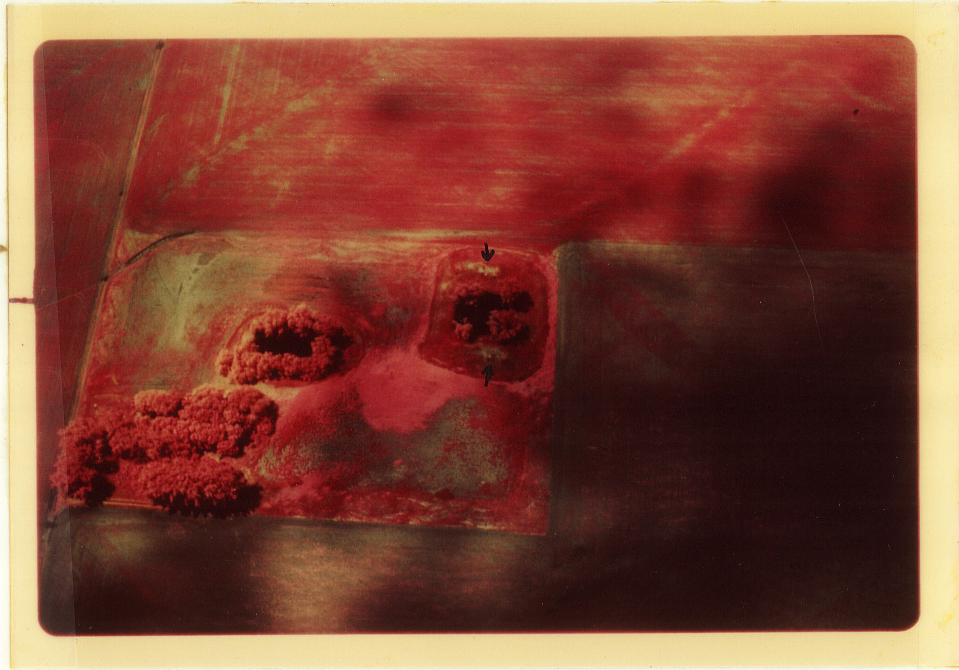


Figure 19 Infrared imagery: Site #2 (Y2 filter)

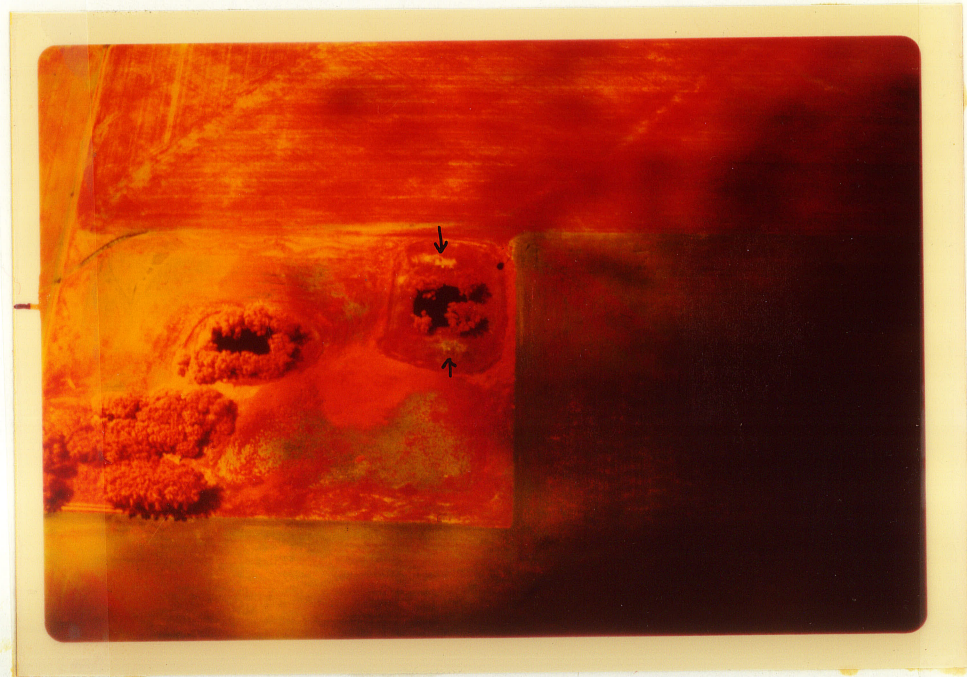


Figure 20 Infrared imagery: Site #2 (R2 filter)

by a distinct light spot amongst the uniformly vegetated dug-out bank. A few of the well-used trails are visible upon close examination. The den signature results from excavated sub- and top-soil and vegetation stress associated with entrances and trails. Somewhat better resolution was achieved with the Y2 filter while better definition and brightness was achieved with the R2 filter. The difference between the two is not considered to be significant for den identification.

Site #3 (Figures 21 and 22)

This site is typical of most den sites identified in the study area. The den has two distinct entrances that are readily identified by the associated excavated material. The dark spots result from top soil excavated from under the road. The light area surrounding the den is a result of vegetation stress caused by pup activity. Notice the disruption of the red vegetated zone adjacent to the road caused by the vegetation stress. Neither the Y2 nor the R2 filtered photographs demonstrates significantly better resolution or den observability over the other.

The den sites can be distinguished in all three habitats selected for this study. Dens located near or in dense vegetative cover (Site #1) are relatively difficult to identify from the infrared results. Dens located in open areas (Site #2 and Site #3) are more easily identified from infrared imagery. The potential of infrared remote sensing for fox dens in the study area is not adversely affected by the limited

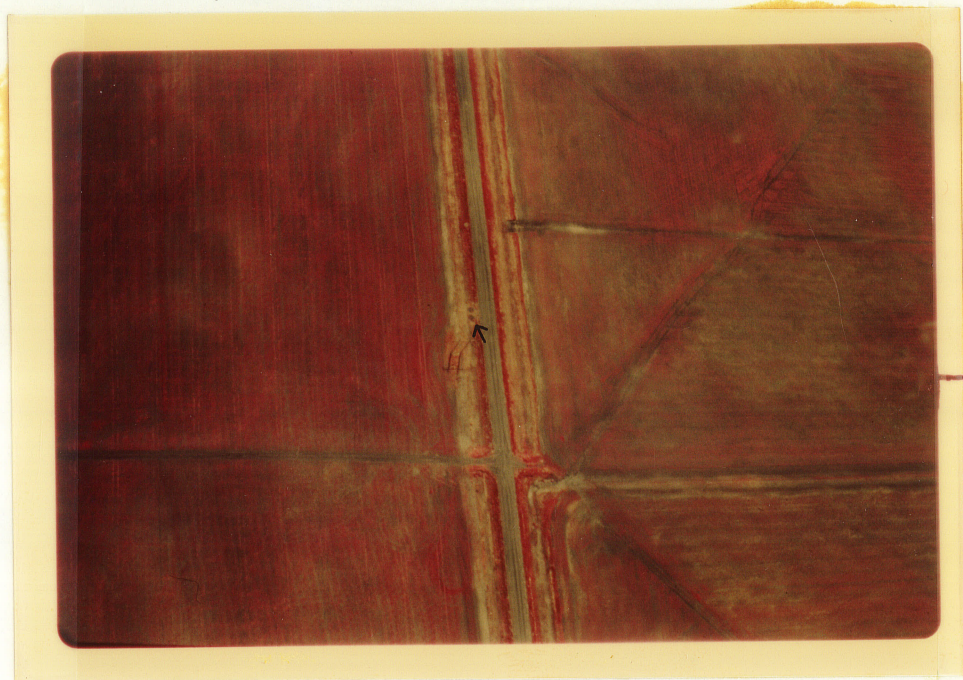


Figure 21 Infrared Imagery: Site #3 (Y2 filter)



Figure 22 Infrared imagery: Site #3 (R2 filter)

ability to record dens in dense vegetative cover. Site #1 was the only den located near dense vegetative cover in the study area. Most dens are located some distance from treed cover consequently, the potential of infrared imagery for the location of fox dens (in the cropland region of Manitoba) is good.

The infrared slides were analysed further to determine if the fox dens recorded as a unique density, or signature, which could be readily identified. Figure 23 illustrates the video tube display associated with Site #3. The arrow indicates the den location.

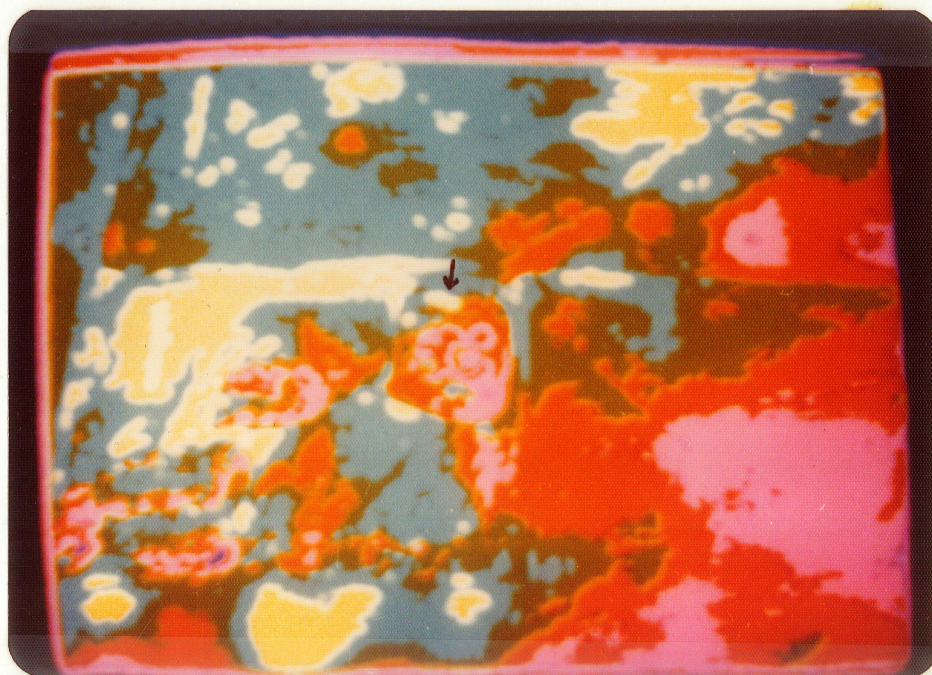


Figure 23 Density sliced display of Site #2

The den sites do not reflect in a specific electromagnetic wavelength range that could be isolated by this method. The density slicer was designed to differentiate between different emulsion densities on black and white transparencies. Different colour tones may exhibit the same density, consequently, the degree of differentiation between features attainable with colour infrared film may not be as good as that possible with black and white film. Better density sliced results may have been achieved in this study with black and white infrared film. Substantial savings could be achieved (for full scale township monitoring) if black and white infrared film demonstrates adequate den definition.

4.3 Questionnaire and Interview Sampling

Both questionnaire sampling and personal interviews of landowners were conducted. Evaluation of the results, keeping in mind the limitations of each, is required to establish the reliability of these methods as a monitoring system.

In reviewing the two methods (personal interviews vs. mail-out questionnaire method) the following main points arise (Crapo and Chubb, 1969, Selltitz et al., 1959, Leedy, 1974):

- 1) the interview method attains a greater response rate.
- 2) an interviewer can normally ensure that all questions are answered fully.
- c) the presence of an interviewer generally ensures that all responses are useable.
- 4) the questionnaire method is considerably less expensive.

5) the questionnaire method can simultaneously question many individuals over a scattered area.

Care was taken both in the questionnaire design and in the conducting of personal interviews to minimize the problems associated with each technique. All interview questioning was restricted to those questions developed for the questionnaire. This helped to maintain consistency in results and simplified the comparison and evaluation of the two methods.

An extremely good questionnaire response rate was achieved with 68 percent and 60 percent responding from study townships 4 and 5 respectively. An overall questionnaire response rate of 64 percent was achieved (Table XVI). The high response rate demonstrates the effectiveness of a well designed questionnaire in eliciting information from land-owners.

4.3.1 Analysis of Questionnaire Response

Question 1. In relation to last year would you consider fox populations to be lower, higher or about the same?

Response:

	Lower	Same	Higher	Total
Tp. 4	8	43	10	61
Tp. 5	5	31	9	45
Total	13	74	19	106

Question 2. Do you at present have an active fox den on your property?

Table XVI Questionnaire response

Township	# Questionnaires Mailed	# Responses
Tp. 4	111	75
Tp. 5	85	51
Total	196	126

This represents an overall response rate of 64.3%.

Response Breakdown:

	Township	Week 1	Week 2	Week 3	Total
First Mailing	4	24	11	12	47
	5	15	9	11	35
	Total	39	20	23	82

	Township	Week 1	Week 2	Total
Second Mailing	4	15	13	28
	5	8	8	16
	Total	23	21	44

Response rate for Tp. 4 = 68%
Response rate for Tp. 6 = 60%

42% response was achieved in the first mailing; the remaining 23% was achieved in the follow-up mailing.

Response:

	Yes	No	Don't Know	Total
Tp. 4	8	36	24	68
Tp. 5	12	14	21	47
Total	20	50	45	115

Question 3. Do you know of any other presently active fox dens within your township?

Response:

	Yes	No	Don't Know	Total
Tp. 4	12	25	28	65
Tp. 5	6	21	20	47
Total	18	46	48	112

If you answered YES to either Question 2 or 3, would you please mark the location of the den site(s) on the township map provided on the reverse of this questionnaire.

Questions 2 and 3.

	# Yes Response	# Sites Located	# Corresponding* with Aerial Survey Results	% Corresponding* with Aerial Survey Results
Tp. 4	20	24	7	29%
Tp. 5	18	13	4	31%

*Includes all sites located within the home range area identified in the aerial surveys.

Question 4. What crops or livestock do you raise?

Response:

	Cereal Grains	Root Crops	Oil Seeds	Other	Poultry	Cattle	Sheep	Hogs	Dairy	Other
Tp. 4	61	1	37	3	16	15	0	23	4	0
Tp. 5	43	1	25	4	6	5	1	8	1	2
Total	104	2	62	7*	22	20	1	31	5	2**

* other includes: peas, corn and clover

**other includes: fish and show horses

Question 5. Do you attribute any damage of property, crops or livestock to fox predation?

Response:

	Yes	No	Total
Tp. 4	4	63	67
Tp. 5	1	45	46
Total	5	108	113

Question 6. If yes, then in your estimation, what is the approximate yearly extent of this damage?

Response:

	Yes	\$<100	\$100	\$200	\$300	\$400	\$500	\$>500
Tp. 4	4	3	1	-	-	-	-	-
Tp. 5	1	0	0	1	-	-	-	-
Total	5	3	1	1	0	0	0	0

Question 7. Do you or members of your household actively hunt or trap fox?

Response:

	Hunt	Trap	Neither	Total
Tp. 4	4	1	65	70
Tp. 5	0	0	45	45
Total	4	1	110	115

Question 8. If you hunted or trapped fox last year, please specify the number taken by each method.

Response:

	Number Shot	Number Trapped	Total
Tp. 6-1	20*	0	20
Tp. 6-2	0	0	0
Total	20	0	20

*the respondent indicated that he did not shoot the animals himself but merely processed them for others. These furs were subsequently marked by the respondent.

Question 9. Please indicate how these animals were disposed of; indicate the number of animals disposed of by each method and the total value received as a result of their sale.

Response:

Method	# of Animals	Total Value
a) fur buyer	--	--
b) auction	20	\$ 900
c) private sale	--	--
d) own use	--	--
e) none	--	--
Total		\$ 900

Question 10. Do you feel that fox populations should be controlled?

Response:

	Yes	No	Don't Know	Total
Tp. 6-1	11	32	25	68
Tp. 6-2	9	24	15	48
Total	20	56	40	116

The questionnaire response to Question 1 suggests that fox population densities have not changed between 1975 and 1976. The regular response distribution, with 70 percent of the respondents indicating that population levels are the same, is in no way conclusive. A "Don't Know" alternative was not included among the possible responses. The response may suggest that landowners subjectively responded "same" because no suitable alternative was not offered. It is impossible to establish the reliability of this response without a 1975 fox population estimate for comparison.

The questionnaire response to Questions 2 and 3 could not be effectively separated because respondents did not indicate which locations were on their property (when more than one location was mapped). Locations of fox dens were recorded on township maps included on the reverse of the questionnaire. A significant proportion of the respondents (17 percent) indicated the presence of an active fox den on their property and 16 percent indicated knowledge of the location of fox dens

elsewhere in the township. A total of 24 and 13 dens were indicated (locating 19 and 13 different den sites) in townships 4 and 5 respectively (an average of 16 dens per township). Basing population estimates on an average of 5 pups or 7 foxes per den then, the information suggests a total population of 112 foxes per township or a density of 1.2 fox per square kilometer. This estimate is exceedingly high and its reliability may be questioned when compared with the aerial survey results. The locations of den sites indicated by landowners are illustrated in Figures 24 and 25.

The response to Question 4 indicates that the majority of crops grown were cereal grains and oil seeds while poultry, cattle, and hogs accounted for the majority of livestock raised.

Only five of the respondents attributed any damage of crops, property, or livestock to fox predation. Estimated damage was less than 600 dollars (less than 400 dollars indicated in Township 4 and 200 dollars in Township 5) representing an average predation damage estimate of less than 3.22 dollars per square kilometer. This figure represents the maximum predator damage attributed to foxes in the two township sample area. Of the five respondents indicating damage, three raised a combination of poultry, hogs and cattle, one raised poultry and cattle, and one raised only hogs. This would suggest that the major predation effect is upon poultry and hogs.

Most of the respondents (96 percent) neither hunt nor trap fox. Only one respondent admitted processing and marketing fox pelts. The animals were shot by an unnamed party and were

Study Township 4

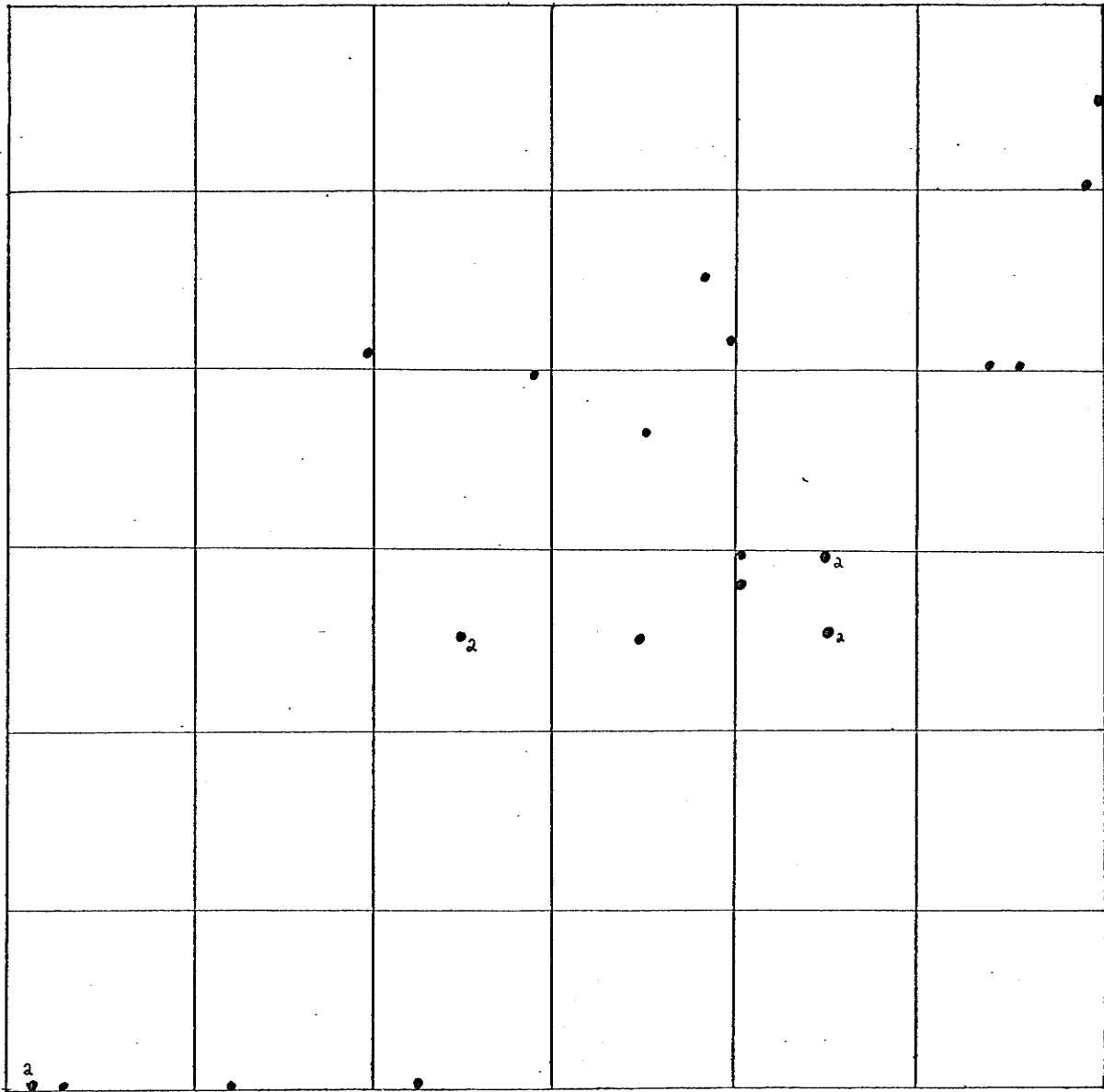
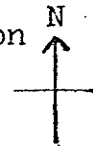


Figure 24 Location of den sites; questionnaire response

Numerals represent the number of respondents reporting the location

Scale 0 1 2 kilometers



Study Township 5

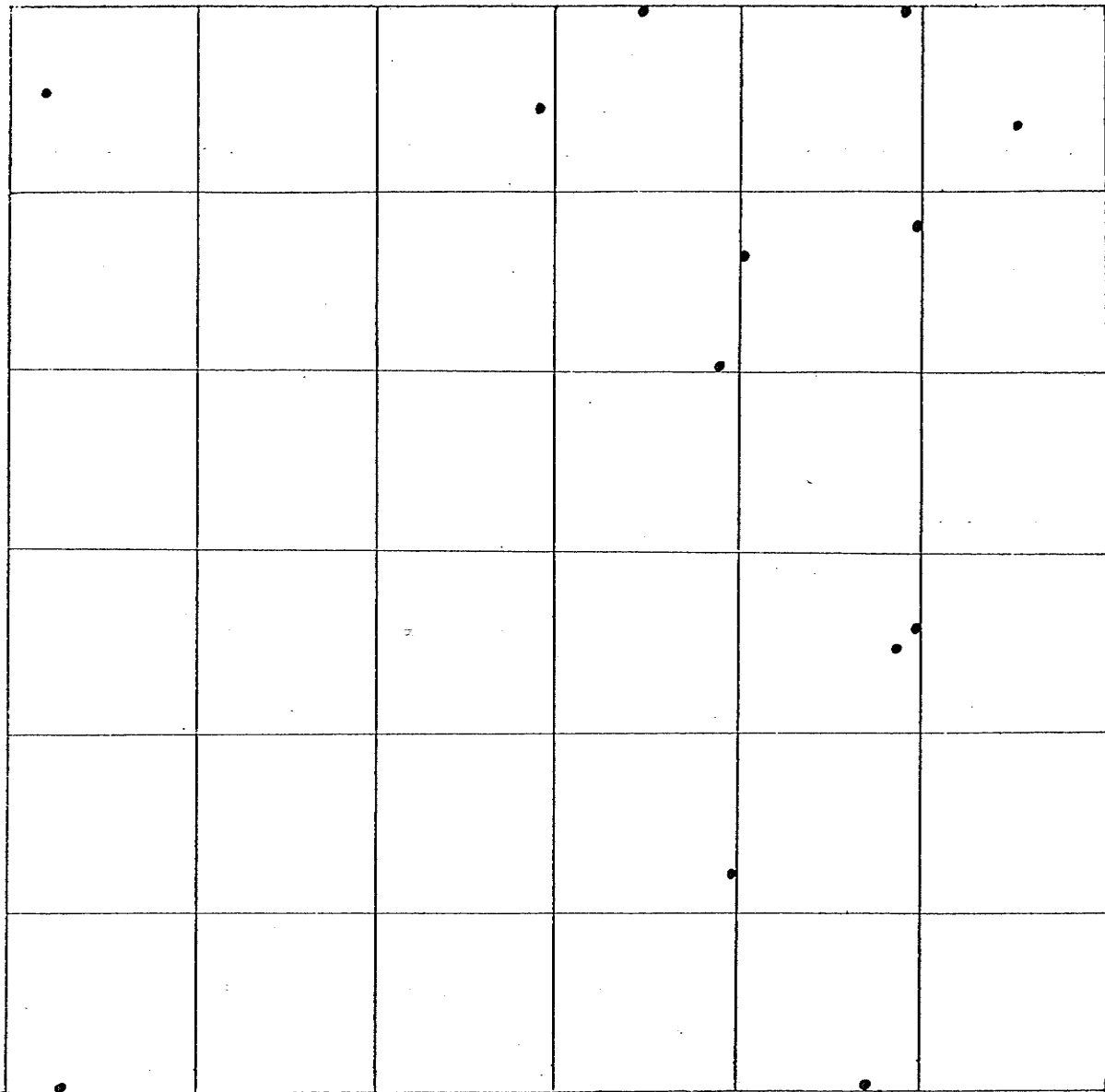
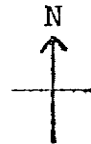


Figure 25 Location of den sites; questionnaire response

Scale 0 1 2
kilometers



subsequently marketed by the respondent. The estimated auction value of the 20 pelts is 900 dollars. This exceeds the estimated maximum predation loss attributable to fox by 300 dollars. Economically, this represents a net benefit to the sample area of 1.61 dollars per square kilometer.

Question 10 was an open question designed to assess attitudes towards fox population control. Only 17 percent indicated that fox populations should be controlled with the remaining respondents either against control (48 percent) or had no opinion (34 percent). In the ensuing comments, many of the respondents who had indicated a positive reaction to population control, qualified their response by stating that control should occur only when population levels increase to a point where the animals become a real problem. Many respondents indicated concern regarding the damage to property and the impact on animal populations resulting from the large number of hunters "from the city."

Landowner interviews were conducted in study township 3 (Tp. 3 Rge. 2 Mer W). A total of 28 personal interviews were conducted and six additional questionnaires were returned by landowners who were absent during the interview period. The township population sampled is considerably smaller than what the municipal tax rolls suggest. There are many absentee landowners in the area and consequently, the municipal tax rolls do not accurately measure rural population (i.e. whether the registered owner actually farms the land). All of the landowners interviewed were permanent residents in the township

and actively farmed their own land and/or farmed under a cash rental or share-crop arrangement.

4.3.2 Analysis of Interview Response

Question 1. In relation to last year would you consider fox populations to be lower, higher, or about the same?

Response:

Lower	Higher	Same	Total
16	4	11	31

Question 2. Do you are present have an active fox den on your property?

Response:

Yes	No	Don't Know	Total
6	21	6	33

Question 3. Do you know of any other presently active fox dens within your township?

Response:

Yes	No	Don't Know	Total
12	10	10	32

If you answered YES to either 2 or 3, would you please mark the location of the den site(s) on the township map provided on the reverse of this questionnaire.

Response:

# Yes Response	# Sites Located	# Corresponding With Survey Result	% Corresponding With Survey Result
18	16	13	81%

These data include one active site not previously located by the aerial survey technique. The high percentage of correspondence reflects landowner knowledge (of those landowners responding YES to question 3) of the location of a conspicuous den site on a well travelled road near the town of Plum Coulee.

Question 4. What crops or livestock do you raise?

Response:

Cereal Grain	Root Crops	Oil Seeds	Other	Poultry	Cattle	Sheep	Hogs	Dairy	Other
31	1	7	2*	7	7	0	14	2	0

*peas

Question 5. Do you attribute any damage of property, crops or livestock to fox predation?

Response:

Yes	No
1	33

Question 6. If YES then in your estimation, what is the approximate yearly extent of the damage

Response:

<\$100	\$100	\$200	\$300	\$400	\$500	>\$500
1	0	0	0	0	0	0

The total result of damage incurred is less than \$100.

Question 7. Do you or members of your household actively hunt or trap fox?

Response:

Hunt	Trap	Neither
6	1	27

Question 8. If you hunted or trapped fox last year, please specify the number taken by each method.

Response:

# Trapped	# Shot
7*	28

*These animals were all taken by one respondent.

Question 9. Please indicate how these animals were disposed of: indicate the number of animals disposed of by each method and the total value received as a result of their sale.

Response:

Method	# of Animals	Total Value \$
a) fur buyer	--	--
b) auction	33	\$ 1,485*
c) private sale	2	90*
d) own use	--	--
e) none	--	--
Total	35	\$ 1,575

*Respondent did not wish to disclose the amount he received for pelts.

Question 10. Do you feel that fox populations should be controlled?

Response:

Yes	No	Don't Know	Total
9	13	11	33

The interview response to Question 1 differed significantly from that obtained in the questionnaire analysis. Just over half of the respondents (52 percent) judged population levels to be lower than in the previous year, while 36 percent judged population levels to be about the same and 13 percent thought that fox populations were higher than in 1975. Without quantitative data with which to compare these results, the validity of the response distribution is questionable; especially since the interview results do not substantiate

the questionnaire response.

A significant proportion of the subjects (18 percent) reported having an active fox den on their property. An equal percent were not aware of den sites on their property, while the majority (64 percent) reported that they did not have an active den on their property. A large portion of the subjects (38 percent) reported knowledge of the location of other den sites in the township. The combined response from questions 2 and 3 accounted for the location of 16 den sites (Figure 26). Three of the dens located were situated just outside the township boundary and therefore, could not be considered when estimating the township population density. A total of 13 dens per township represents an estimated population density of 0.98 fox per square kilometer. The high estimate resulting from both the questionnaire and interview data probably reflects the transient nature of fox families (i.e. the same family may have been spotted at different den sites). Also, old non-active den sites, badger dens, or recent diggings may have been mistaken for active fox dens.

The major crops grown in the interview township were cereal grains and oil seeds. Hogs, poultry, and cattle accounted for most of the livestock raised.

Only one subject (3 percent of those interviewed) reported any damage attributed to fox predation. Estimated damage was valued at less than one hundred dollars. This represents a township predator-inflicted loss of less than 1.07 dollars per square kilometer. The respondent recording

Study Township 3

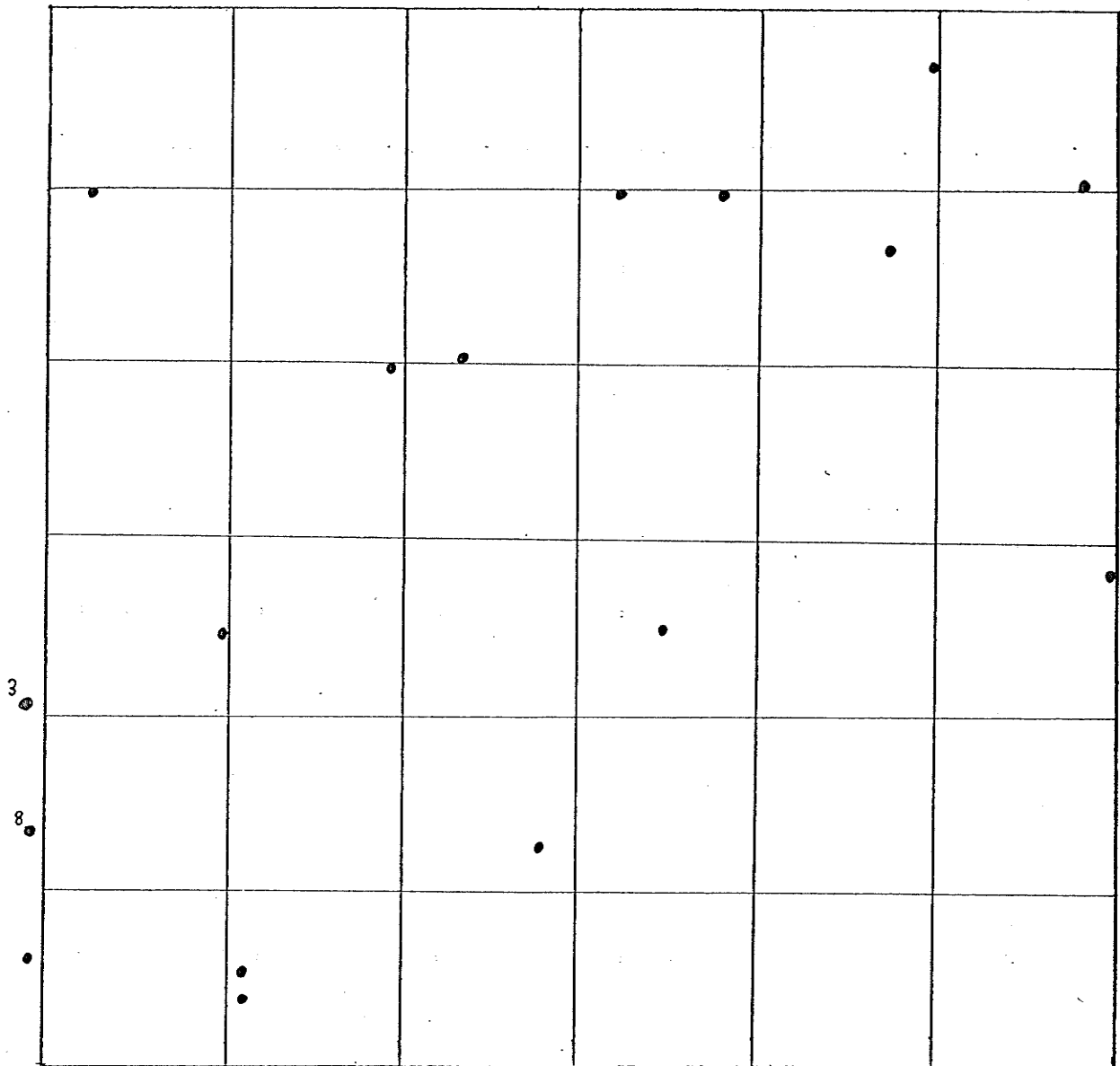


Figure 26 Location of den sites and: interview response.

Numerals represent the number of respondents reporting the location.

Scale 0 1 2
kilometers



the loss raised hogs and indicated that the actual loss figure represented very minimal damage (he did not report the loss of any livestock). However, the landowner declined to comment on the actual nature of the damage that was incurred.

Nearly 80 percent of the landowners interviewed indicated that they neither hunted nor trapped fox. Of the remainder, 17 percent hunted and only one respondent (3 percent) trapped fox. A total harvest of 35 fox was reported by the landowners interviewed (all were taken by one respondent). The majority (28) of these animals were shot and the remainder were trapped; 33 of the pelts were auctioned and two were sold privately. The estimated fur value of the fox taken is approximately 1,575 dollars. This represents an economic gain to the township of 16.89 dollars per square kilometer or a net economic gain (predator value minus predator inflicted loss) of 15.82 dollars per square kilometer.

In response to Question 10, 27 percent felt that fox populations should be controlled, 39 percent felt that populations should not be controlled and the remaining 33 percent did not know. Many of the respondents who advocated population control qualified their response by stating that control should occur only when populations increased to a level where the animals became a nuisance.

4.4 Comparison of Monitoring Techniques

Two main criteria require evaluation when comparing the monitoring techniques used; these are 1) reliability, and

2) feasibility. It was assumed from the outset that aerial surveys would yield the most reliable estimates. Consequently, the reliability of both the questionnaire response and the interview response can be compared with this information. The infrared imagery was conducted to establish the potential of this method for monitoring fox populations. However, the reliability of this method cannot be established on the basis of the work completed in this study. The feasibility of each of the techniques would have to be based on the reliability and the cost of developing these techniques for full scale fox population monitoring.

4.4.1 Aerial Survey Results

The open nature of the study area was ideally suited for aerial location of fox dens. Aerial surveys will generally yield an underestimate of actual population levels (Caughley et al., 1976) and therefore population densities acquired by this method probably represent minimum estimates. Reliability could possibly be improved by employing experienced observers.

The cost of conducting aerial surveys is the major constraint (Table XVII). These costs do not reflect realistic costs of conducting the aerial survey. Volunteers were used as spotters and aided in the ground verification of sites. Considerable cost savings were achieved by renting private aircraft rather than conducting the surveys through Manitoba Government Air Services.

Table XVII Costs: aerial surveys

Activity	Cost
Aerial Survey (Tp. 1, 2 and 3) 7.5 hr. @ \$32/hr.	\$ 252.01
Aerial Survey (Tp. 4, 5 and 6) 10.2 hr. @ \$24/hr.	244.80
Ground Verification (Mileage @ 19.5¢/mi.)	554.39
Meals for pilot and spotters	15.30
Wage (1.5 months @ \$500/mo.)	<u>600.00</u>
Total	\$1,666.50*

*Average flight time required per township was 3 hrs. Costs include all those incurred in the aerial survey and subsequent ground verification of den sites over the 6 township study area. Average cost per township = \$277.75.

4.4.2 Infrared Imagery Analysis

This method has demonstrated some potential as a fox population monitoring technique. The results of this study are not conclusive of the potential of infrared remote sensing for fox population monitoring and the reliability of the technique should be determined by further experimentation. Preliminary evaluation costs are given in Table XVIII. These costs do not reflect the realistic costs of conducting township monitoring using remote sensing. Two volunteers accompanied the author during the photography flight, one aided in the actual photography while the other recorded data.

Table XVIII Costs: infrared imagery data collection

Activity	Cost
Aerial Photography (Flight cost) 1.68 hr. @ \$32/hr.	\$ 53.76
Travel cost (@ 19.5¢/mi.)	97.50
Film, Equipment and Processing	38.45
Meals	6.70
Wage (0.75 months @ \$400/mo.)	<u>300.00</u>
Total	\$ 496.41

The costs associated with remote sensing, using infrared imagery, are extremely variable and depend upon photographic scale, camera format, type of film, type of imagery (i.e. prints or transparencies), flight time, and technical and labour costs. The cost per township could vary from approximately 400 dollars, to in excess of, 1,000 dollars. Minimum estimates would exceed the aerial survey costs by the additional cost required for film and processing. The extra costs, however, may be justified as the infrared imagery technique could be applied to other projects or monitoring studies in the same township. Infrared imagery yields total coverage and leaves a permanent record for further analysis. The benefits of these factors should be considered when evaluating the potential of this monitoring technique.

4.4.3 Questionnaire Sampling of Landowners

Fox population estimates, based on the questionnaire response, do not appear to be very reliable. For example, the extremely even response distribution recorded for Question 1 may suggest that landowners know little of fox population trends. The response was remarkably close to a 15 percent Lower, 70 percent Same, 15 percent Higher distribution. If we assume that a 0.15, 0.70, 0.15 response distribution would be expected if landowners knew little of population trends then, we could not refute this hypothesis by use of the Chi square test (using a .05 level of significance) (Mendenhall, 1971).

Lack of knowledge regarding fox populations became evident in the landowner response to Questions 2 and 3. A total of 24 and 13 den sites were indicated in study townships 4 and 5, respectively. Of these, only one site corresponded with the aerial survey results in township 4 (4.2 percent correspondence) and two sites in township 5 corresponded to the aerial survey results (15.4 percent correspondence) (Figures 27 and 28). The overlays indicate the location of den sites recorded by the landowners and can be compared with the underlying locations and home ranges identified by the aerial surveys method. Considering the transitory nature of fox families, we can assume that den locations may have changed, especially since the aerial surveys and questionnaire sampling were not conducted at the same time. Therefore, a better correlation of aerial and questionnaire data can be made by including the number of recorded den locations situated within the hypothetical home range

Study Township 4

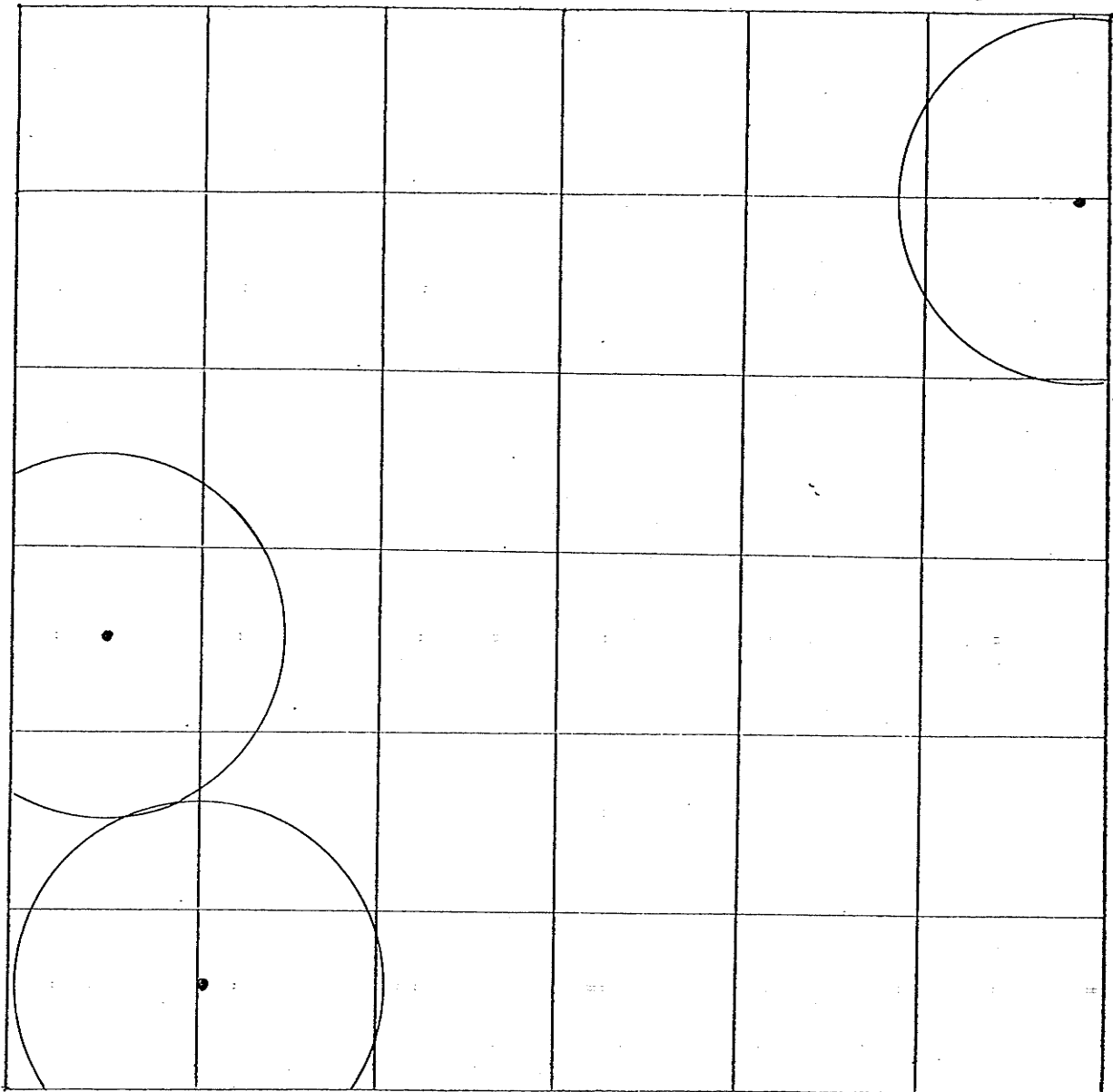


Figure 27 Comparison of den locations: questionnaire response vs. aerial surveys.

Scale 0 1 2
kilometers



Study Township 4

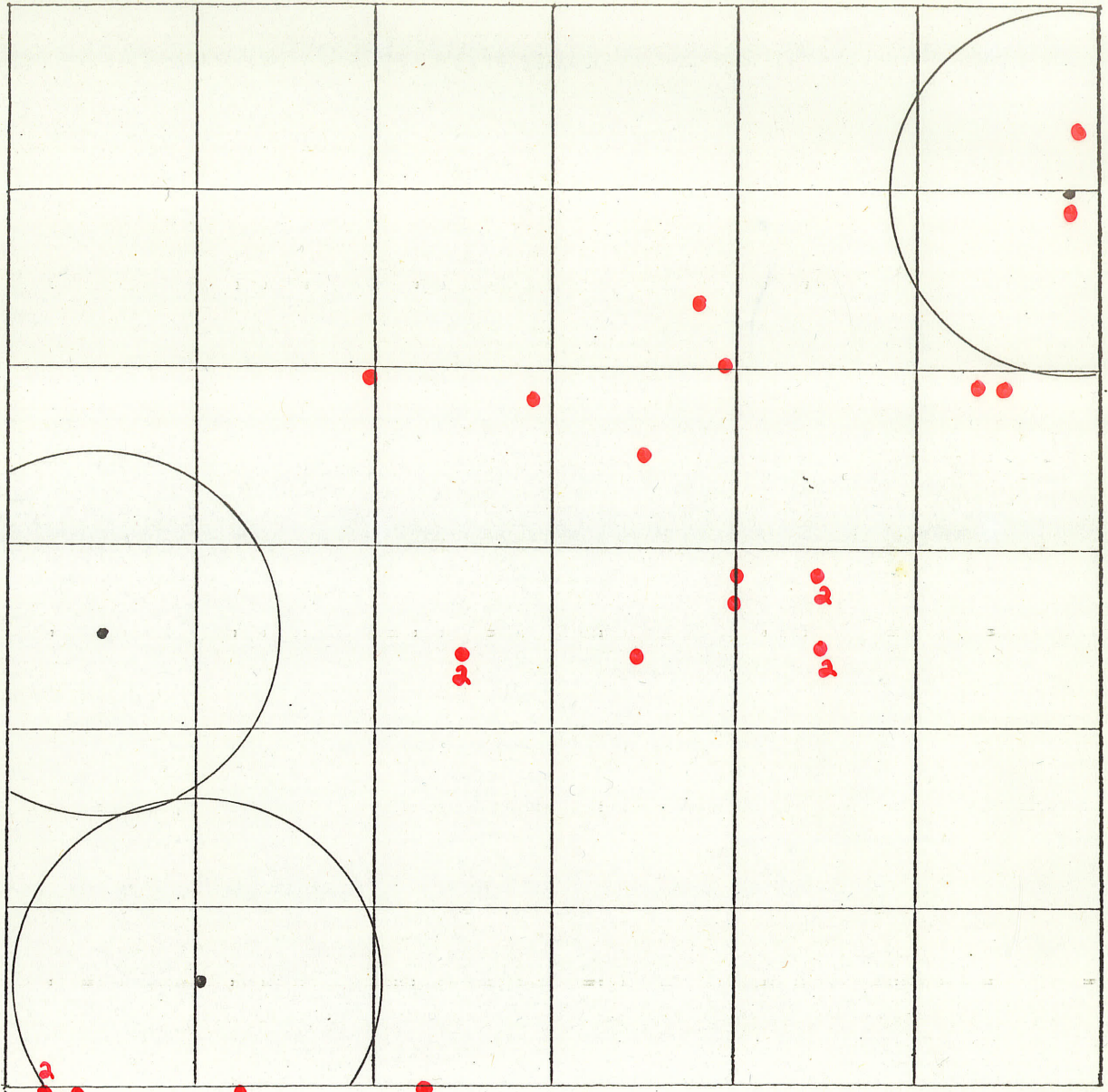


Figure 27 Comparison of den locations: questionnaire response vs. aerial surveys.

Scale 0 1 2
kilometers



Study Township 5

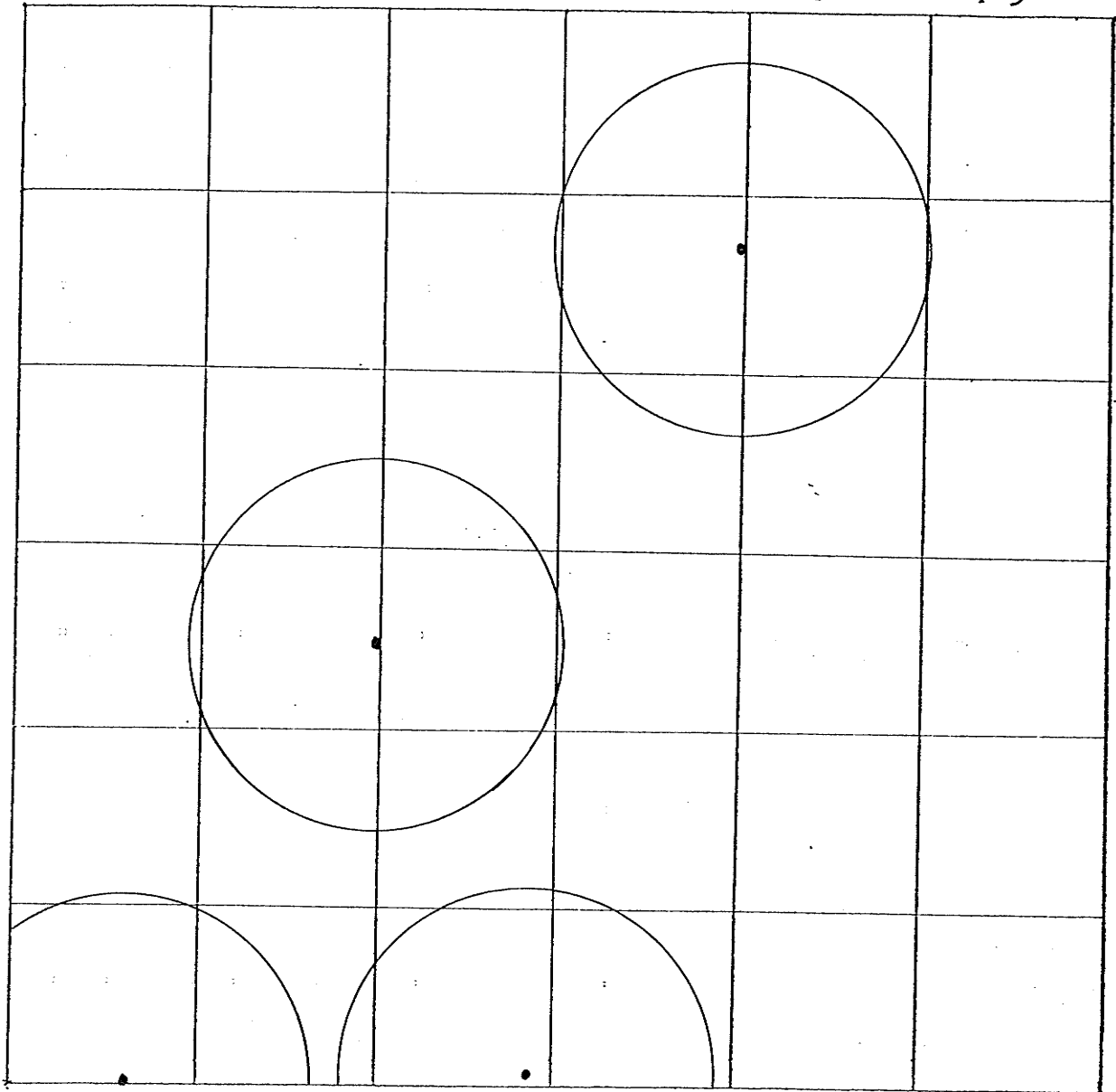


Figure 28 Comparison of den locations: questionnaire response vs. aerial surveys.

Scale 0 1 2
kilometers



Study Township 5

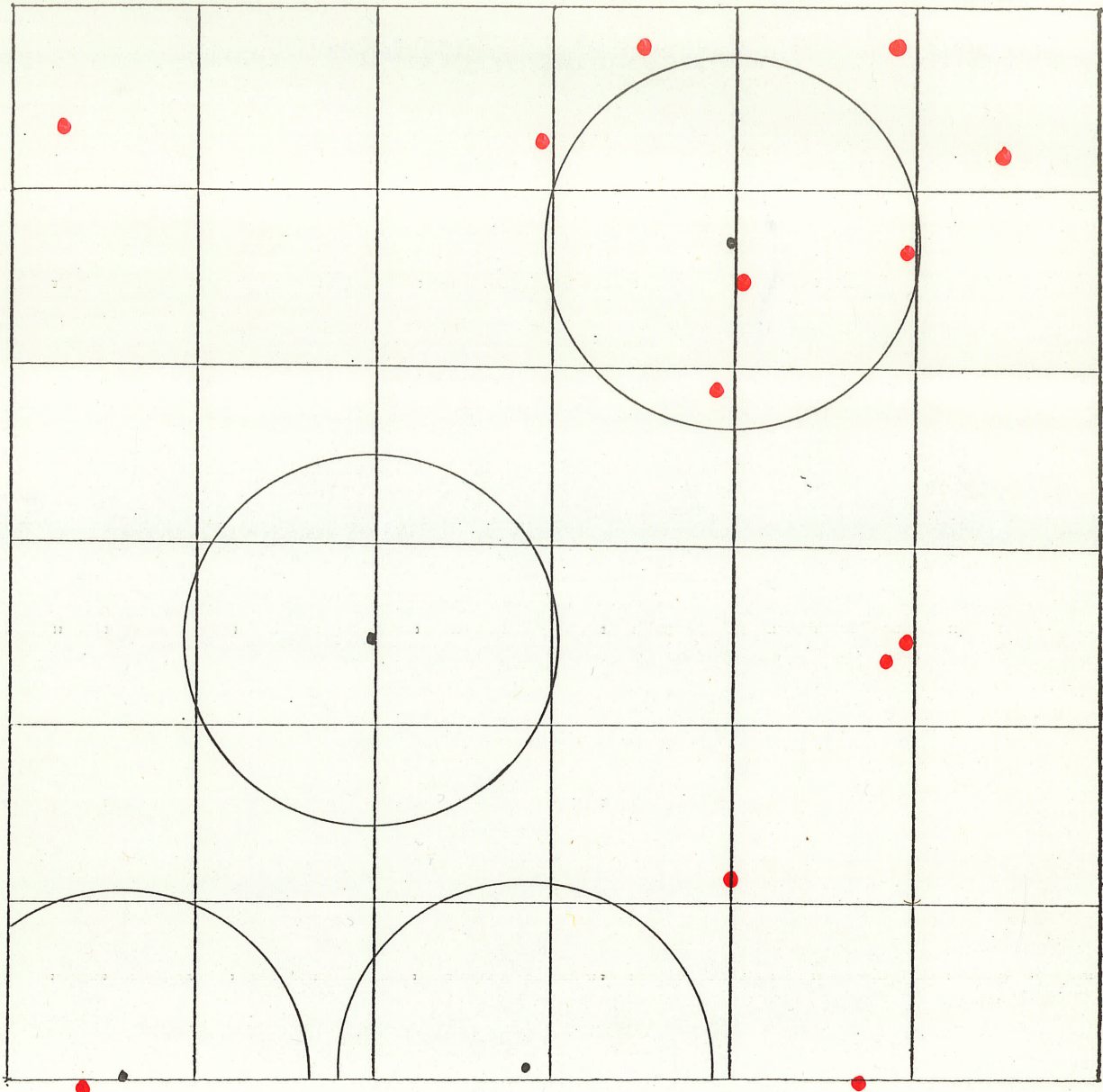
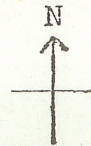


Figure 28

Comparison of den locations: questionnaire response vs. aerial surveys.

Scale 0 1 2
kilometers



boundary. Seven den sites in township 4 and four den sites in township 5 met this criteria. This corresponds to a 29 percent and 31 percent correlation with the aerial survey data for townships 4 and 5 respectively. One new den site, not previously located by the aerial survey technique, was located in township 4 (Figure 27; "*" signifies the location of this site).

Although the correlation with aerial located den sites is not particularly good, the questionnaire method could be used to develop a population index. The questionnaire method has many advantages which could be effectively used to complement an aerial survey monitoring system. These are:

- 1) the acquisition of other pertinent information, i.e. predator-inflicted loss, attitudes regarding predator and predator control, trapping and hunting pressure, etc.
- 2) low cost
- 3) adaptability to other areas of the Province, or other species
- 4) method to increase the reliability of aerial, or other monitoring systems

Questionnaire sampling should be conducted concurrent with other monitoring systems to increase the reliability of population estimates. The costs of conducting the questionnaire portion of the study (for 2 townships) are included in Table XIX.

Table XIX Costs: questionnaire sampling

Item	Cost
Questionnaire and Cover Letters (Printing)	\$ 112.00
Envelopes	20.00
Postage	51.36
Survey Results (Printing and Postage)	14.50
Wage (1 month @ \$400/mo.)	<u>400.00</u>
Total	\$ 597.86

The actual cost of conducting the questionnaire sampling (i.e. excluding time involved in questionnaire development) per township is approximately 100 dollars.

4.4.4 Interview Sampling of Landowners

The interview sampling yielded more reliable information than did questionnaire sampling. The response distribution to Question 1 was significantly different from that obtained by the questionnaire (at the .05 level of significance). This response indicates that either the landowners have some knowledge of population trends or that some interviewer bias was interjected. Further examination of data collected over successive years would be required to fully evaluate this response.

Response to Questions 2 and 3 showed much better correlation with the aerial survey results. A total of 16 fox den locations were recorded by the landowners. Thirteen of the locations corresponded with sites located by the aerial survey technique (Figure 29) (i.e. an 81 percent

Study Township 3

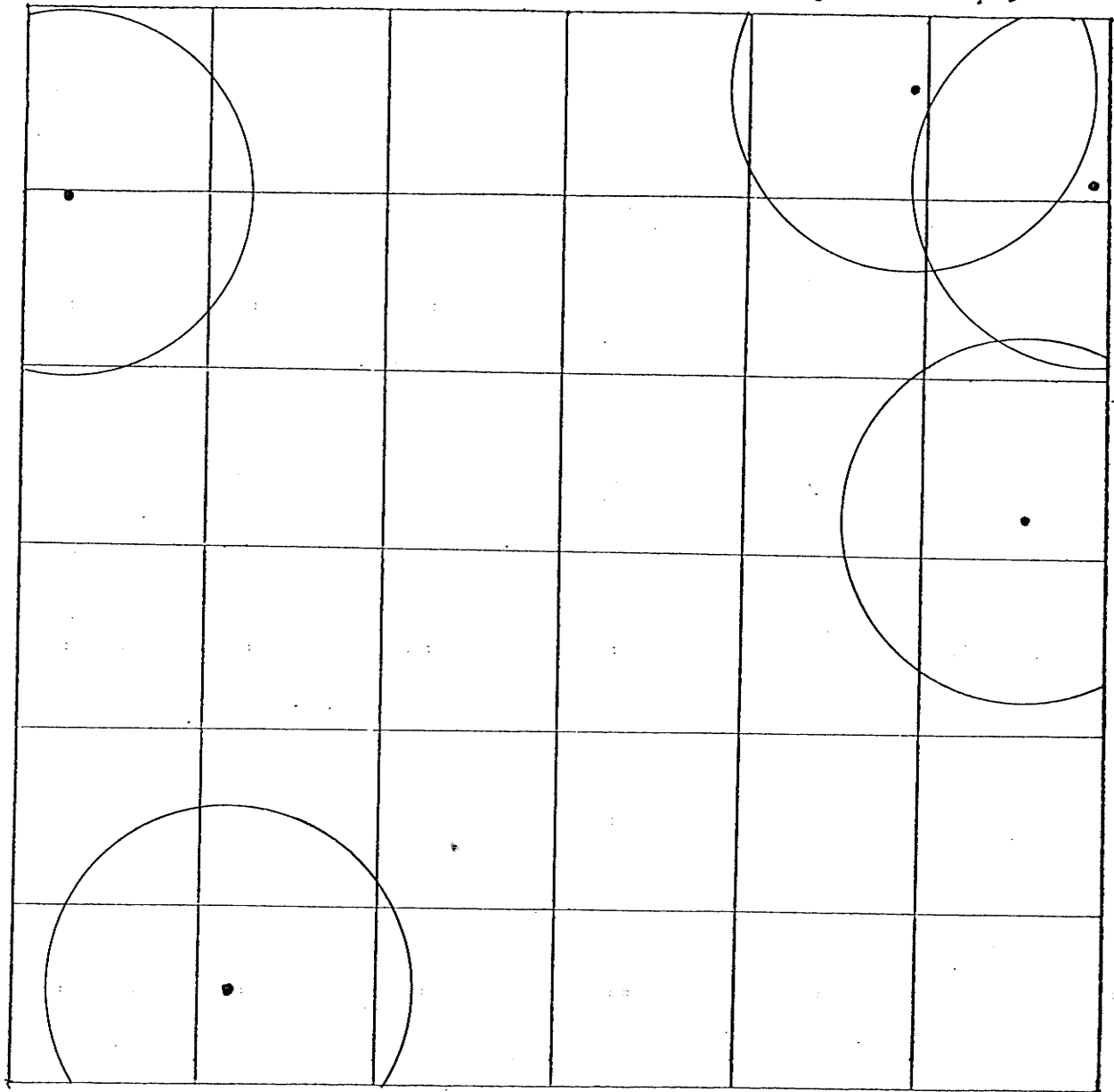
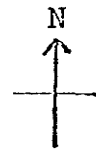


Figure 29 Comparison of den locations: interview response vs. aerial surveys.

Numerals represent the number of respondents reporting the location.



Scale 0 1 2
kilometers

Study Township 3

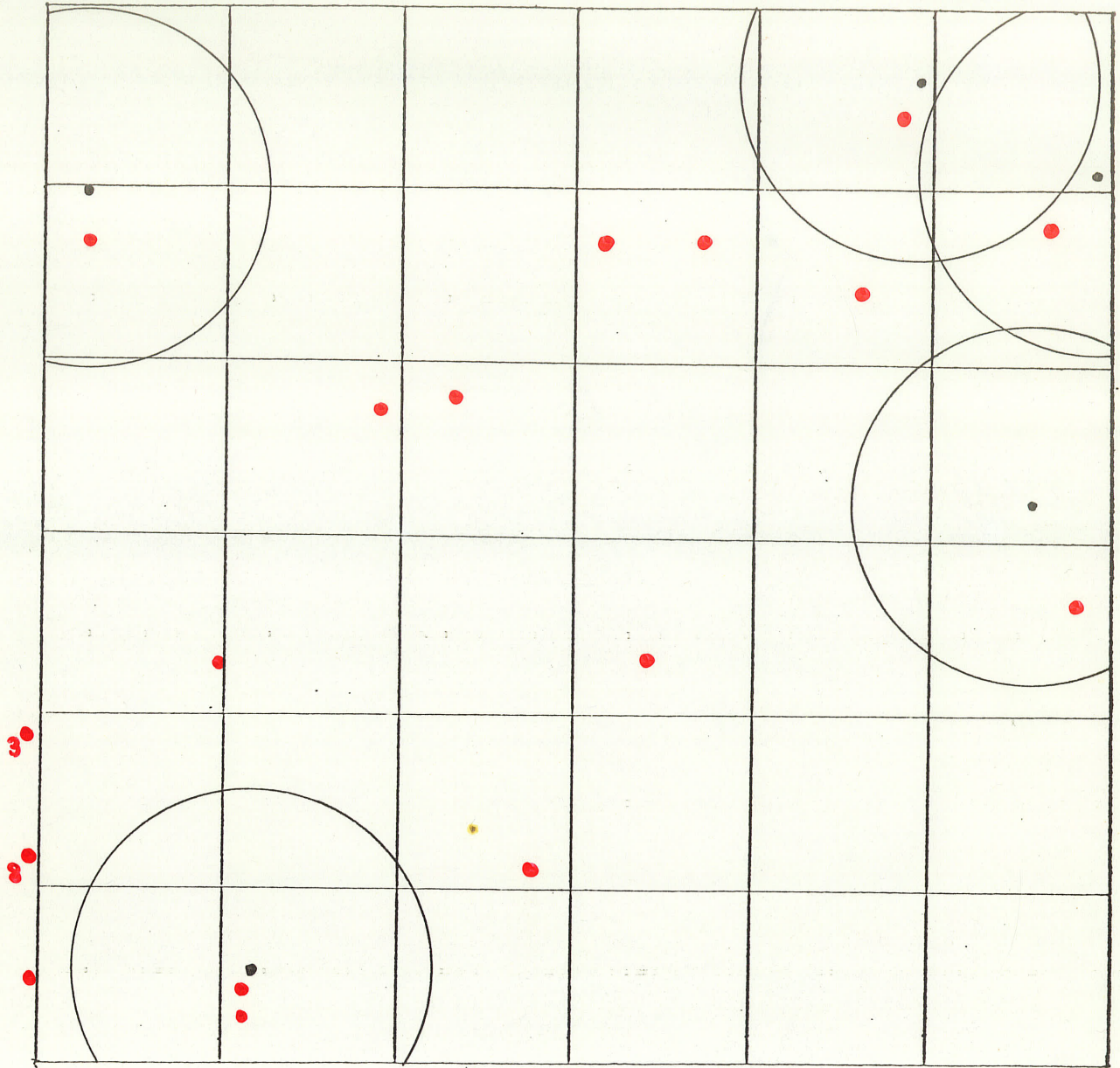


Figure 29 Comparison of den locations: interview response vs. aerial surveys.

Numerals represent the number of respondents reporting the location.



Scale 0 1 2 kilometers

correspondence). Eight of these positive identifications were associated with a conspicuous den site located just outside the township boundary. If this site, and two others (probably alternate den sites of the one mentioned) which are located outside the township boundary are omitted from this analysis, then a total of 13 sites were recorded in the township. Five of the responses correspond with sites located by the aerial survey technique and one new site (i.e. not located during the aerial surveys) was located ("*" indicates the location of this site in Figure 29). Six of the 13 sites located (46 percent) fall within the hypothetical home range boundaries of the dens located by the aerial survey technique. The overlay (Figure 29) indicates the location of den sites recorded by landowners and can be compared with the underlying locations and home range boundaries identified in the aerial surveys.

Correlation of interview data with data acquired by the aerial survey technique was significantly better. Consequently, more reliable information regarding population levels (in comparison with the questionnaire results) can be achieved with this technique. Estimates of predator-inflicted loss were smaller in the interview data with only one landowner reporting a loss. The extent of the loss was estimated at less than 100 dollars but, when questioned further regarding the loss, the landowner could not substantiate his claim. Five landowners reported losses in the 2 township questionnaire study area. Estimates of predator-inflicted loss averaged less than 300 dollars per township. Predator-inflicted loss estimates may

have been overestimated in the questionnaire response and possible this tendency was stifled by the presence of an interviewer. Although the interview response appears more reliable than the questionnaire response, this result can only be quantified by correlation with known fox densities. The reliability of the other data could only be established with further research.

The costs incurred in conducting personal interviews of landowners is given in Table XX.

Table XX Costs: Interview sampling of landowners

Description	Cost
Mileage (625 miles @ 19.5¢/mi.)	\$ 121.88
Wage (0.25 months @ \$400/mo.)	<u>100.00</u>
Total	\$ 221.88

A cost of 221.88 dollars or, 6.53 dollars per interview, was incurred. Costs would vary according to the interviewer's wage and the mileage involved in sampling different townships. This estimate does not include question preparation because these costs have been accounted for in the questionnaire development costs. As in all cost estimates included in this section, no time allowances were made for the evaluation of the results.

4.4.5 Summary

The aerial survey technique provides reliable data but costs are high. The infrared imagery results may provide

reliable data if analysed by a competent technician, however the questionable reliability and high costs may be prohibitive. Both questionnaire and interview data can be questioned in terms of reliability. The actual cost of administering questionnaires is less than the associated cost of conducting interviews but the reliability of questionnaire data is not as good. Either of these techniques, however, can be used to increase the reliability of an aerial survey monitoring system (by locating missed den sites) in addition to generating other pertinent data.

Two additional den sites were located through questionnaire and interview sampling of landowners in 3 townships. The corresponding distribution of den sites and adjusted population estimates are given in Table XXI.

Table XXI Fox population density based on the results of a combination of monitoring techniques

Township	# Active Den Sites	Total # Fox	Density/ km ²
1	2	14	0.15
2	6	42	0.45
3	6	42	0.45
4	4	28	0.30
5	4	28	0.30
6	<u>3</u>	<u>21</u>	<u>0.23</u>
Total	25	175	0.31

An average of 4.17 dens per township were located by a combination of monitoring techniques. This represents a more accurate population estimate (based on an average of 5 pups

per den, i.e. 7 foxes per den) of 0.31 fox per square kilometer. Therefore, at the time of the survey, the estimated fox population inhabiting the cropland region of Manitoba (approximately 20,200 km²) is 6,300 animals. Natural and anthropogenic mortality rates are not known, consequently no "harvestable" estimates can be determined. If we assume that all foxes surviving the winter mate (i.e. the number of foxes inhabiting the study region prior to parturition is based on 2 foxes per den site) then approximately 50 foxes mated in the study area. This represents a 1975-76 winter survival population density of 0.09 fox per square kilometer.

Use of questionnaire of interview-generated data in conjunction with an aerial survey monitoring system will yield the most reliable population estimates and the interview method will yield the best estimates at minimum cost. The reliability of the interview method will vary between townships depending on individual knowledge of den locations. One respondent, of those interviewed, accounted for 4 of the 5 known den sites in the township. If this landowner had not been contacted, the reliability of the interview sampling would have been reduced. The aerial survey technique (as a sole monitoring technique) would provide the best estimates at moderate cost. Therefore the reliability of population monitoring will vary with the "willingness to pay." Table XXII illustrates the relationship between reliability and cost experienced in this study.

Table XXII Reliability vs. costs

Reliability	Monitoring System	Cost
Low ↓ High	Questionnaire Sampling Interview Sampling Aerial Surveys Combination of Systems	Low ↓ High

4.5 Predator Inflicted Loss vs. Economic Value

Estimated predator-inflicted loss in the three township sample area was 700 dollars, or 2.50 dollars per square kilometer. Estimated landowner income derived from the harvest of fox populations was 2,475 dollars, or 8.85 dollars per square kilometer. The net economic benefit derived from the harvest of fox populations in the sample area was 1,775 dollars, or 6.35 dollars per square kilometer. Since the economic benefits outweigh the economic losses incurred, fox populations in the area should not be harvested as predators.

The predation losses probably result from a few problem animals and not from the entire fox population. If these animals could be located and removed, then the level of predation would decline significantly. Because of the anonymity of the questionnaire response it was impossible to contact landowners experiencing predator-inflicted losses. The one landowner interviewed (recording a loss) could not substantiate his claim or positively identify foxes as the actual cause of the loss. Consequently, it is questionable whether the losses inflicted by foxes as predators can even be quantified as

reported losses may have been caused by stray dogs or other nuisance animals.

Landowners experiencing losses are in the best position to locate and remove problem animals under Section 42(1) of The Wildlife Act. Problem animals could be adequately controlled under this provision and landowners could alleviate predator losses and derive an income from the harvest and marketing of furs. However, none of the landowners experiencing a predator-inflicted loss in the sample area either trap or hunt fox.

Lower predation costs (as compared to fur value) from an economic efficiency perspective, suggests that foxes should not be harvested as predators. Landowner response (or lack of response) to predator-inflicted loss further suggests that actual predation losses attributable to fox populations are not significant. Trapping, in response to high market prices, and the removal of problem animals by landowners (under Section 42(1) of The Wildlife Act) should be sufficient to significantly lower predation problems. Predation losses recorded in this study (especially in conjunction with current high fur prices), are not sufficient to warrant control of fox populations pursuant to The Predator Control Act.

V. CONCLUSIONS

All techniques evaluated in this study demonstrated some potential for further development as predator population monitoring systems. Considerable variation in reliability of the methods for estimating population levels was evident but difficult to quantify in a short term study.

It became apparent early in the study that any treatment of fox populations solely as predators was unwarranted. The value of foxes as fur bearers has steadily increased and has probably stimulated more hunting and trapping pressure on the species than was previously witnessed under various predator control programs. Questionnaire and interview sampling of landowners generated data regarding predator-inflicted loss, also hunting and trapping pressure on fox populations.

The following conclusions can be made on the basis of information gathered in this study:

1. The estimated red fox population density of the "cropland" region of Manitoba, during the spring of 1976, was 0.31 fox per square kilometer. This estimate is based on a total of 25 active den sites and an average litter size of 5 pups per den in the study area.
2. The most reliable population estimates are derived from a combination of monitoring techniques. When considering a single fox population monitoring method, the aerial survey

technique provides the most reliable estimates.

3. Neither questionnaire sampling nor landowner interviews are considered reliable enough to provide accurate fox population estimates in themselves. They can, however, provide valuable information not attainable by the other techniques. Landowner interviews appear more reliable than questionnaire sampling for locating active fox dens and estimating fox population trends, predator-inflicted loss, and incomes derived from fox harvest.

4. The harvest of fox populations in the sample area accounted for a net economic gain of 6.35 dollars per square kilometer. The potential value of foxes in the study area exceeds the estimated economic loss that they inflict. Therefore, the rural fox population should not be harvested as predators. Landowner questionnaire and interview response indicate that fox populations should not be controlled unless populations increase to a level where the species poses an economic threat as a predator.

5. An economic supply model based on historical data (where prices are adjusted according to the wholesale price index) could be used as a valuable management tool for estimating market impact on fox harvest.

VI. RECOMMENDATIONS

The effect of fox predation on livestock has decreased significantly with the advent of better animal husbandry techniques. Foxes no longer pose a substantial economic threat as predators. Current high fur prices have increased the fox harvest value to such an extent that the fox now represents one of Manitoba's most valuable fur bearing species. Existing government policy does not reflect the changing values and attitudes governing fox harvest and management. The following recommendations are proposed:

1. A red fox population monitoring system should be implemented on an annual basis to provide accurate population estimates and to monitor trapping and hunting pressure on the species. Research should include den excavation and pup tagging to obtain quantifiable mortality and dispersion data.
2. The economic supply model should be developed further, refined and tested for reliability in predicting market impact on fox harvest. If applicable, similar models should be developed for other fur bearing species.
3. A red fox information pamphlet should be developed and distributed to the public. The pamphlet should stress the important role of the red fox as a predator species in natural systems and the impact of high trapping and hunting pressure upon populations. The fox should be portrayed as an integral

link in natural food chains and not as a major predator on domestic livestock.

4. The predator classification, presently including foxes, should be seriously reconsidered. Foxes should either be removed from this classification or a predator season should be implemented (coinciding with the trapping season in unorganized territory) to prevent the over harvest of foxes as predators during periods when furs are of little value.

5. A flexible predator or fur bearer management program should be instituted so that fox populations (and other fur bearer-predator species) can be better managed in response to fluctuating market conditions and population levels.

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APPENDIX I

Scientific and common names of plant and animal species mentioned in this report.

Mammals

Badger	<u>Taxidea taxus</u>
Beaver	<u>Castor canadensis</u>
Black Bear	<u>Ursus americanus</u>
Bobcat	<u>Lynx rufus</u>
Coyote	<u>Canis latrans</u>
Fisher	<u>Martes pennanti</u>
Fox (arctic)	<u>Alopex lagopus</u>
Fox (coloured)	<u>Vulpes fulva</u>
Ground Squirrel, thirteen-line	<u>Citellus tridecemlineatus</u>
Jackrabbit, whitetail	<u>Lepus townsendii</u>
Lynx	<u>Lynx canadensis</u>
Marten	<u>Martes americana</u>
Meadow Vole	<u>Microtus pennsylvanicus</u>
Mink	<u>Mustella vison</u>
Muskrat	<u>Ondatra zibethica</u>
Otter	<u>Lutra canadensis</u>
Red Squirrel	<u>Tamiasciurus hudsonicus</u>
Weasel	<u>Mustella spp.</u>
Wolf	<u>Canis lupus</u>
Wolverine	<u>Gulo luscus</u>

Shrubs and Sub-Shrubs

Alder	<u>Alnus spp.</u>
Dwarf Birch	<u>Betula glandulosa</u>
Buffaloberry	<u>Sherperdia argentea</u>
Choke Cherry	<u>Prunus virginiana</u>
Pin Cherry	<u>Prunus pensylvanica</u>
Cranberry	<u>Viburnum trilobum</u>
Red Osier Dogwood	<u>Cornus stolonifera</u>
Beaked Hazel	<u>Corylus cornuta</u>
Labrador Tea	<u>Ledum groenlandicum</u>
Prairie Rose	<u>Rosa acicularis</u>
Saskatoon	<u>Amelanchier Alnifolia</u>
Silverberry	<u>Elaeagnus commutata</u>
Snowberry	<u>Symphiocarpos occidentalis</u>
Willow	<u>Salix spp.</u>

Trees

Black Ash	<u>Fraxinus nigra</u>
Aspen	<u>Populus tremuloides</u>
Balsam Fir	<u>Abies balsamea</u>
Basswood	<u>Tillia americana</u>
White Birch	<u>Betula papyrifera</u>
Bur Oak	<u>Quercus macrucarpa</u>

Trees (Concluded)

White Cedar
Eastern Cottonwood
White Elm
Jack Pine
Manitoba Maple
Balsam Poplar
Black Spruce
White Spruce
Tamarack

Thuja occidentalis
Populus deltoides
Ulmus americana
Pinus banksiana
Acer negundo
Populus balsamifera
Picea mariana
Picea glanca
Larix laricina

APPENDIX II

KODAK EKTACHROME Infrared AERO Film, Type 8443

This is a false-color reversal film originally designed for camouflage detection by aerial photography. It must be exposed by illumination having daylight quality. In 35mm form it is useful for many biological, medical, and pictorial purposes. Unlike the usual color film, its three image layers are sensitized to green, red, and infrared instead of to blue, green, and red. A yellow filter is used on the camera to withhold blue light, to which these layers are also sensitive. Table V, page 33, lists subject renditions. The infrared-sensitivity limit is about 900 m μ ; the material cannot be used in thermography. Since the image on the film is made up from both visible-light and infrared records, and since a small lens opening is usually required for depth of field, there is seldom any need to make a lens adjustment for infrared focus.

Filters and Illumination: A yellow filter must always be placed over the camera lens. For outdoor use, a KODAK WRATTEN Filter No. 8, 12, or 15 can be utilized. However, for scientific photography, where a "biological" color balance is necessary for consistent results, the No. 12 filter must be used. The No. 12 filter must also be adopted for indoor biological work and medical photography. Here, every effort should be made to employ electronic flash lighting. Flashbulbs are not suitable. When illumination of photoflood (3400 K) quality has to be used, a KODAK Color Compensating Filter CC20C and a Corning Glass Filter C.S. No. 1-59 (3966) (specify diameter) provide an excellent balance; in some applications a CC50C-2 filter instead may suffice.

Slight color variations due to individual emulsion, aging, lighting, and processing are unavoidable. For exacting work, Table IV, page 29, shows how to use filters for trimming the color balance. Use a minimum number of filters in order to avoid degrading the image.

Lighting: Lamps must be arranged for flat, even illumination. "Tent" lighting is often best for patients, plants, and other indoor subjects.

EXPOSURE

It is not possible to apply an ordinary speed rating to this film because of its infrared sensitivity. Also, varying amounts of infrared reflection will not be read appropriately by an exposure meter. A meter setting of ASA 100 is suggested for trial (see "Latitude"), or a sunlight exposure of 1/125 second at $f/16$. This takes into account the No. 12 filter. Exposure tests can be made to determine the effects of other yellow or color-trimming filters. Further data are given on page 42.

Exposure Data:

Illumination	Filter	Meter Setting
Daylight	KODAK WRATTEN No. 12	ASA 100
Photoflood (3400 K) Quartz-halogen	KODAK CC20C plus Corning C.S. 1-59 and KODAK WRATTEN No. 12	ASA 50

Electronic Flash Guide Numbers, with KODAK WRATTEN Filter No. 12:

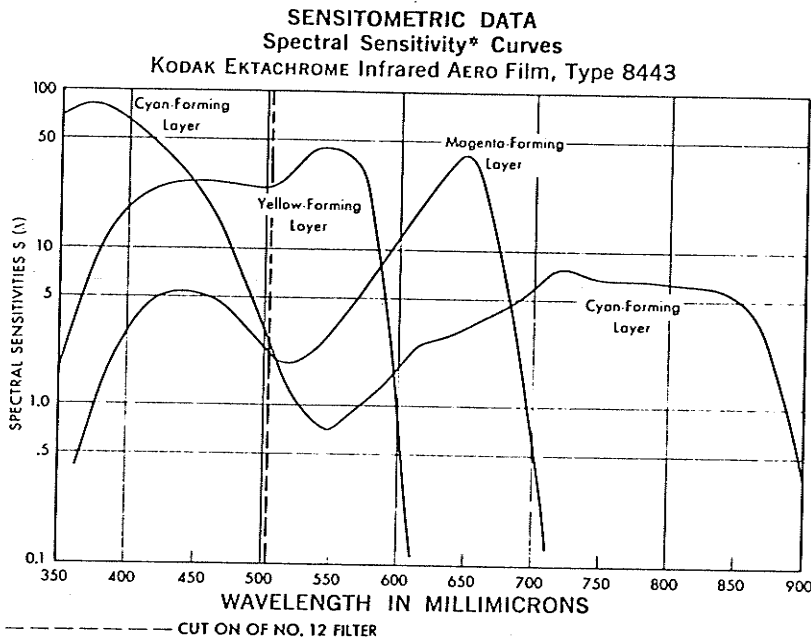
Output of Unit (BCPS or ECPS)	350	1000	2000	4000	8000
Guide Number for Trial	45	80	110	160	220

(Kodak, 1968)

Reciprocity Data (filter factor is included):

Exposure Time (seconds)	1/1000	1/100	1/10	1
Exposure Increase (stops)	none	none	1 stop	1½ stops
Additional Filter	none	none	CC30B	CC60B

Latitude: Due to its primary use, this film is a contrasty material. This quality makes it valuable for biological applications. However, it has only about $\pm 1/2$ -stop latitude; exposure for best results is critical. Tests, ranging from 3 stops less to 2 stops more than the calculated exposure will usually serve to calibrate a given setup. After making the first tests, you can adopt $1/2$ -stop adjustments, or bracketing, for the actual project.



*Spectral Sensitivity, $S(\lambda)$, = $1/E(\lambda)$, where $E(\lambda)$ is the energy in ergs/cm², of monochromatic radiation at wavelength λ required to reduce the dye image density in the individual layer to an equivalent neutral density of 1.0 above minimum density. Data are adjusted to correspond to an effective exposure time of 1/100 second.

PROCESSING

Process in the KODAK EKTACHROME Film Processing Chemicals, process E-3. This provides optimum infrared differentiation in medical and other biological applications. Process E-4 may be adopted if the photographer is not particular about obtaining specific false-color renditions.

No safelighting or infrared-inspection equipment is tolerable in the darkroom during processing. The photographer will usually have to do the work himself. Any custom-processing laboratory accepting rolls must be advised of the above. Forms Available: Standard aerial film sizes—70mm x 100 foot rolls—sheet films (for information on minimum order quantities write: Aerial and BIMAT Films, Dept. 917, Eastman Kodak Company, Rochester, N. Y. 14650)—35mm, 20-exposure rolls.

(Kodak, 1968)

APPENDIX III

QUESTIONNAIRE AND COVER LETTERS
USED FOR LANDOWNER SAMPLING IN
TOWNSHIPS 4 and 5.



THE UNIVERSITY OF MANITOBA

NATURAL RESOURCE INSTITUTE

WINNIPEG, MANITOBA R3T 2N2

June 24, 1976

Dear Landowner:

Your township has been selected as one of the study regions for the development and evaluation of several different animal population monitoring techniques. Recent fur prices, predation problems and concern regarding our wildlife resources has prompted this study into the development of a reliable and economical method of estimating predator population levels.

Earlier this spring, an aerial survey was flown over your township to locate red fox den sites. Attempts at remote sensing using infrared photography was also conducted. The enclosed questionnaire represents a third method to be evaluated. The information which you can provide will be used both as a check on work previously completed and evaluated as an independent monitoring system.

Funding for this study has been supplied by the Natural Resource Institute of the University of Manitoba, the Department of Agriculture; Animal Industry Branch and the Wildlife Research Branch of the Department of Renewable Resources and Transportation Services. Your co-operation is essential for the evaluation of the questionnaire method as a viable monitoring system.

The questionnaire has been designed to require a minimum of your time to complete. In most cases you can answer by checking the appropriate response. Results of this study can be made available to you upon completion.

Thank you for your assistance.

Yours, truly. A

Graham P. Latonas



THE UNIVERSITY OF MANITOBA

NATURAL RESOURCE INSTITUTE

WINNIPEG, MANITOBA R3T 2N2

August 10, 1976

Dear Landowner:

As of yet, we have not received your reply to the "1976 Fox Population Survey" which was sent to you several weeks ago. I realize that this is probably a busy time of year for you and the matter may have slipped your attention.

All landowners within your township have been contacted. We require your knowledge of red fox populations within your area. Many completed questionnaires have been received, but unfortunately, returns to date have not been sufficient to permit full evaluation of the results.

This questionnaire represents one portion of a fox population monitoring system currently being evaluated for agricultural areas of Manitoba. It is anticipated that this survey will yield valuable information regarding red fox numbers and possible predation problems.

We have enclosed another copy of the questionnaire. Any information which you can supply will be gratefully received.

Yours truly

Graham P. Latonas

P.S. If your reply to the first questionnaire is in the mail, **you need not** reply again. Thank you for your co-operation.

1976 FOX POPULATION SURVEY

Please check the appropriate answer.

1. In relation to last year would you consider fox population levels to be lower, higher or about the same?
 LOWER ___ SAME ___ HIGHER ___
2. Do you at present have an active fox den on your property?
 YES ___ NO ___ DON'T KNOW ___
3. Do you know of any other presently active fox dens within your township?
 YES ___ NO ___ DON'T KNOW ___

If you answered YES to either question 2 or 3, would you please mark the location of the den site(s) on the township map on the reverse of this questionnaire.

4. What crops or livestock do you raise?
- | | |
|---------------------------|---------------------------|
| ___ cereal grains | ___ poultry |
| ___ root crops | ___ cattle |
| ___ oil seeds | ___ sheep |
| ___ other(please specify) | ___ hogs |
| _____ | ___ dairy |
| | ___ other(please specify) |
| | _____ |

5. Do you attribute any damage of property, crops or livestock to fox predation?
 YES ___ NO ___

6. If yes, then in your estimation, what is the approximate yearly extent of the damage?
- | | |
|---------------------|------------------------|
| ___ less than \$100 | ___ \$400 |
| ___ \$100 | ___ \$500 |
| ___ \$200 | ___ greater than \$500 |
| ___ \$300 | |

6. Do you or members of your household actively hunt or trap fox?
 HUNT ___ TRAP ___ NEITHER ___

7. If you hunted or trapped fox last year please specify the number taken by each method?
 NUMBER TRAPPED ___ NUMBER SHOT ___

8. Please indicate how these animals were disposed of; indicate the number of animals disposed of by each method and the total value received as a result of their sale.

Method	Number of Animals	Total Value \$
1. fur buyer		
2. auction		
3. private sale		
4. own use		
5. none		

9. Do you feel that fox populations should be controlled?
 YES ___ NO ___ DON'T KNOW ___

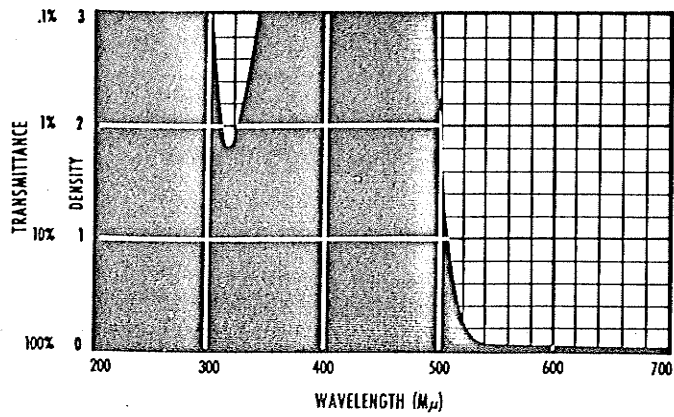
10. Additional comments:

If you would like to be sent a summary of the results of this study please print your name and address below. Thank you for your co-operation.

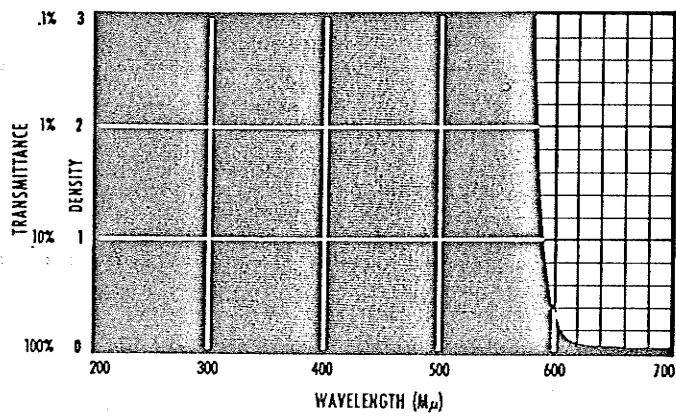
APPENDIX IV

Transmittance characteristics of the filters used in this study

KODAK WRATTEN Filter No. 12



KODAK WRATTEN Filter No. 25(A)



(Kodak, 1968)

APPENDIX V

APPENDIX V

APPENDIX V

Infrared imagery date collection

	Altitude 450 m										Altitude 900 m									
Site #1	Yellow Filter (Y2)					Red Filter (R2)					Yellow Filter (Y2)					Red Filter (R2)				
	1/500 sec.					1/500 sec.					1/500 sec.					1/500 sec.				
Exposure	f4	+ $\frac{1}{2}$	5.6	+ $\frac{1}{2}$	8	f4	+ $\frac{1}{2}$	5.6	+ $\frac{1}{2}$	8	f4	+ $\frac{1}{2}$	5.6	+ $\frac{1}{2}$	8	f4	+ $\frac{1}{2}$	5.6	+ $\frac{1}{2}$	8
Film #	2	2	2	2	2	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1
Frame #	1, 2	3	4	5	6	1, 2	3	4	5	6	7	8	9	10	11	7, 8	9	10	11	
<u>Site #2</u>																				
Film #	2	2	2	2	2	1	1	1	1	1	2	2	2	2	4	1	1	1	1	3
Frame #	12	13	14	15	16	12	13	14	15	16	17	18	19	20	1, 2	17	18	19	20	1, 2
<u>Site #3</u>																				
Film #	4	4	4	4	4	3	3	3	3	3	4	4	4	4	4	3	3	3	3	3
Frame #	3	4	5	6	7	3	4	5	6	7	8	9	10	11	12	8	9	10	11	12
<u>Site #3</u>																				
Altitude 1500 m																				
Exposure @ 1/500	Yellow Filter (Y2)						Red Filter (R2)													
	f4	+ $\frac{1}{2}$	5.6	+ $\frac{1}{2}$	8	+ $\frac{1}{2}$	f4	+ $\frac{1}{2}$	5.6	+ $\frac{1}{2}$	8	+ $\frac{1}{2}$								
Film #	4	4	4	4	4	4	3	3	3	3	3	3								
Frame #	13	14	15	16	17	18	13	14	15	16	17	18								