NUISANCE BEAVER BIOLOGY AND CONTROL IN NORTH-CENTRAL WISCONSIN

by

Ronald P. Peterson

A thesis
submitted in partial fulfillment
of the requirements for the degree
MASTER OF SCIENCE

College of Natural Resources

UNIVERSITY OF WISCONSIN
Stevens Point, Wisconsin

August 1979

APPROVED BY THE GRADUATE COMMITTEE OF:

Neil F. Payne

Neil F. Payne, Committee Chairman
Assistant Professor of Wildlife

R. K. Anderson

Raymond K. Anderson
Professor of Wildlife

Lyle E. Nauman

Lyle E. Nauman
Associate Professor of Wildlife

Phillip V. Vanderschaegen

Phillip V. Vanderschaegen
Game Manager
Wisconsin Department of Natural Resources

ABSTRACT

From 1 June 1976 to 2 September 1977, a study was conducted in Oneida and Forest counties, Wisconsin to determine; 1) trends in the number, types, and sources of beaver damage complaints, and 2) the size, age and sex structure, and productivity of nuisance beaver colonies. About 700 beaver complaints for 1965-1977 were obtained from the study area. Sixty-eight beaver colonies were trapped, involving 166 beaver trapped and 42 colonies trapped out.

A long-term increase in beaver complaints was related to increases in human and beaver populations. Road (41 percent), timber (32 percent), and lakeshore (11 percent) were the prevalent damage types. Road and railroad complaints were most recurrent; timber complaints were among the least recurrent. Private complainants were prevalent (46 percent) with government (35 percent) and commercial complainants (19 percent) comprising the remainder. Little change was noted in the relative percentages of either damage types or complaint sources.

Of 56 beaver colonies, 66.1 percent were families, 19.6 percent were pairs, and 14.3 percent were singles. Number of beaver per trapped-out colony averaged 3.60; the mean for family colonies was 5.67. Of 166 beaver trapped, 34.3 percent were kits. Kits comprised 45.3 percent of the beaver from trapped-out colonies, suggesting that kits were under-represented in the entire sample. Yearlings (< 1.5

years) also were under-represented. Annual mortality was 45.8 percent; kit and adult mortality was 73.1 percent and 23.2 percent, respectively. The sex ratio was about 1:1. Productivity increased and prenatal mortality decreased with age. Mean litter size was 3.41; prenatal mortality was 21.9 percent.

ACKNOWLEDGEMENTS

I thank the Wisconsin Department of Natural Resources, Bureau of Game Management for funding the trapping operation and providing access to beaver complaint files.

Special thanks go to my advisor, N. F. Payne, for his help in project development, data analysis, and manuscript preparation and to P. V. Vanderschaegen and F. L. Johnson of the Department of Natural Resources for their help during fieldwork.

Committee members R. K. Anderson and L. E. Nauman and graduate students M. Davis, T. Engel, B. Folley, and D. Sasse are acknowledged for their help and advice during all phases of this project.

Special thanks go to my wife, Leslie, whose encouragement and confidence were invaluable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

The beaver (Castor canadensis) is one of the most important furbearers in Wisconsin, being both an economic asset and a liability. Beaver pelts brought $235,304 to trappers in 1976 (Wisconsin Department of Natural Resources 1976), but the damming, burrowing, and cutting activities of beaver cost the State of Wisconsin more than $205,000 (estimate based on Wisconsin Department of Natural Resources (WDNR) files).

Wisconsin beaver are subject to control by three methods: 1) removal of animals and offending structures by game management personnel of the WDNR under State Statute 29.59, 2) removal of animals and offending structures by the complainant under permit from the WDNR, and 3) extension of the regular beaver season and removal of bag limits on waters with recurrent beaver problems. Control operations begin at the close of the regular beaver season (late March or early April) and end with freezeup in the fall.

Most control work is done by the WDNR. Few beaver are taken on permits because complainants rarely have the equipment or expertise. In addition, any beaver taken in this manner are confiscated by the State, further reducing the incentive for landowners to solve their own beaver problems. The number of beaver taken in the extended season is highly variable (due to weather, pelt prices, primeness of fur) and the effect on nuisance beaver problems appears to be negligible.

Money for beaver control could be better spent on other game management concerns, and costs for labor and equipment are rising. Beaver problems appear to be increasing but at an unknown rate. The effect of control on the biology of beaver is also unknown. To partially fill the need for this information, a study was conducted with the following objectives:

1) to determine trends in the number, types, and sources of beaver damage complaints.

2) to determine the size, age and sex structure, and productivity of nuisance beaver colonies.

STUDY AREA

The study area was Oneida and Forest counties, in north-central Wisconsin (Fig. 1). Land area totals 5501 km^2 of which about 85 percent is forested (Spencer and Thorne 1972). Lakes and streams total 372 km^2 and 2479 km, respectively (Andrews and Threinen 1966, Steuck and Andrews 1977). Oneida and Forest counties have human populations of 28,914 and 8,357, respectively, with concentrations at Rhinelander (8,643) and Crandon (1,779) (Wisconsin Legislative Reference Bureau 1977). Major industries are logging, paper manufacturing, and tourism.

The climate of the area has been described as

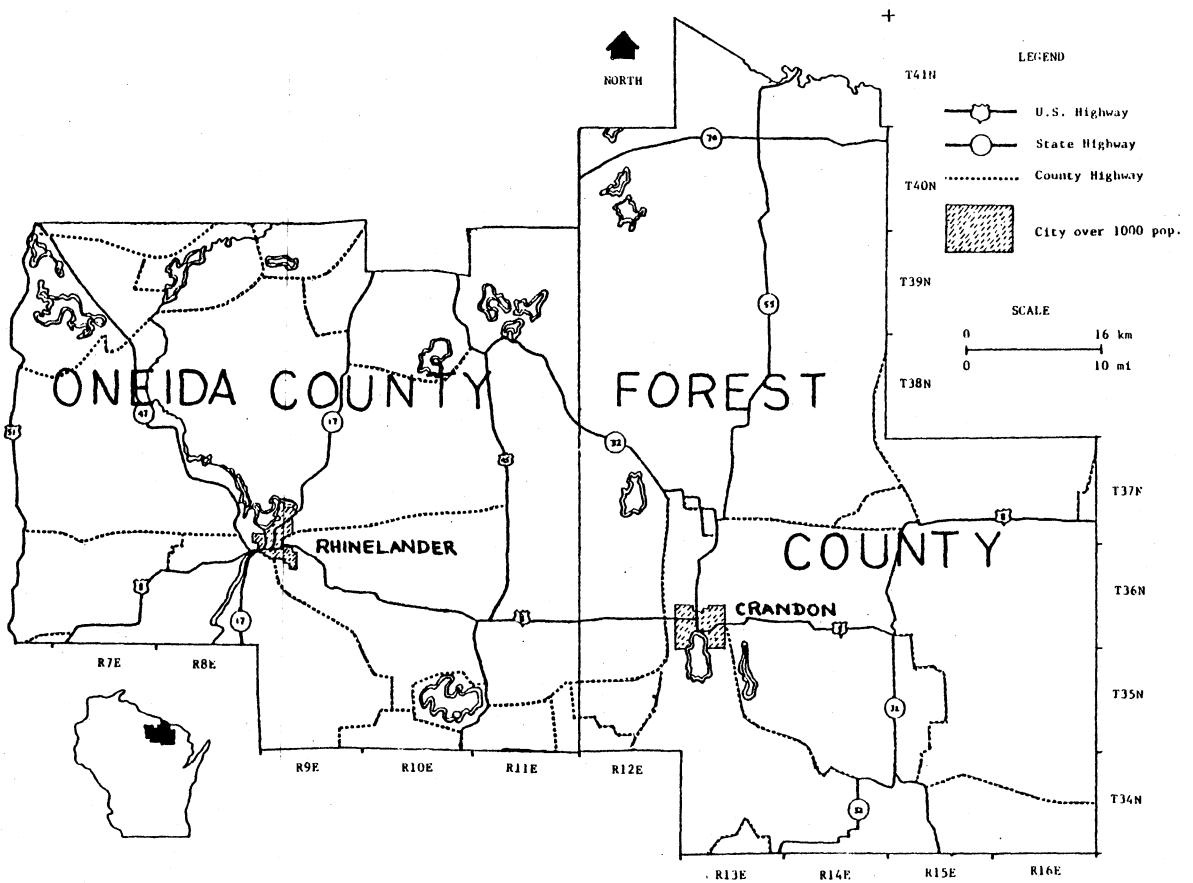


Figure 1. Location of the study area in north-central Wisconsin.

continental with long, cold winters and short, warm summers (Steuck and Andrews 1977). Mean annual temperature is 24°C with extremes of -41°C and 42°C. Mean annual precipitation is 79.8 cm with extremes of 45.7 cm and 107.5 cm. Snowfall averages 144 cm with extremes of 84 cm and 219 cm.

The region was glaciated, being classed primarily as pitted outwash with some areas of terminal and ground moraine. Soil types are primarily sands and stoney, sandy loams with silt loams, mineral soils and organic soils less common (U.S. Geological Survey 1976).

The major forest types (in decreasing order of prevalence) are aspen (Populus spp.), swamp conifers, and pine (Pinus spp.) in Oneida County, and northern hardwoods, swamp conifers, and aspen in Forest County (Spencer and Thorne 1972).

According to the habitat suitability classifications used by Rutherford (1964) in Colorado, the study area provides substantial "excellent" beaver habitat. Stream gradients are typically gentle, floodplains large, soil types suitable for burrowing, and food supplies abundant.

METHODS

Complaints

Complaint Trends

WDNR complaint records for the study area were reviewed for 1965-1977. To determine if complaints had increased

over the past 30 years, the mean annual complaint total for 1965-1977 was tested against that found by Knudsen (1952, 1954, 1956) for 1946-1954 with a two-sample t-test. Linear regression was used to determine if either human or beaver populations were related to complaint numbers. Human population data were taken from census records; beaver population data were taken from aerial survey results of 1972, and 1974-1976. Data for 1973 were unavailable.

Damage Types and Complaint Sources

Complaints were categorized by the following damage types: 1) roads, 2) timber, 3) lakeshore, 4) railroads, 5) fish habitat, 6) agriculture, and 7) miscellaneous (e.g. private dwellings, boathouses). A detailed description of this classification scheme was given by Knudsen (1952) (Appendix A). Two-sample t-tests were used to determine if any damage types averaged higher from 1965-1977 than from 1946-1954. Complaints also were categorized by the following sources: 1) private parties, 2) commercial interests, 3) towns, 4) counties, 5) state agencies, and 6) federal agencies. Complaint locations for each year since 1966 were compared to those of the previous year to determine which damage types and complaint sources were most recurrent and if sources and types for recurrent complaints were the same from year to year.

Nuisance Colonies

Trapping

Bailey live-traps were the main traps used for nuisance beaver. Leg-hold (sizes 4 and 14) and Conibear (size 330) traps were used in remote areas and where live-traps could not be set. Castoreum, placed on existing or simulated scent mounds, was the main lure used. Auditory lure (i.e. the sound of water rushing through a small hole in the dam) was used sparingly, as were "blind" sets with no lure. Set locations for Bailey and Conibear traps were mostly channels between activity centers (e.g. lodge, dam(s), feeding areas, scent mounds). Conibears also were set in culverts being blocked by beaver. Leg-hold traps were set on lodges, dams, and where beaver were entering and leaving the water.

Trapping was continued until all beaver activity (e.g. repair of broken dams, fresh cutting) had ceased for 1 week. Trapped-out locations were checked periodically throughout the collection period. Renewed activity, 2 or more weeks after cessation, was considered evidence of ingress.

Colony Size

Colonies were categorized as single, pair, and family colonies (Gunson 1970, Payne 1975). Mean number of occupants per colony was determined from trapped-out colonies. Colonies were considered trapped-out if all beaver 1 year or older were caught. The numbers of kits in such colonies

were estimated from placental scars or fetuses in adult females. Newborn kits would be under-represented in a trapped sample because signs of their presence are inconspicous or absent. Also, trap susceptability of kits may be low if trapping is not concentrated near the lodge.

Locations trapped both in 1976 and 1977 were considered separate colonies for each year.

Age and Sex Structure

Among live-trapped animals, kits were separated from older beaver by the presence of temporary premolars (van Nostrand and Stephenson 1964) and by their conspicuously small size in the early summer months. They were sexed by palpation, eartagged (in 1977), and released into non-problem areas.

Yearlings and adults were killed for removal of jawbones and female reproductive tracts. Ages were determined by basal opening and cementum annuli of the cheek teeth (van Nostrand and Stephenson 1964, Klevezal' and Kleinenberg 1967, Larson and van Nostrand 1968).

Chi-square tests for goodness of fit were used to determine if sex ratios were significantly different from equality. Age-specific and overall mortality rates were determined with a composite time-specific life table (Deevey 1947, Hickey 1952, Caughley 1966). When samples from a given age class had more members than the preceding age class, the counts were averaged (Payne 1975).

Productivity

Ovarian and uterine analysis (Hodgdon 1949, Provost 1962, Brenner 1964) was used to determine productivity. Ten percent formalin and Mossman's AFA (Provost 1962) were used to fix and store reproductive tracts in 1976 and 1977, respectively.

Prenatal mortality (i.e. percent of ova that were unfertilized, unimplanted, or resorbed) was determined by subtracting the number of placental scars from the number of corpora lutea or fresh corpora albicantia.

RESULTS

Complaints

Complaint Trends

The mean numbers of annual complaints for 1946-1954 and 1965-1977 (Fig.2) were 25.2 and 61.0, respectively, which were significantly different ($t=6.5$; 20 df; $P<0.01$). A significant relationship ($P<0.01$) was found between human population and beaver complaints in Oneida County (Fig. 3) ($r=0.82$; 20 df). The human population of Forest County was not significantly related ($P>0.10$) to complaints.

Fall beaver population were significantly related ($r=0.92$; 3 df; $P<0.05$) to complaints registered the following year for 4 years between 1972 and 1976 (data from 1973 were missing) (Fig. 4 and Appendix B).

Figure 2. Beaver damage complaints registered in Oneida and Forest counties, Wisconsin, 1946-1954 and 1965-1977.

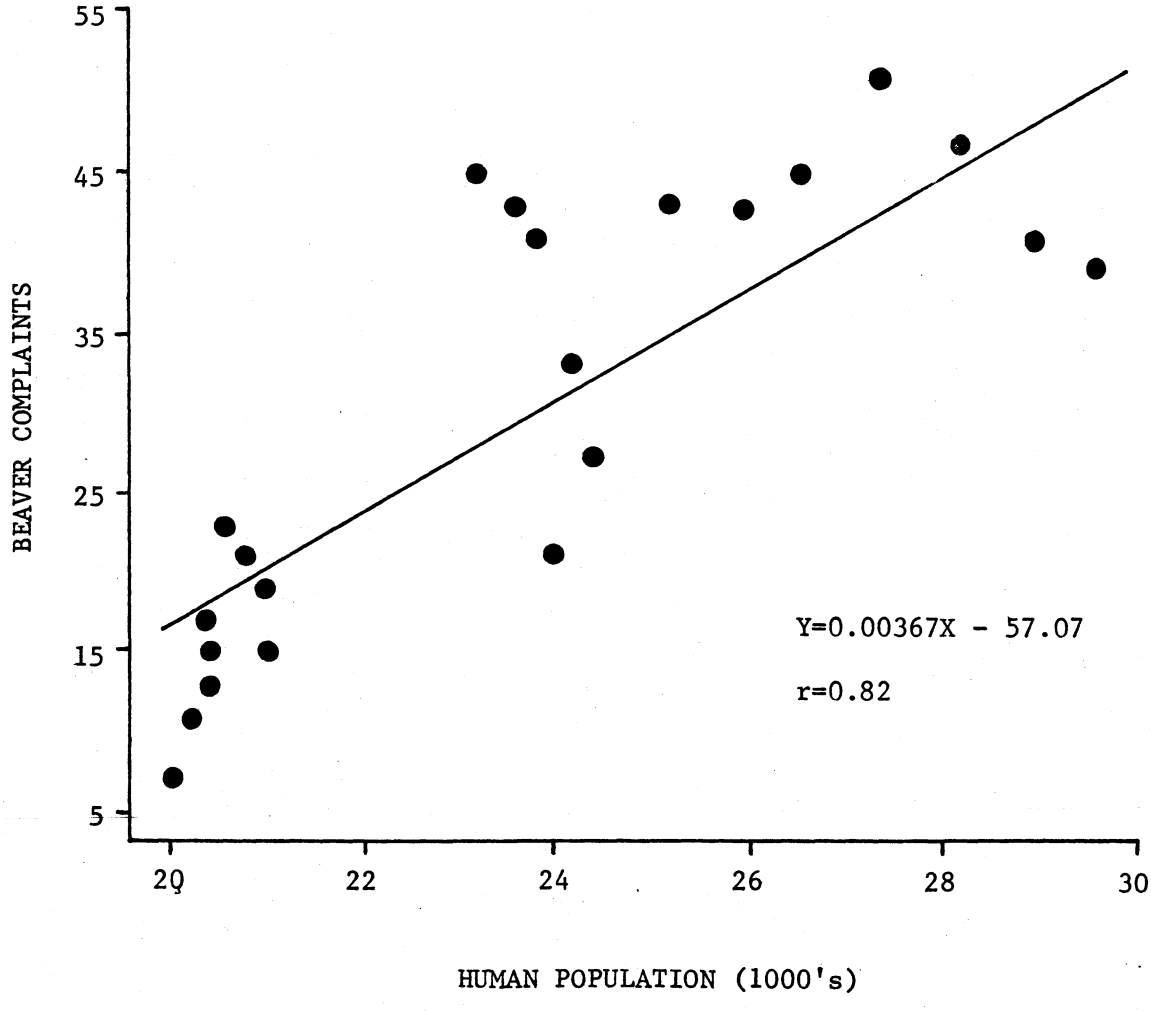


Figure 3. Relationship between human population and beaver damage complaints in Oneida County, Wisconsin, 1946-1954 and 1965-1977.

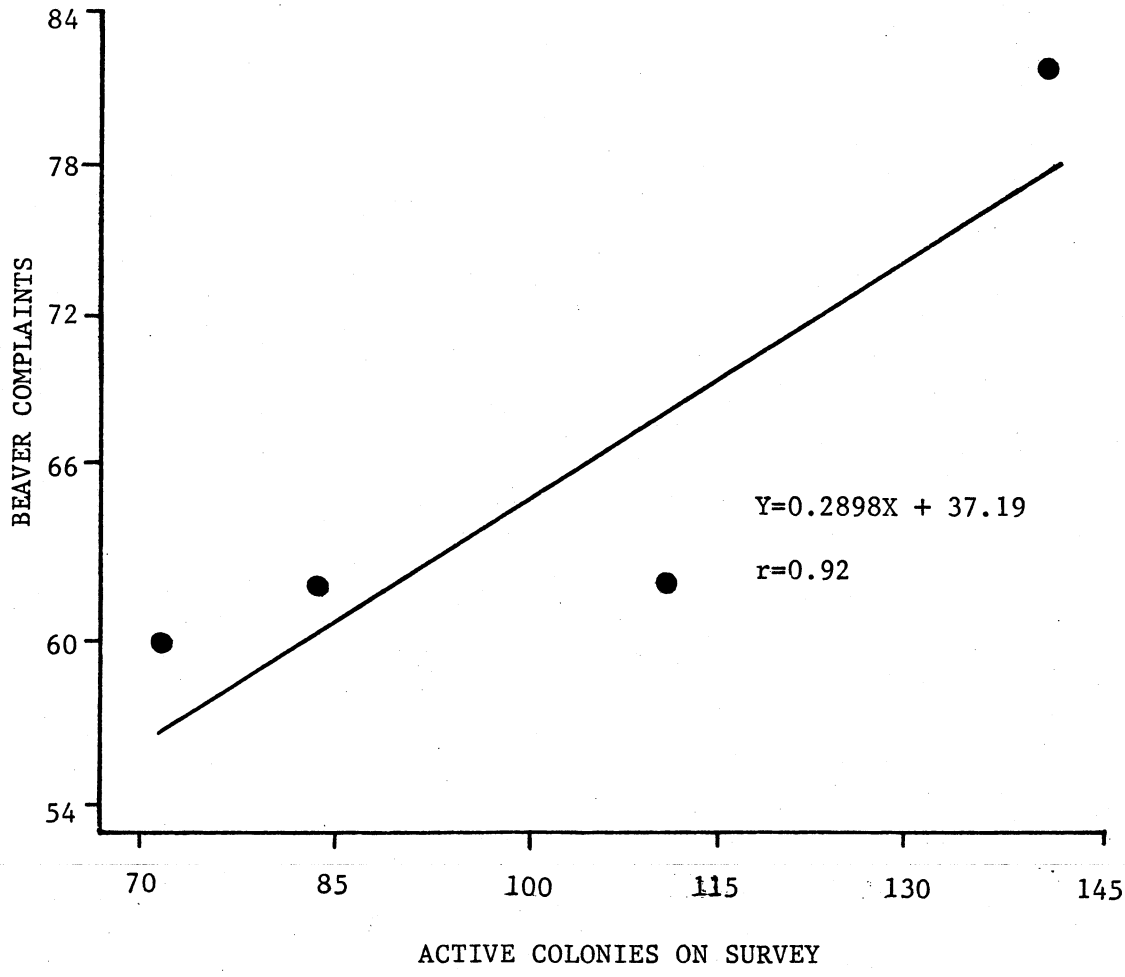


Figure 4. Relationship between fall aerial beaver surveys and complaints registered the following year, 1972 and 1974-1976.

Damage Types and Complaint Sources

Data on damage types and complaint sources were incomplete for the portion of Oneida County west of U.S. Highway 51. Prevalence of damage types in the remainder of the study area from 1965-1977 (Table 1) was as follows: 1) roads (41 percent), 2) timber (32 percent), 3) lakeshore (11 percent), 4) railroads (7 percent), 5) fish habitat (5 percent), 6) miscellaneous (3 percent), and 7) agriculture (1 percent). Mean numbers of annual occurrences for all damage types except agricultural were significantly higher ($P<0.05$) from 1965-1977 than 1946-1954 (Table 2), though the 1965-1977 values represented a 17.5 percent smaller land area than those for 1946-1954. As a percentage of total complaints, only agricultural complaints changed significantly ($t=2.85$; 8 df; $P<0.05$) from 1946-1954 to 1965-1977, showing a decrease.

Of 61 study area locations involved in complaints during 1976 and 1977, 27 (44.3 percent) involved plugged road culverts; of 31 road complaints, 23 (74.2 percent) involved plugged culverts.

Prevalence of complaint sources on the study area east of U.S. Highway 51 from 1965-1977 (Table 3) was as follows: 1) private parties (46 percent), 2) commercial interests (19 percent), 3) towns (16 percent), 4) counties (10 percent), 5) federal agencies (6 percent), and 6) state agencies (3 percent).

The most common combinations of damage types and

Table 1. Types and numbers of annual beaver complaints in Oneida and Forest counties east of U.S. Highway 51, 1965-1977.

Year	Damage Type							Total
	Road	Timber	Lake	Rail-road	Fish	Agri-culture	Misc.	
1965	14	20	4	6	4	1	0	49
1966	19	21	6	5	2	0	0	53
1967	21	9	9	5	3	0	1	48
1968	5	5	2	1	0	0	0	13
1969	12	17	5	0	2	0	2	38
1970	19	7	6	1	3	1	1	38
1971	22	20	4	5	2	1	2	56
1972	26	17	9	5	2	1	1	61
1973	27	17	5	1	0	1	1	52
1974	21	30	10	5	3	0	3	72
1975	24	30	4	5	3	0	6	72
1976	22	15	6	7	4	1	3	58
1977	36	8	4	2	2	1	2	55
Total	268	216	74	48	30	7	22	665
Percent	40.3	32.5	11.1	7.2	4.5	1.1	3.3	

Table 2. Types and numbers of annual beaver complaints in Oneida and Forest counties, Wisconsin, 1946-1954 (from Knudsen 1952, 1954, 1956).

Year	Damage Type							Total
	Road	Timber	Lake	Rail-road	Fish	Agri-culture	Misc.	
1946	4	1	2	0	0	1	0	8
1947	4	7	4	1	0	1	1	18
1948	8	10	2	2	1	1	3	27
1949	12	20	2	5	0	2	1	42
1950	14	15	1	4	3	1	1	39
1951	13	6	2	3	2	0	0	26
1952	11	10	1	1	1	1	1	26
1953	3	6	3	1	1	2	1	17
1954	7	4	3	1	1	6	0	22
Total	76	79	20	18	9	15	8	225
Percent	33.8	35.1	8.9	8.0	4.0	6.7	3.6	

Table 3. Sources and numbers of annual beaver complaints in Oneida and Forest counties east of U.S. Highway 51, 1965-1977.

Year	Complaint Sources						
	Private	Commercial	Federal	State	County	Town	Total
1965	24	11	3	3	1	7	49
1966	26	7	4	0	8	8	53
1967	17	6	8	2	7	8	48
1968	7	2	0	0	1	3	13
1969	22	4	3	1	3	5	38
1970	16	4	1	2	4	11	38
1971	23	12	4	1	5	11	56
1972[a]	14	10	0	0	4	4	32
1973	24	9	2	1	3	13	52
1974	40	11	5	3	5	8	72
1975	39	13	3	3	5	9	72
1976	28	9	5	0	7	9	58
1977	17	8	1	1	9	19	55
Total	297	106	39	17	62	115	636
Percent	46.7	16.7	6.1	2.7	9.8	18.1	

[a]Oneida County complaints only.

complaint sources (Table 4) were: 1) private/timber (26 percent, 2) town/road (18 percent), 3) private/lake (11 percent), 4) county/road (9 percent), 5) commercial/railroad (7 percent), and 6) commercial/road (6 percent).

Recurrence of Complaints

Locations of Forest County complaints in 1972 were unknown; thus determining complaint recurrence was impossible Mean number of recurrences per new complaint (i.e. number of recurrent complaints/number of new complaints) for Oneida County from 1965-1977 was 0.94 (Table 5). Mean number of recurrences per new complaint by damage type was as follows: 1) roads (1.41), 2) railroads (1.38), 3) agriculture (1.00), 4) lakeshore (0.95), 5) timber (0.50), 6) miscellaneous (0.40), and 7) fish habitat (0.00). Mean number of recurrences per new complaint by complaint source was as follows: 1) town (1.62), 2) county (1.18), 3) commercial (1.00), 4) state (0.75), 5) private (0.70), and 6) federal (0.00). Only 3 federal complaints occurred in Oneida County during this period.

The most recurrent combinations of damage types and complaint sources were town/road with a mean of 1.74, private/road with 1.50, commercial/railroad with 1.38, and county/road with 1.18. Private/lakeshore, state/lakeshore, commercial/agriculture, and state/ miscellaneous complaints all averaged 1.00 recurrence per new complaint but for the

Table 4. Types, sources, and numbers of beaver complaints in Oneida and Forest counties east of U.S. Highway 51, 1965-1977[a].

Source	Damage Type							
	Road	Timber	Lake	Rail-road	Fish	Agri-culture	Misc.	Total
Private	25	167	69	0	21	3	13	298
Commerc.	39	15	0	45	0	4	1	104
Town	111	2	1	0	0	0	0	114
County	60	3	0	0	0	0	0	63
State	3	2	1	0	7	0	4	17
Federal	16	20	0	0	0	0	3	39
Total	254	209	71	45	28	7	21	635

[a]Forest County data on complaint sources for 1972 was missing.

Table 5. Mean number of recurrences per new complaint[a] in Oneida County, Wisconsin, 1965-1977. Complaints were classified by their original damage types and complaint sources. R = number of recurrent complaints; N = number of new complaints.

Complaint Source	Damage Type													
	Road (R/N)	Timb. (R/N)	Lake. (R/N)	R.R. (R/N)	Fish (R/N)	Agri. (R/N)	Misc. (R/N)	Total (R/N)
Private	1.50 (12/8)	0.54 (30/56)	1.00 (20/20)	-- (0/0)	0.00 (0/1)	-- (0/0)	0.00 (0/3)	0.70 (62/88)
Commerc.	0.91 (10/11)	0.25 (1/4)	-- (0/0)	1.38 (18/13)	-- (0/0)	1.00 (2/2)	0.00 (0/1)	1.00 (31/31)
Town	1.74 (47/27)	0.00 (0/1)	0.00 (0/1)	-- (0/0)	-- (0/0)	-- (0/0)	-- (0/0)	1.62 (47/29)
County	1.18 (13/11)	-- (0/0)	-- (0/0)	-- (0/0)	-- (0/0)	-- (0/0)	-- (0/0)	1.18 (13/11)
State	-- (0/0)	-- (0/0)	1.00 (1/1)	-- (0/0)	0.00 (0/1)	-- (0/0)	1.00 (2/2)	0.75 (3/4)
Federal	0.00 (0/1)	0.00 (0/1)	-- (0/0)	-- (0/0)	-- (0/0)	-- (0/0)	0.00 (0/1)	0.00 (0/3)
Total	1.41 (82/58)	0.50 (31/62)	0.95 (21/22)	1.38 (18/13)	0.00 (0/2)	1.00 (2/2)	0.40 (2/7)	0.94 (156/166)

[a] Recurrences per new complaint = number of recurrent complaints / number of new complaints.

last 3 combinations this value was based on 2 or fewer original complaints. Commercial/road, commercial/timber, and private/timber complaints recurred least (except for some combinations which occurred rarely and did not recur), with means of 0.91, 0.65, and 0.25 recurrences per new complaint, respectively.

Of 71 recurring complaints in Oneida County, 24 (33.3 percent) were not always reported by the same source; 25 (34.7 percent) were not always reported as the same damage type.

Nuisance Colonies

Trapping

An attempt was made to trap out all beaver colonies involved in complaints during the summers of 1976 and 1977. Fifty-nine locations were trapped (Appendix C), of which 9 were trapped in both years.

Of 28 colonies trapped in 1976, 16 (57 percent) were trapped out. Of 12 incompletely trapped colonies, 8 had 2 or more beaver caught, 1 had 1 caught, and 3 had none caught. Of 40 colonies trapped in 1977, 26 (65 percent) were trapped out. Of 14 incompletely trapped colonies, 5 had 2 or more beaver caught, 6 had 1 caught, and 3 had none caught.

I caught 166 beaver (Appendix D). Bailey, leg-hold, and Conibear traps were used to catch 82, 50, and 31 beaver,

respectively; 2 kits were caught by hand and 1 beaver was shot with a .22 caliber rifle.

Colony Size

Of 56 colonies that were trapped out or had 3 or more beaver present, 8 (14.3 percent) were single, 11 (19.6 percent) were pair, and 37 (66.1 percent) were family colonies (Table 6). The mean number of occupants in 42 trapped-out colonies was 3.60; the mean for 21 family colonies was 5.67.

Incompletely trapped colonies appeared to average about the same number of occupants as trapped-out colonies. The mean number of beaver trapped from 26 incompletely trapped colonies was 2.42. Since there was at least 1 more beaver in each of these colonies, the mean number of occupants was at least 3.42. Most incompletely trapped colonies showed evidence of only 1 remaining beaver so the mean number of occupants probably was not much higher than 3.42.

Age Structure

Age structure of the 166 beaver caught (Table 7) was as follows: 57 were kits (34.3 percent), 19 were yearlings (11.4 percent), 28 were 2-year-olds (16.9 percent), 27 were 3-year-olds (16.3 percent), 25 were 4-year-olds (15.1 percent), 6 were 5-year-olds (3.6 percent), and 3 were 6 years or older (2.6 percent). Of 148 beaver from trapped-out colonies (Table 8), 67 were kits (45.3 percent) (estimated

Table 6. Size classifications of 56 nuisance beaver colonies in Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977.

Year	Colony Type						Total
	Single		Pair		Family		
	No.	%	No.	%	No.	%	
1976	3	12.5	3	12.5	18	75.0	24
1977	5	15.6	8	25.0	19	59.4	32
Total	8	14.3	11	19.6	37	66.1	56

Table 7. Age class distribution of 166 nuisance beaver trapped in Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977.

Age Class	Beaver Trapped	Percent
K	57	34.3
1	19	11.5
2	28	16.9
3	27	16.3
4	25	15.1
5	6	3.6
6	2	1.2
7	1	0.6
8	1	0.6
Total	166	100.1

Table 8. Age distributions in 9 single, 10 pair, and 21 family nuisance beaver colonies trapped out in Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977.

Age Class	Colony Type			Total
	Single	Pair	Family	
K[a]	0	0	67	67
1	1	6	9	16
2	2	10	6	18
3	3	2	16	21
4	3	1	14	18
5	0	1	4	5
6	0	0	1	1
7	0	0	1	1
8	0	0	1	1
Total	9	20	119	148

[a]Kits estimated by placental scars and fetuses.

from placental scars and fetuses), 16 were yearlings (10.8 percent), 18 were 2-year-olds (12.2 percent), 21 were 3-year-olds (14.2 percent), 18 were 4-year-olds (12.2 percent), 5 were 5-year-olds (3.4 percent), and 3 were 6 years or older (2.1 percent). Kits comprised a significantly smaller percentage of the entire trapped sample than the trapped-out sample (X^2=3.9; 1 df; $P<0.05$), suggesting that they were under-represented in the trapped sample.

Beaver in single and pair colonies were mostly 4 years or younger. Pair colonies contained 37.5 percent of the yearlings and 55.5 percent of the 2-year-olds caught. Excluding kits, family colonies were mostly 3 and 4-year-old beaver. The oldest beaver caught was an 8-year-old male.

Of 119 beaver from 21 trapped-out family colonies, 67 were kits (56.3 percent), 16 were yearlings (13.4 percent), 18 were 2-year-olds (15.1 percent), and 47 were 3 years or older (39.5 percent). Of 20 beaver from 10 pair colonies, 6 were yearlings (30.0 percent), 10 were 2-year-olds (50.0 percent), and 4 were 3 years or older (20.0 percent). Of 9 beaver from single colonies, 1 was a yearling (11.1 percent), 2 were 2-year-olds (22.2 percent), 3 were 3-year-olds (33.3 percent), and 3 were 4-year-olds.

Overall mortality for 148 beaver from trapped-out colonies was 45.8 percent annually (Table 9). Adult mortality was 23.2 percent; kit mortality was 73.1 percent.

Table 9. Composite time-specific life table for 148 beaver from trapped-out nuisance colonies in Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977. Kits were estimated by placental scars and fetuses in adult females.

Age x	Alive lx'	Adjusted lx''	Per 1000 lx	Dead dx	Mort. Rate qx	Life Expect. ex	Cum. Mort.
K	67	67	1000	731	0.731	1.711	0.731
1	16	18	269	0	0.000	4.002	0.731
2	18	18	269	0	0.000	3.002	0.731
3	21	18	269	0	0.000	2.002	0.731
4	18	18	269	194	0.721	1.002	0.925
5	5	5	75	55	0.733	1.300	0.998
6	1	1	20	0	0.000	2.500	0.998
7	1	1	20	0	0.000	1.500	0.998
8	1	1	20	20	1.000	0.500	1.000
Total	148	147	2157	1000	0.458	2.076	-----
Less Kits	81	80	1157	269	0.232	2.378	-----

Sex Structure

The sex ratio for 52 beaver 1 year or older from 21 trapped-out family colonies was 91 males:100 females. Beaver from 11 pair colonies had a sex ratio of 180 males: 100 females. Neither ratio is significantly different ($P>0.05$) from a 1:1 ratio. Of 9 single colonies, 8 contained males and 1 beaver was released by WDNR personnel without being sexed.

Of 11 pair colonies, 5 (45.5 percent) contained 2 beaver of the same sex and in 4 cases both were males. Three family colonies had more than 1 male 3 years or older. One colony had 8 and 4-year-old males and a 4-year-old female with 5 placental scars.

The male:female ratios among 54 kits trapped and for 7 fetuses collected were 110:100 and 80:100, respectively. Neither ratio is significantly different ($P>0.05$) from a 1:1 ratio.

Productivity

Kits and yearlings ($\leq$1.5 years) were not reproductively active. Numbers of ovulations and litter sizes increased with age (Table 10) and prenatal mortality decreased (Table 11).

The mean number of ovulations for 24 females having ovulated was 3.70; age-specific ovulation means ranged from 2.43 in 3-year-olds (2-year-olds averaged 2.50) to 6.0 in 5-year-olds. Of 15 female 2-year-olds, 7 (46.7 percent)

Table 10. Age-specific reproduction in female nuisance beaver from Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977.

Age Class (yrs)	Number Females Examined	Pregnancy %	Fetuses		Placental Scars		Corpora[a] Lutea		Corpora Albicantia[b]					
									Large (≥ 2 mm)		Small (< 2 mm)		Total	
			x̄ no.	freq.	x̄ no.	freq.	x̄ no.	freq.	x̄ no.	freq.	x̄ no.	freq.	x̄ no.	freq.
K	26	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
2	15	13.3	2.00	1	2.00	1	2.50	4	2.20	5	0	0	2.20	5[c]
3	8	87.5	2.00	1	2.17	6	2.43	7	5.30	3	3.00[d]	3	5.00	5
4	13	84.6	4.00	2	4.10	9	4.18	11	4.00	2	1.30	3	3.00	4
5	2	100	0	0	5.50	2	6.00	2	4.00	1	3.00	1	7.00	1
Total[e]	38	57.9	3.00	4	3.50	18	3.70	24	3.54	11	2.29	7	3.67	15

[a]Includes corpora albicantia from births occurring the immediately preceding spring as indicated by their coloration (Provost 1964).

[b]Includes only corpora albicantia 1 year or older.

[c]The five 2-year-olds with corpora albicantia showed no evidence of breeding. These corpora were apparently remnants of corpora lutea of ovulation.

[d]One 3-year-old had 1 small and 6 large corpora albicantia, suggesting that 1 may have resulted from a corpus luteum of ovulation.

[e]Includes beaver 2 years or older.

Table 11. Age-specific prenatal mortality in 38 female beaver from Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977.

Age (yrs)	No. Females Examined	No. Females Ovulating	No. Corpora Lutea[a]	No. Placental Scars or Fetuses	Prenatal Mortality (%)
2	15	7	21	4	80.1
3	8	7	17	15	11.8
4	13	11	46	45	2.2
5	2	2	12	11	8.3
Total	38	27	96	75	21.9

[a]Includes corpora albicantia from the immediately preceding spring as indicated by their coloration (Provost 1962).

had ovulated. Mean litter size for 22 parous females (based on placental scars and fetuses) was 3.41; age-specific mean litter sizes ranged from 2.00 in 2-year-olds to 5.50 in 5-year-olds.

The percentage of ova that were unfertilized, unimplanted, or resorbed (i.e. prenatal mortality) was 21.9; age-specific prenatal mortality ranged from 80.1 percent in 2-year-olds to 2.2 percent in 4-year-olds (5-year-olds had 8.3 percent mortality based on 12 ovulations).

Of 36 colonies where both adults were present, pregnancy occurred in 32 (86.5 percent). Age-specific percent pregnancy ranged from 13.3 in 2-year-olds to 100.0 in 5-year-olds. No more than 1 pregnant female was found in any of the colonies trapped.

Nonovulated luteinized follicles (corpora lutea accessoria) were not found in any of the beaver examined. Corpora lutea of ovulation occurred in 7 of 23 females having ovulated (30.4 percent). Total corpora albicantia (over 1 year old) averaged 3.67 per female having them. Large corpora albicantia ($\geq$2 mm) averaged 3.54 per female having them. The presence of large corpora albicantia in 5 female 2-year-olds that had not bred indicates that they result from corpora lutea of ovulation as well as corpora lutea of pregnancy.

DISCUSSION

Complaints

Beaver complaints probably will continue to increase in north-central Wisconsin. Human population on the study area is projected to increase at a rate higher than the national average in the next 10 years (Gustafson 1973). Abundant recreational opportunities and improved highways have increased development and inflow of seasonal inhabitants from population centers in southern Wisconsin and northern Illinois.

The beaver population also appears to be increasing. Harvests are high despite continuing low pelt prices (see Appendix E). As fuel and equipment costs rise, pressure on beaver from private trappers may decrease. At some point, disease may aid in lowering the beaver population (Knudsen 1953, Stenlund 1953, Lawrence 1956) but this is highly undesirable.

Beaver damage types in north-central Wisconsin are similar to those reported elsewhere in the northern U.S. Prevalence of damage types reported by Hodgdon and Hunt (1966) in Maine was as as follows: 1) road or railroad (27 percent), 2) woodlands (21 percent), 3) cultivated fields (15 percent), 4) water supply (7 percent), and 7) miscellaneous or unspecified (22 percent). Parsons and Brown (1978) in New York reported prevalence among 58 complaints in 1971 and 1972 as follows: 1) plugging road culverts (41

percent), 2) flooding land (33 percent), 3) plugging ponds (19 percent), 4) flooding camp (5 percent), and 5) cutting trees (2 percent). Grasse and Putnam (1955) in Wyoming and Longley and Moyle (1963) in Minnesota mentioned similar damage types. In the southern U.S., commercial timber damage is predominant (Arner et al. 1969, Cooper 1970, Byford 1974).

Damage types have not changed much since 1946 and probably will remain similar in the future with road and timber complaints being prevalent. As found in New York by Parsons and Brown (1978), a high percentage of road complaints on the study area involved culverts as damsites. The high recurrence of road and railroad complaints is probably due to the permanence of the structures being damaged. Timber complaints are probably less recurrent because a timber stand cannot be damaged for many years once the initial damage has occurred.

The need for a continuing, organized beaver control operation is evident in the prevalence of private complainants (46 percent) who mostly lack the resources to control beaver.

Nuisance Colonies

The size, age structure, and productivity of nuisance colonies are affected by the intense trapping pressure put on them by both private and state trappers. They appear to be smaller, younger, and possibly less productive than

non-nuisance colonies studied by other workers.

Summer-trapped nuisance colonies on the study area showed proportions of single, pair, and family colonies similar to those found in winter by other workers. Gunson (1970) in Saskatchewan found 17.4 percent single, 23.9 percent pair, and 58.7 percent family colonies in 46 winter-trapped colonies from 2 habitats with different harvest intensities. He did not state whether his sample was randomly or systematically chosen. Payne (1975) in Newfoundland found 15.2 percent single, 21.7 percent pair, and 63.0 percent family colonies in 46 randomly selected winter-trapped colonies.

If nuisance colonies were likewise trapped in winter (following summer control operations) there probably would be a higher proportion of single and pair colonies due to fragmentation of family colonies by trapping and ingress of subadults into trapped-out territories.

Mean numbers of beaver per family colony and for all colonies combined seemed low compared to results of other workers at similar latitudes (Table 12), though data were collected just after birth and before kits were subject to much natural mortality. Gunson (1970) reported 97.3 percent survival of kits in their first 5 months of life. Payne (1975) in Newfoundland found 3.7 beaver per colony in poor beaver habitat.

The age structure of the nuisance beaver trapped was unusual in that fewer yearlings were caught than 2, 3, or

Table 12. Mean numbers of beaver in colonies from different latitudes in North America.

Lat. (°N)	Authority	Location	Mean Colony Size	Habitat
30-34	Parrish (1960)	Georgia	5.3	-----
30-34	Wilkenson (1962)	Alabama	4.6	-----
38-40	Hay (1958)	Colorado	5.1	Willow
38-40	Hay (1958)	Colorado	7.8	Aspen
38-40	MacDonald (1956)	Colorado	5.5	-----
38-40	Rutherford (1964)	Colorado	4.5	Willow
38-40	Rutherford (1964)	Colorado	5.1	Aspen
38-40	Swank (1949)	West Virginia	5.3	-----
42-46	Bradt (1947)	Michigan	5.1	-----
42-46	Shelton (1966)	Michigan	6.4	-----
44-47	Hodgdon and Hunt (1966)	Maine	4.3	-----
45-46	This Study	Wisconsin	3.6	Aspen
46-49	Hammond (1943)	North Dakota	4.3	-----
46-52	Bergerud and Miller (1977)	Newfoundland	4.6	Alder/Birch
46-52	Payne (1975)	Newfoundland	3.7	Alder/Birch
58-60	Hakala (1952)	Alaska	3.2	-----

4-year-old beaver. The combined effects of high annual kit mortality (73.1 percent) and ingress of 2 and 3-year-olds into frequently trapped-out colonies might explain this phenomenon. Dispersal by beaver over 2 years old probably occurs since 3 colonies on the study area had 3 or 4-year-old occupants (all males) in the presence of an older pair of adults.

Boyce (1974) in Alaska and Payne (1975) in Newfoundland found kits under-represented in the harvest apparently due to trapping techniques selective for older beaver. Though kits may have been slightly under-represented in summer trapping on the study area, they apparently experience heavy annual harvest mortality as suggested by the low number of yearlings. Gunson (1970) in Saskatchewan reported kits representing from 23.4-51.5 percent of the harvest depending on habitat type. He stated that age class distribution among beaver caught in the lodge entrance approximated that of the entire population. Payne (1975) found kits equally trap susceptable at 1-3 m and 6-9 m from the lodge. During winter in Wisconsin, traps may be set no closer than 4.6 m from the lodge. My observations indicate that most trappers set traps as close to the lodge as legally possible.

The oldest beaver caught on the study area (8 years) was much younger than beaver reported by Boyce (1974) in Alaska (15 years), Gunson (1970) in Saskatchewan (20 years), Henry and Bookhout (1969) in Ohio (13 years), Larson (1967) in Maryland (23 years), and Payne (1975) in Newfoundland

(20 years). Most of these workers found many beaver over 10 years of age. The relative youth of the beaver I trapped suggests that nuisance beaver are restricted to younger age classes that disperse into unoccupied territories of heavily trapped nuisance colonies.

Many workers have reported disparate sex ratios but there has been little consistency as to which sex predominates. Chi-square analysis of data from Benson (1936), Boyce (1974), Bradt (1947), Grinnell et al. (1937), Gunson (1970), Hammond (1943), Hodgdon and Hunt (1966), Longley and Moyle (1963), Leege and Williams (1967), Payne (1975), Provost (1958), Rutherford (1964), and Wilkenson (1962) yielded no significant differences ($P>0.05$) from a 1:1 ratio.

Bond (1956) in Vermont reported 120 males:100 females in 702 young beaver which was significantly different from a 1:1 ratio ($X^2=8.67$; 1 df; $P<0.05$) but the sex ratio in adults (80 males:100 females) was not. Bergerud and Miller (1977) in Newfoundland found significantly more female than male yearlings in live-trapping ($X^2=4.30$; 1 df; $P<0.05$; n=39) but the overall, adult, 2-year-old, kit, and kill-trapped yearling sex ratios were not significantly different ($P>0.05$) from a 1:1 ratio. They found that yearling males made large summer movements which, as Payne (1975) suggested, could explain this difference if live-trapping was concentrated around the lodge. The high percentages of males in single and pair colonies on the study area suggest that

males may be more mobile in the summer than females.

Beer (1955) found that the adult female will remain in the colony if her mate is trapped but that the opposite is true of the adult male. My observations on the study area suggest this may not be necessarily true. At 1 colony, the adult female was trapped in winter and the carcass was given to me. In May, when control efforts were initiated, a 4-year-old male was present. Despite repeated disturbance of the lodge and dams and attempts to shoot this beaver, he still remained. On 1 occasion this male approached me within 1.5 m apparently trying to drive me from the lodge.

Productivity on the study area was very similar to that found by Henry and Bookhout (1969) in Ohio, with low ovulation and litter size in the first breeding season and a rapid increase to peak productivity in the 3, 4, and 5 year age classes. Gunson (1970) in Saskatchewan and Payne (1975) in Newfoundland found similar patterns but with more gradual increases to peak productivity. This may be a manifestation of larger sample sizes or poorer habitats in the latter two studies.

Henry and Bookhout (1969) in Ohio found 11-16 percent prenatal mortality and Gunson (1970) in Saskatchewan found a range from 6.7-28.1 with mortality highest in poor quality habitats. Prenatal mortality on the study area (21.9 percent) was inflated by the high rate in 2-year-olds (80.1 percent). It is possible that reproductive success may be low in 2-year-olds due to delayed dispersal which would

allow a dominant breeder in a family colony to suppress estrus or maturation of the subordinate or interfere with copulation (Payne 1975). Brenner (1964) found resorption only in primiparous 2-year-olds.

As with Payne (1975) and Bergerud and Miller (1977), no more than 1 pregnant female was found in any of the colonies examined. Overall percent pregnancy was low (57.9 percent) because of the high number of nonbreeding 2-year-olds. Percent pregnancy in adults (82.6 percent) compared favorably with Gunson (1970) in Saskatchewan who found 85-95 percent pregnancy in adults. Boyce (1974) in Alaska found 45 and 50 percent pregnancy in adult females from 2 areas with different harvest intensities but did not speculate on the cause of such low productivity. Payne (1975) in Newfoundland found 70 percent pregnancy in adult females with 24.3 percent pregnancy in yearlings.

The lack of nonovulated luteinized follicles in the beaver examined agrees with Provost (1962) who felt that they seldom occurred in beaver. The presence of corpora lutea of ovulation and corpora albicantia resulting from them complicate the use of ovarian analysis as an indicator of productivity. The inclusion of yearlings in such analysis is likely to aggravate this problem.

RECOMMENDATIONS

Since road complaints are prevalent and most recurrent in north-central Wisconsin, the greatest cost reduction would be gained by alleviating this damage type. Future research is needed to develop improved culvert designs and olfactory repellents to make culverts less attractive to beaver.

As a short-term measure, heavy wire grates can be placed on the upstream end of such culverts to keep beaver out and aid in debris removal. These grates can be cooperatively maintained by town, county, commercial, and state employees. At existing road complaint locations, additional fill and larger culverts with grates should be installed if possible.

"Beaver pipes" (Laramie 1963), which also require regular maintenance, can be used in most flooding situations, though where accessable, they may be prone to vandalism. Further research should be directed toward improving such water control structures to reduce maintenance.

To alleviate timber cutting complaints, landowners should be educated in the use of exclusion fencing (Huey 1956, Longley and Moyle 1963) and taste repellents such as trinitrobenzene-aniline (Huey 1956, U. S. Fish and Wildlife Service 1962).

For most damage types, trapping remains the most effective means of beaver control. Where trapping is done by WDNR employees, help should be solicited from the complainant

if feasible. Much travel can be eliminated if the complainant checks traps and contacts the trapper in the event of a capture. Commercial landowners with extensive acreage could provide exclusive trapping rights to trappers who concentrate on their nuisance locations.

In remote locations, limited use of toxicants (Cooper 1970, Hill 1976) may be desirable. Explosives applied to active lodges also could be tested as a method to destroy or disrupt colonies far from human habitation.

Since extended seasons, as well as a liberal regular season, and the present permit system have not reduced nuisance beaver problems, autumn open water seasons should be considered. Permittees should be allowed to keep the pelts of nuisance beaver. Fur values, especially in the closed season, do not offset the cost of pelt preparation by state employees, often resulting in unused pelts. In Minnesota, conservation officers assign nuisance beaver colonies to private individuals for trapping in the fall. Pelts are kept by the trapper. This system has been in use since 1919 (Longley and Moyle 1963).

To reduce new complaints arising from development of lakeshore or woodland property, undeveloped areas prone to beaver damage should be zoned to make any landowner developing such land liable for the control of any beaver damage occurring there. The WDNR can set criteria as to what constitutes a damage-prone area based on a land suitability classification system (Slough and Sadleir 1977) and act in

an advisory capacity when control is undertaken. If beaver control costs and more desirable alternative uses of beaver control money were publicized, landowners and sportsmen's groups may supply additional manpower for control efforts.

Trapping pressure at nuisance colonies should be maintained at the highest possible level. It is easier to discourage or remove dispersing subadults than resident families. Heavy trapping pressure also prevents female beaver from reaching the age of peak productivity. By keeping beaver in the younger age classes, the low percent pregnancy and high prenatal mortality will limit productivity.

Payne (1975) stated that by selectively removing only adult beaver from colonies, reproduction would be eliminated from about 10 percent of the colonies. Theoretically, by allowing only 1 or 2 beaver per colony to be harvested, the trappers would exert more effort at selectivity and hence would remove the most productive animals first. Under a registered trapline system this may be feasible, but under Wisconsin conditions it would undoubtedly fail. With the present low pelt prices for beaver and the amount of effort necessary to trap beaver under ice, any further restriction of beaver harvest would cause many trappers to turn to more profitable enterprises.

Damage locations should be checked often so immigrating beaver do not have a chance to become entrenched. Application of taste repellents at aspen and willow (Salix spp.) stands close to the lodge may discourage recolonization.

Since beaver are highly territorial (Aleksiuk 1968, Bergerud and Miller 1977), maintenance of simulated scent mounds should be tested as a possible deterrent, though in remote areas it may prove too costly.

Transplantation of beaver should be minimized on the study area. Because of the large movements made by transplanted beaver upon release (Knudsen and Hale 1965), they or their offspring may return to nuisance locations. An alternative to killing captured beaver is to transplant them to areas with small beaver populations and heavy trapping pressure. Beaver also should be considered as potential laboratory animals for medical research. Young kits, which have not been weaned, would not survive transplantation in most cases and their small size makes them most suitable for being caged.

The number of dispersing beaver available to recolonize trapped-out nuisance colonies might be reduced by sterilizing the adult beaver in colonies farther upstream. Because trappers would be continually removing sterilized beaver from the population, mechanosterilization of either males or females (Brooks 1977, Fleming 1977) probably would be too costly. Chemosterilization would be fairly inexpensive, as treated baits could be placed quickly at colonies in one visit. Preliminary work has been done on chemosterilants (Harper 1968) though no compound has been tested thoroughly enough to be considered effective.

LITERATURE CITED

Aleksiuk, M. 1968. Scent-mound communication, territoriality, and population regulation in beaver (Castor canadensis Kuhl). J. Mammal. 49(4):759-762.

Andrews, L. M., and C. W. Threinen. 1966. Surface water resources of Oneida County. Wisconsin Cons. Dep., Madison. 284 pp.

Arner, D. H., J. Baker, D. Wesley, and B. Herring. 1969. An inventory and study of beaver impounded water in Mississippi. Proc. Am. Conf. Southeast Arizona Game Fish Comm. 23:110-128.

Beer, J. R. 1955. Movements of tagged beaver. J. Wildl. Manage. 19(4):492-493.

Benson, S. B. 1936. Notes on the sex ratio and breeding of the beaver in Michigan. Occasional Papers, Mus. Zool., Univ. Michigan, Ann Arbor. 6 pp.

Bergerud, A. T., and D. R. Miller. 1977. Population dynamics of Newfoundland beaver. Can. J. Zool. 55(9): 1480-1492.

Bond, C. F. 1956. Correlations between reproductive condition and skull characteristics of beaver. J. Mammal. 37(4):506-512.

Boyce, M. S. 1974. Beaver population ecology in interior Alaska. M. S. thesis, Univ. Alaska, Fairbanks. 161 pp.

Bradt, G. W. 1947. Michigan beaver management. Michigan Dep. Cons., Lansing. 56 pp.

Brenner, F. J. 1964. Reproduction of the beaver in Crawford County, Pennsylvania. J. Wildl. Manage. 28(4):743-747.

Brooks, R. P. 1977. Induced sterility of the adult female beaver (Castor canadensis) and colony fecundity. M. S. thesis, Univ. Massachusetts, Amherst. 90 pp.

Byford, J. L. 1974. Beavers in Tennessee: control, utilization, and management. Univ. Tennessee Agri. Ext. Serv. publ. 687. 13 pp.

Caughley, G. 1966. Mortality patterns in mammals. Ecology 47(6):906-918.

Cooper, W. L. 1970. Preliminary investigations of certain beaver control methods in Alabama. M. S. thesis, Auburn Univ., Auburn, Alabama. 74 pp.

Deevey, W. S., Jr. 1947. Life tables for natural populations of animals. Quart. Rev. Biol. 22(4):283-314.

Fleming, M. W. 1977. Induced sterility of the adult male beaver (Castor canadensis) and colony fecundity. M. S. thesis, Univ. Massachusetts, Amherst. 59 pp.

Grasse, J. E., and E. F. Putnam. 1955. Beaver management and ecology in Wyoming. Wyoming Game Fish Comm., Cheyenne. Bull. 6. 74 pp.

Grinnell, J., J. S. Dixon, and J. M. Linsdale. 1937. Furbearing mammals of California. Univ. California Press, Berkeley. 2:269-727.

Gunson, J. R. 1970. Dynamics of the beaver in Saskatchewan's northern forest. M. S. thesis, Univ. Alberta, Edmonton. 122 pp.

Gustafson, N. C. 1973. Recent trends/future prospects: a look at upper midwest population changes. Upper Midwest Council, Minneapolis. 69 pp.

Hakala, J. B. 1952. The life history and general ecology of the beaver (Castor canadensis) in interior Alaska. M. S. thesis, Univ. Alaska, College. 181 pp.

Hammond, M. C. 1943. Beaver on the Lower Souris Refuge. J. Wildl. Manage. 7(3):316-321.

Harper, W. R. 1968. Chemosterilant assessment for beaver. M. S. thesis, Colorado State Univ., Fort Collins. 40 pp.

Hay, K. G. 1958. Beaver census methods in the Rocky Mountain region. J. Wildl. Manage. 22(4):395-402.

Henry, D. B., and T. A. Bookhout. 1969. Productivity of beavers in northeastern Ohio. J. Wildl. Manage. 33(4): 927-932.

Hickey, J. J. 1952. Survival studies of banded birds. U. S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. 15. 177 pp.

Hill, E. P. 1976. Control methods for nuisance beaver in the southeastern United States. Proc. Vert. Pest Control Conf. 7:85-98.

Hodgdon, K. W. 1949. Productivity data from placental scars in beaver. J. Wildl. Manage. 13(4):412-414.

_____, and J. H. Hunt. 1966. Beaver management in Maine. Maine Dep. Inland Fish. Game., August. 102 pp.

Huey, W. S. 1956. New Mexico beaver management. New Mexico Dep. Game Fish, Santa Fe. 49 pp.

Klevezal', G. A., and S. E. Kleinenberg. 1967. Age determination of mammals by layered structure in teeth and bone. Translation Series No. 1024 (1969). Fish. Res. Bd. Can., Arctic Biological Sta., Ste. Anne de Bellevue, Quebec. 142 pp.

Knudsen, G. J. 1952. Progress report; miscellaneous beaver damage. Wisconsin Wildl. Res. 11(2):67-89.

_____. 1953. Beaver die-off. Wisconsin Cons. Bull. 18(9):20-23.

_____. 1954. Job completion report; general beaver damage. Wisconsin Wildl. Res. 13(1):117-130.

_____. 1956. Job completion report; general beaver damage. Wisconsin Wildl. Res. 15(2):155-158.

_____, and J. B. Hale. 1965. Movements of transplanted beaver in Wisconsin. J. Wildl. Manage. 29(4): 685-688.

Laramie, H. A., Jr. 1963. A device for the control of problem beavers. J. Wildl. Manage. 27(3):471-476.

Larson, J. S. 1967. Age structure and sexual maturity within a western Maryland beaver Castor canadensis population. J. Mammal. 48(3):408-413.

_____, and F. C. van Nostrand. 1968. An evaluation of beaver aging techniques. J. Wildl. Manage. 32(1): 99-103.

Lawrence, W. H. 1956. Beaver die-off in Michigan. J. Wildl. Manage. 20(2):184-187.

Leege, T. A., and R. M. Williams. 1967. Beaver productivity in Idaho. J. Wildl. Manage. 31(2):326-332.

Longley, W. H., and J. B. Moyle. 1963. The beaver in Minnesota. Minnesota Dep. Cons., St. Paul. 87 pp.

MacDonald, D. 1956. Beaver carrying capacity of certain mountain streams in North Park, Colorado. M. S. thesis, Colorado State Univ., Fort Collins. 136 pp.

Parrish, W. F., Jr. 1960. Status of the beaver (Castor canadensis carolinensis) in Georgia, 1959. M. S. thesis, Univ. Georgia, Athens. 62 pp.

Parsons, G., and M. Brown. 1979. Effect of a four-year closure of trapping season for beaver in Fulton County. N. Y. Fish Game J. 25(1):23-30.

Payne, N. F. 1975. Trapline management and population biology of Newfoundland beaver. Ph. D. thesis, Utah State Univ., Logan. 178 pp.

Provost, E. E. 1958. Studies on the reproduction and population dynamics in beaver. Ph. D. thesis, Washington State Univ., Pullman. 78 pp.

_____. 1962. Morphological characteristics of the beaver ovary. J. Wildl. Manage. 26(3):272-278.

Rutherford, W. H. 1964. The beaver in Colorado / its biology, ecology, management, and economics. Colorado Game, Fish, and Parks Dep., Denver. 49 pp.

Shelton, P. C. 1966. Ecological studies of beavers, wolves, and moose in Isle Royale National Park, Michigan. Ph. D. thesis, Purdue Univ., Lafayette, Indiana. 308 pp.

Slough, B. G., and R. M. F. S. Sadlier. 1977. A land capability classification system for beaver (Castor canadensis Kuhl). Can. J. Zool. 55(8):1324-1335.

Spencer, J. S., and H. W. Thorne. 1972. Wisconsin's 1968 timber resource. U. S. For. Serv. Res. Bull. NC-15. 80 pp.

Stenlund, M. H. 1953. Report of a Minnesota beaver die-off, 1951-52. J. Wildl. Manage. 17(3):376-377.

Steuck, R., and L. M. Andrews. 1977. Surface water resources of Forest County. Wisconsin Dep. Nat. Res., Madison. 199 pp.

Swank, W. G. 1949. Beaver ecology and management in West Virginia. West Virginia Cons. Comm., Charleston. 65 pp.

U. S. Fish and Wildlife Service. 1962. Sources of supply: repellents. Agri. Exp. Sta., Purdue Univ., Bull. 512. 2 pp.

U. S. Geological Survey. 1976. Mineral and water resources of Wisconsin. U. S. Gov. Printing Off., Washington. 185 pp.

van Nostrand, F. C., and A. B. Stephenson. 1964. Age determination for beaver by tooth development. J. Wildl. Manage. 28(3):430-434.

Wilkenson, P. M. 1962. A life history study of the beaver in east-central Alabama. M. S. thesis, Auburn Univ., Auburn, Alabama. 91 pp.

Wisconsin Department of Natural Resources. 1976. Wisconsin fur harvest report. Wisconsin Dep. Nat. Res., Madison. 2 pp.

Wisconsin Legislative Reference Bureau. 1977. The State of Wisconsin blue book. Wisconsin Dep. Admin., Madison. 986 pp.

APPENDICES

Appendix A. Description of beaver damage types in Wisconsin (from Knudsen 1952).

Agricultural. This type of damage consists mainly of lowland crops or fields that are inundated by beaver flowages. Wild hay, tame hay, corn and some orchards are affected most here. Cranberry farms have trouble with the beaver either stopping up drainage ditches so flood water will not leave the berry marshes, or stopping up inlet ditches so water does not reach the berry marshes in sufficient quantity. Occasionally beaver flowages are a hazard to live stock. A few cases are recorded where sheep or cattle have actually drowned while trying to cross or wade in beaver ponds. Farm lanes, farm roads, farm bridges and outbuildings are occasionally flooded. In a very few cases fence posts have been cut off by beaver. Consumption of farm crops has rarely been recorded and this is usually where the beaver have been cutting a little corn for food. Burrows endangered horses, in rare instances.

Timber. This type of damage is done mostly to lowland timber trees such as spruce, balsam, tamarack, cedar, ash, elm, maple, aspen and cottonwood. Damage is usually the direct result of flooding the timber stands with subsequent drowning of the trees. Cutting of the timber is much less serious, though many complainants had this as their main objection to beaver, especially on lakes in the resort areas of the state where various lawn trees were cut in front of cabins. There are records of pine stands being killed by

Appendix A. Continued.

beaver flooding, but because these trees are often on higher land or slopes they are not usually drowned in large areas.

Lakeshore. Lakeshore damage occurs when a beaver builds a dam across an outlet of a lake and causes the water to rise to a foot or more above the normal level of the lake. This results in flooding private piers, floating boathouses off their foundations, inundation of beaches and lawns, drowning trees bordering the lake, and softening and washing away of shoreline wave barriers. Damage of this nature occurs mostly in the counties with many lakes and causes resort owners much chagrin. A few complaints have been recorded in which the beaver built a dam across an inlet of a lake and held back the water from the lake, causing the shoreline to recede.

Fish. Trout streams are the usual sites for complaints against the presence of beaver and their dams. The reasons for the concern should be well known to everyone reading this report. Trout hatcheries frequently complained that the beaver were either holding back water from their raceways or flooding their rearing ponds by plugging screens or building small dams below the hatcheries. Spring fish "runs" into lakes are arrested by beaver dams on occasion.

Roads. Road, highway and fire lane complaints resulted from beaver plugging culverts and bridges that allow streams to flow under the road bed, and from beaver dams that were built downstream from a road but close enough so that the

Appendix A. Continued.

backed-up water flooded the road bed and bridge fill. In many cases, the road itself was submerged. The road bed softens and washes out on occasion.

Railroad. Railroad complaints were received by the department for exactly the same reasons as road complaints. There is always great danger to a train when the railroad bed is softened. Beaver may leave a large cutting lying across a track in rare cases, causing the train to stop while the "log" is removed.

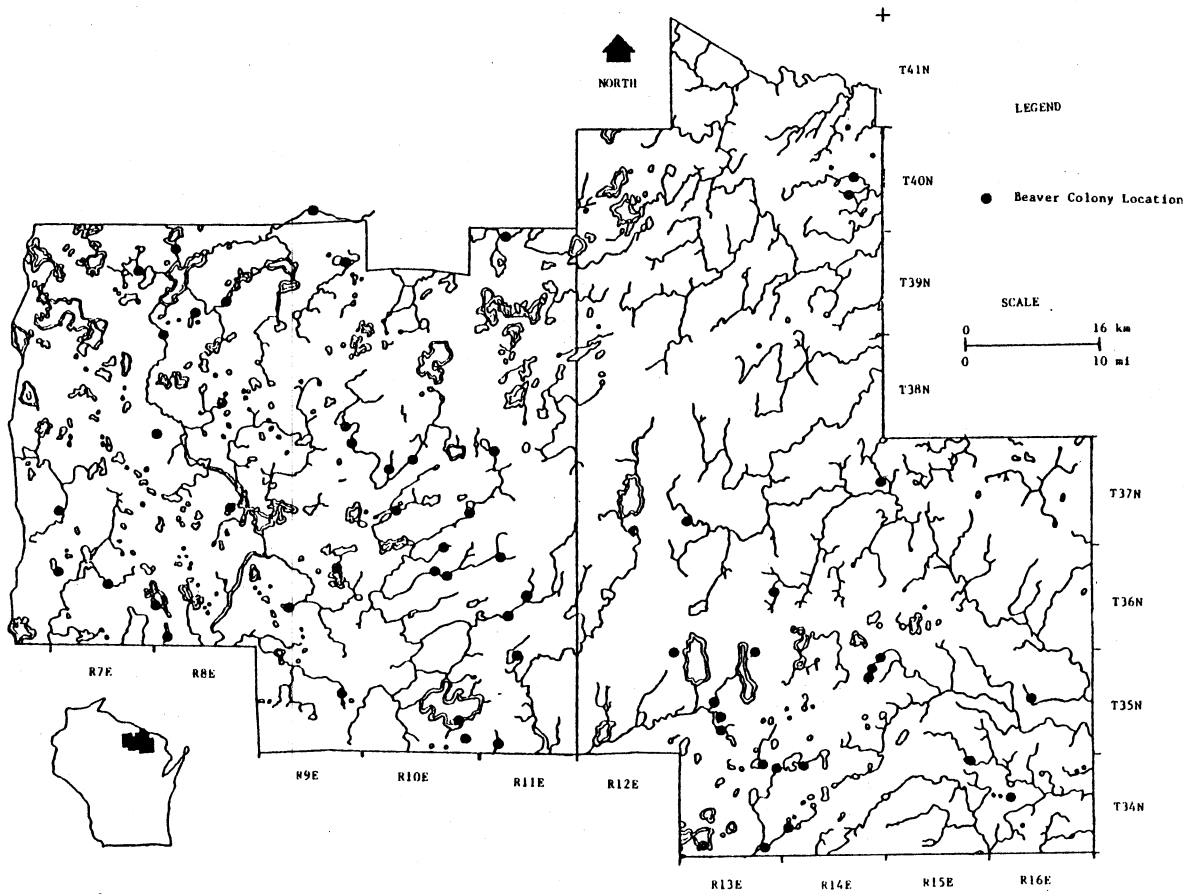
Miscellaneous damage. Complaints in this classification are much less common but are nevertheless of importance. A listing of some of them follow in brief form: Beaver dams built in concrete dam gates; water held back from power dam; basements flooded; interlake thoroughfares blocked by dams or felled trees; trash racks in power dams plugged; drinking water springs flooded; wild rice stands flooded out; farmers kept from inundated marl deposits; minnow trapping operations flooded; flooded man-made dam aprons from below allowing no water level control; flooded game refuge; stopped flow of water from lake to marsh; held back water from fire fighting crews; flooded flowage dikes from below; silting lake bottom for swimming; flooded creamery disposal ditch; felled trees into power lines; put sticks in water wheel and stopped power; flooded marsh and made it too wet to dredge; flooded bridge-building operations.

Appendix B. Results of aerial beaver surveys conducted by the Wisconsin Department of Natural Resources on trout waters (1,086 stream km) of the study area, 1972-1977.

Year	Active Colonies		
	Oneida County	Forest County	Combined
1972	48	63	111
1973[a]	--	--	---
1974	67	81	148
1975	26	58	84
1976[b]	33	39	72
1977	47	76	123

[a]Data missing.

[b]Survey was conducted after ice formation.



Appendix C. Locations of 59 nuisance beaver colonies trapped in Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977.

Appendix D. Size, status (i.e. whether trapped out), and composition by age and sex of 59 nuisance beaver locations trapped in Oneida, Forest, and Vilas counties, Wisconsin, 1976-1977. Numbers of placental scars and fetuses in the adult females are indicated. Beaver are listed in order of capture.

1976

Location Number[a]	Beaver[b]	Colony Size[c]	Trapped-Out?[d]	Plac. Scars or Fetuses
O-1	4M	S	Y	-
O-1	2unk.[e]	S	Y	unk.
O-2	Ad.M, KF, KM, KF, KF	F	N	-
O-4	1M, 7M	P	Y	-
O-5	4F, 2F, KM, 5M, KF	F	Y	6
O-6	4F, 6M, 2F, KM, KF, KM, KF	F	Y	6
O-8	4F(pregnant), 3F	F	Y	2
O-9	KM, 2F, 4F, KM, KF	F	N	6
O-10	KM, KM	F	N	-
O-11	3M, 4F	F	Y	3
O-14U	KM, KM, KF, KM, KF, KF, 3F	F	N	-
O-14D	KM, KF, KF, KF, KM, KF	F	N	-
O-15	2M	-	N	-
O-16	3M, KF, 4F, unk.K, KF	F	Y	3
O-17	3M	S	Y	-
F-2	1M, Ad.M	F	N	-
F-3	3F, 3F, 1M	F	Y	3
F-4	2M, 2M	P	Y	-
F-6	Ad.F, Ad.F	P	Y	-
F-7	3M, 7M, 5F, KF, KF, KM	F	Y	6
F-8	3F, 1M	F	N	1
F-9	4F	F	Y	4
F-10	2M, KM, KF, 1unk.	F	N	-
F-12	3F	F	N	2
F-13	4M	S	Y	-
V-1	4F	F	Y	3

Appendix D. Continued.

1977

Location Number	Beaver	Colony Size	Trapped-Out?	Plac. Scars or Fetuses
O-5	3M, 2F(pregnant)	F	Y	2
O-13	2M	S	Y	-
O-14U	4F(pregnant)[f], 1M, 4M, 2F	F	Y	5
O-15	1M, 3M, 1F	F	Y	-
O-16	2M, 2F	P	Y	-
O-19	3M, 2F, 2F	F	Y	-
O-20	3M	-	N	-
O-21	5M, 4F(pregnant)	F	Y	3
O-22	4M, 1F, 5F	F	Y	5
O-23	KM, KM, 1F, 5M, 3M, unk.K, 4F	F	Y	3
O-24	4M	F[g]	N	-
O-25	2F, 3M	P	Y	-
O-26	1M, 1F	P	Y	-
O-27	3M, 3F	F	Y	1
O-28	3M	S	Y	-
O-29	2F	-	N	-
O-30	3M	S	Y	-
O-31	KM, KM, KM, KM, 8M, 4M, 4F	F	Y	5
O-32	2M	-	N	-
O-33	KF, 6M, KF	F	N	-
O-34	4M	S	Y	-
O-35	5M, KM, KM	F	N	-
F-2	4F, 1F	F	Y	1
F-4	4F, 1M	P	Y	-
F-8	3M	-	N	-
F-10	4M	-	N	-
F-14	3M, 3M	P	Y	-
F-15	3F, 1M	F	Y	3
F-16	3F, 3M	F	Y	3
F-17	2M, 3M	P	Y	-
F-19	4M, 1M, 2M, 1M	F	Y	-
F-20	1M	S	Y	-
F-21	1M, 2F	P	Y	-
F-22	2M, 2M, KF, 2F, KM	F	N	-
F-23	KM, 2M, KF, KF, KF, 4M	F	N	-
F-24	2M, 1F	P	Y	-
F-25	KM, KM, KF, 4M, KM, 2M	F	N	-

Appendix D. Continued.

[a]O=Oneida County, V=Vilas County, F=Forest County. Numbers refer to order in which colonies were trapped.

[b]Age is followed by sex. M=male, F=female.

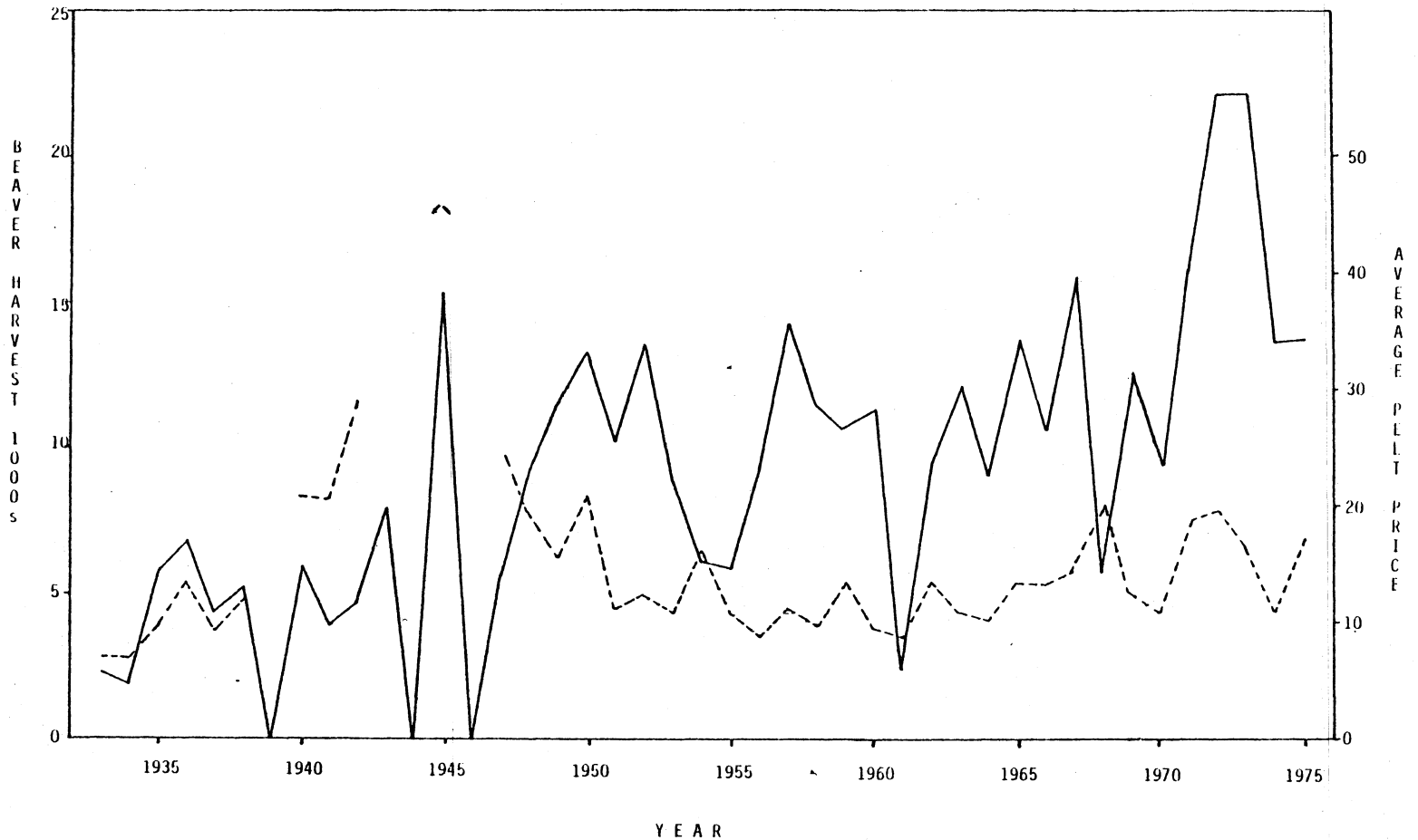
[c]S=single, P=pair, F=family.

[d]Y=yes, N=no.

[e]Beaver was caught by other DNR personnel more than 2 weeks after colony was trapped out.

[f]Beaver was caught in winter and provided by trapper.

[g]Kits were seen by a reliable observer.



Appendix E. Wisconsin beaver harvests (solid line) and average pelt prices (dashed line), 1933-1975.