

POPULATION CHARACTERISTICS OF
UNEXPLOITED BEAVER AND MUSKRAT
POPULATIONS

by

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PREFACE

This thesis consists of two technical papers describing the data I recorded while studying beaver (Castor canadensis) and muskrat (Ondatra zibethicus) populations on Sandhill Wildlife Area in central Wisconsin, 1981-83. Both papers, "Effects of Trapping on Beaver Colony Density, Structure, and Reproduction" and "Structure of an Unharvested Muskrat Population in an Infertile Wetland" will be submitted to the Journal of Wildlife Management. Data recorded but not presented in these papers are provided in the Appendices.

My committee chairman, Dr. Neil Payne, reviewed the thesis and influenced my professional growth and development. Dr. James Hardin provided suggestions to earlier drafts and Dr. Fred Hilpert assisted in statistical analysis of the data. Dr. Daniel Trainer and Dr. Steven Van Horn provided additional review of the thesis.

Personnel at Sandhill Wildlife Area, Wisconsin Department of Natural Resources, supported and cooperated throughout the study, especially Joe Haug who was instrumental in establishing this project and influenced my professional and personal growth.

My parents encouraged my education. My wife, Tracy, commented editorially, typed, and provided moral support throughout.

ABSTRACT

A trapline system for beaver (Castor canadensis) and muskrat (Ondatra zibethicus) occurred on Sandhill Wildlife Area during 1981, 1982, and 1983 to harvest populations unexploited for at least 19 years. We censused 48 beaver colonies ($1.30/\text{km}^2$) in 1981, 38 ($1.02/\text{km}^2$) in 1982, and 18 ($0.49/\text{km}^2$) in 1983. A winter harvest of 3.9 beaver/colony in 1981 resulted in a 21% decline in active colonies; subsequent harvest of 3.2 beaver/colony in 1982 caused a 58% decline. In 1981 and 1982, 89% of the beaver harvest was achieved during the first 16 days of the season and involved 64% of the trapping effort. Lack of exploitation may have delayed sexual maturation and dispersal and increased the number of non-breeding adults. In 1981, 35% of the females ($N=51$) had placental scars, fewer ($P>0.05$) than the 80% ($N=25$) found in 1982. Breeding females averaged 3.1 placental scars in 1981 ($N=56$) and 3.6 in 1982 ($N=72$). Yearlings reproduced after 1 year of harvest when about 79% of the available colony sites were occupied. Despite an initial increase in reproductive effort after 1 season of harvest, the population was reduced after the 2nd harvest, apparently due to the effective system of harvest.

Muskrat harvest and number of trapnights declined ($P>0.05$) after 1981. Sex ratios of adults and juveniles favored males ($P<0.05$) all years. The harvest of 245 young/100 adults in 1981 was different ($P>0.05$) from the 180/100 adults in 1983, but not different from the 198/100

adults in 1982. Placental scars averaged 9.5/adult female (N=166) for the 3 years. Marsh fertility appears to influence sex-specific mortality and limit reproductive success of muskrats on Sandhill.

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EFFECTS OF TRAPPING ON BEAVER COLONY DENSITY, STRUCTURE, AND REPRODUCTION.

Nordstrom (1972) and Boyce (1974) conducted studies comparing the population dynamics and density between trapped and untrapped beaver populations. Parsons (1975) and Parsons and Brown (1978) investigated the effects of a 4-year closure of the beaver trapping season in New York, and Payne (1982) after a 5-year closure in Newfoundland. This study was undertaken to determine the influence of trapping on colony density, structure, and reproduction of a beaver population unexploited for at least 19 years.

STUDY AREA

Sandhill Wildlife Area, in central Wisconsin, has a 2.5-m high deer proof fence enclosing 37 km². The area is managed by the Wisconsin Department of Natural Resources as an experimental and demonstration area with emphasis on wildlife habitat and managed hunting. No furbearer trapping occurred on the area since the state bought the land in 1962; furbearer harvest records are unavailable before then. Habitat composition and forest management on Sandhill was described by Kubisiak et al. (1980). The property has 419 ha of surface water including 16 impoundments, 39 km of drainage ditch and a 0.8-km segment of stream. The drainage ditches are remnants of the farming attempts of the early

1900's (Grange 1949). Drainage ditches and impoundments are the major sources of permanent water. Impoundments are 0.6-0.9 m deep; drainage ditches average 1.2 m deep. Annual freezeouts and winter-kill of fish occur commonly in many of the shallow impoundments. The area is drained to the east and south by the Wisconsin River drainage system. Baldassarre and Nauman (1981) described vegetation cover types of emergent and submergent species in 2 major impoundments on Sandhill, and found low marsh fertility.

METHODS

A trapline system for beaver occurred on Sandhill during December 1981, 1982, and 1983. Each year, the 8 trappers involved reported daily at the Sandhill office the beaver harvest for each colony, capture date, number of trapnights, and carcass identification number. Carcasses were tagged through the tail with self-locking, numbered tags, and returned skinned the next day.

Tag numbers were attached to or placed with the jawbones and reproductive tracts. Reproductive tracts were preserved in 10% formalin and examined (Hodgdon 1949, Leege and Williams 1967). Ages of beaver were determined by basal closure and cementum annuli of teeth (van Nostrand and Stephenson 1964, Klevezal' and Kleinenberg 1967, Larson and van Nostrand 1968).

In fall 1981 and 1982, an aerial survey was conducted with a Cessna 337 Skymaster to determine the number of active beaver colonies (Hay 1958). Ground checks were

conducted each year to assure complete coverage and to verify active colony sites. In 1983 this census was based on complete ground coverage only. Beaver population density was expressed in colonies/km² due to the relatively flat terrain and numerous wetlands and impoundments (Hill 1982).

To determine colony size, age, and sex structure, selection of beaver colonies to be completely trapped each year was based on nuisance activities associated with the colony site. The state of Wisconsin prohibits beaver trapping within 4.6 m of the lodge and/or dam. This restriction was lifted on these selected colonies to facilitate removal of all beaver from the colony. Complete removal was determined by placing a piece of trembling aspen (Populus tremuloides) through the ice near the lodge entrance; evidence of gnawing on the branch indicated the presence of additional beaver (Payne 1982). Trappers provided additional information regarding the presence or absence of beaver activity. Age composition of beaver families was calculated (Novak 1977).

RESULTS

Colony Density and Harvest

We censused 48 colonies (1.30/km²) in 1981, 38 (1.02/km²) in 1982, and 18 (0.49/km²) in 1983. In 1981 we also censused 13 active colonies on a 31-km² area harvested next to Sandhill. Ground surveys were not conducted to verify active colonies on this area; actual density was probably between 0.42/km² and 0.52/km², assuming that 22%

were missed as were on Sandhill.

The beaver harvest was 183 in 1981, 116 in 1982, and 4 in 1983. Life table analysis of the 1981 sample indicated annual mortality was about 34%, which represents natural mortality for previous years from the unharvested population. Estimated harvest mortality was 72% in 1981 and 68% in 1982. In 1981 and 1982, 89% of the beaver harvest was achieved during the first 16 days of the season and involved 64% of the trapping effort (Table 1). Beaver were completely removed from 11 of 23 colonies to be completely trapped in 1981, and 12 of 25 in 1982. During 1983, only 2 colony sites were recolonized after complete removal in 1981 and 1982. In 1981, 137 beaver were removed from 35 incompletely trapped colonies ($\bar{x} = 3.9/\text{colony}$) and 81 from 25 colonies in 1982 ($\bar{x} = 3.2/\text{colony}$).

Colony Structure

The sex ratio of 75 beaver (97 males:100 females) in 23 colonies completely trapped, and 223 other beaver (85 males:100 females) trapped during 1981 and 1982, was not different. The mean age in 1981 ($N=183$) was 2.9 years, different ($P<0.05$) from 2.2 years in 1982 ($N=116$). Kits comprised 34% of the harvest in 1981 and 58% in 1982. The sample consisted of 43% adults (2.5 years and older) in 1981 and 32% in 1982.

There were more ($P<0.05$) single and pair colonies in 1982 than in 1981 (Table 2). Of the colonies trapped, 9% ($N=46$) were single or pair in 1981 and 22% ($N=37$) in 1982.

The average size of 23 completely trapped family colonies was 5.4 beaver/colony (range 4-8). Average colony size was 3.4 beaver/colony with single and pair colonies included (Table 3). Average colony size decreased 31% from 1981 to 1982. Family size, calculated with capture data (Novak 1977), was 5.7 beaver in 1981 and 5.4 in 1982. Calculations indicated that the average family colony had 1.89 kits, 1.34 non-breeding yearlings and 2.47 adults in 1981, and 3.13 kits, 0.22 breeding yearlings, 0.32 non-breeding yearlings and 1.87 adults in 1982.

Of the 35 family colonies incompletely trapped, 26% ($N=35$) had 2.5-year-olds in 1981, and 0 ($N=25$) in 1982. In 1981, 2 family colonies completely trapped had 4 or more beaver 2.5 years old or older, of which each had 2 or 3 beaver 2.5 years old. Of 11 family colonies completely trapped, 3 (27%) had 3 beaver 2.5 years old or older. In both years, of 9 pair colonies completely trapped, 8 had yearlings. In both years, all 11 family colonies completely trapped contained kits. In 1981, all 7 family colonies had 15 kits (2.14 kits/colony); in 1982, all 4 family colonies had 12 kits (3.00 kits/colony).

Some colonies consisted of atypical situations. In 1981 1 colony had 14 beaver removed. Six ageclasses were present; 3 kits, 4 yearlings, 3 2.5-year-olds, 2 3.5-year-olds, 1 8.5-year-old, and 1 10.5-year-old. Reproductive tracts from 2 females indicated previous parturition. An adult female with 4 placental scars was found dead during summer

1982; 4 kits were harvested from that colony that fall.

Reproduction

Logarithmic regression of female age (kits omitted) and mean number of placental scars/female resulted in a correlation coefficient of 0.563 ($N=51$) in 1981 and 0.579 ($N=25$) in 1982. No females younger than 3 years bred in 1981; yearlings and 2-year-olds bred in 1982.

In 1981, 35% of the females ($N=51$) had placental scars, fewer ($P>0.05$) than the 80% ($N=25$) found in 1982. Excluding yearlings, 58% ($N=31$) had placental scars in 1981, fewer ($P>0.05$) than the 86% ($N=25$) in 1982. Breeding females averaged 3.1 placental scars in 1981 ($N=56$) and 3.6 in 1982 ($N=72$). There was a difference ($P>0.05$) between the 2 means when the breeding yearlings were excluded.

DISCUSSION

Density and Harvest

Beaver colony density throughout North America varies widely and depends on habitat quality, trapping intensity (Larson and Gunson 1983), and mutually exclusive territories (Bergerud and Miller 1977). Availability of suitable sites for lodge and cache construction and adequate forage influences distribution of colonies (Boyce 1981a). Replacement of conifers by deciduous trees through active forest management has expanded potential beaver habitat and increased population levels in Ontario (Ingle-Sidorowicz 1982). Unexploited populations in Alberta indicated 1.06 colonies/km² in 1976, 1.07 in Manitoba during 1973-80

(Larson and Gunson 1983), and $0.34/\text{km}^2$ in Newfoundland (Payne 1984**b**) where habitat quality for beaver is marginal (Payne 1984**a,b**). Comparison of trapped and untrapped populations indicated higher densities without trapping in New Brunswick (Nordstrom 1972) and New York (Parsons and Brown 1978).

Parsons and Brown (1981) reported a harvest of 2.0 beaver/colony resulting in a 39% decline of active colonies with a 37-day February-March trapping season in New York. Similar seasons appeared to stabilize the population at the reduced level. During a 14-16-day February season resulting in a harvest of 1.8 beaver/colony, colonies declined 27% initially; similar seasons increased the original beaver population level (Parsons and Brown 1981). Trapping season length accounted for annual variation in Missouri beaver harvests (Erickson 1981). A winter harvest of 3.9 beaver/colony in 1981 on Sandhill resulted in a 21% decline in active colonies; subsequent harvest of 3.2 beaver/colony in 1982 caused a 58% decline. Trappers took 89% of the total beaver harvest during the 1st 16 days of December. Colony density during 1983 was reduced to levels found in the trapped population censused outside Sandhill in 1981, which had similar habitat. A 21% reduction in colony density indicated a 33% decline in the estimated beaver population from 1981 to 1982 on Sandhill. Swenson et al. (1983) suggested that cache surveys were unreliable in indicating population size or trend of beaver.

The overall annual mortality (34%) before 1981 is

similar to the 28% from unharvested and 27% from harvested populations in Newfoundland (Payne 1984a), and the 31% from those exploited in Saskatchewan (Gunson 1970). During winter 1981, tularemia (Francisella tularensis) was identified in beaver on Sandhill and may have increased mortality above normal. Tularemia outbreaks were not documented on Sandhill before 1981. Extensive surveys indicated 4 beaver colonies were eradicated by tularemia in 1981. Tularemia epizootics have been linked to overpopulation in beaver (Banfield 1954).

Reproduction

An increase in the mean litter size and pregnancy rate suggests compensatory reproduction in beaver on Sandhill after 1 year of exploitation. Adult pregnancy rates (86%) in 1982 after 1 year of harvest were similar to the 87% in north-central Wisconsin (Peterson 1979) from a regularly harvested population. Pregnancy rates (58%) in 1981 were low compared to the 87% in Massachusetts (Lyons 1979), and the 86% in New York (Parsons and Brown 1978) from unexploited populations. Reduced pregnancy rates after fall harvest have been reported in Idaho (Leege and Williams 1967), Maine (Hodgdon and Hunt 1955), and Minnesota (Longley and Moyle 1963) due to potential disruption of the dominant breeding pair. The increased pregnancy rate on Sandhill during 1982 suggests replacement of a dominant breeder by a delayed disperser (Brooks et al. 1980, Payne 1984b), because the percentage of colonies with such breeders was high and

probably density dependent (Molini et al. 1981).

Delayed sexual maturation may have reduced reproduction of beaver before exploitation. After exploitation, yearlings bred and the number of non-breeding adults decreased. Lack of exploitation of beaver can delay age at 1st reproduction (Lyons 1979, Boyce 1981b) and increase the number of non-breeding adults (Nordstrom 1972). Parsons and Brown (1979) found little or no yearling reproduction when more than 40% of the potential colony sites were occupied. Unexploited populations have available colony sites saturated with territorial adults; fewer dispersers can colonize them (Boyce 1981b). Probably most or all available colony sites were occupied on Sandhill in 1981 after at least 19 years of unexploited growth. In 1982, yearling reproduction was found after 1 year of harvest when about 79% of the available colony sites was occupied. Yearling reproduction can be important to beaver population growth if many yearlings disperse, establish colonies, and are dominant females (Payne 1982, 1984b). Beaver productivity is characterized by low average litter size and pregnancy rates for young and old beaver, with peak production during middle years (Payne 1984b). Despite increased reproduction in older and potentially more productive beaver, the population declined after 2 years of intensive harvest on Sandhill when harvest mortality exceeded capability for compensatory reproduction.

Colony Structure

More single and pair colonies were found on Sandhill 1 year after trapping than the previous year, as Payne (1982) found. More yearlings occurred in pair colonies the 1st year, a possible result of high colony density (Payne 1982). The average colony size decreased after exploitation due to harvest mortality and dispersal of 2.5-year-old or older beaver. Family colonies normally do not contain 2.5-year-olds due to normal dispersal of juveniles when they are 2 years old (Leege 1968). Failure to disperse has been attributed to lack of colonization sites and high colony density (Novakowski 1965, Norstrom 1972, Bergerud and Miller 1977, Payne 1982). Computer simulation indicates that the number of beaver colonies in which subadults delayed dispersal, increased substantially after 20 years of unexploited population growth (Molini et al. 1981). Individuals delaying dispersal could be larger and behaviorally more prepared for future dispersal (Novakowski 1965). Delayed dispersers could therefore have a selective advantage over younger dispersers at high population densities when suitable colony sites are limited (Molini et al. 1981).

Many of the shallower impoundments and associated wetlands freeze solid in winter on Sandhill, resulting in inaccessible browse piles, and possible starvation of the colony. Winter starvation was thought to be limiting in the Northwest Territories (Aleksiuk 1968) and Alaska (Boyce 1974).

Exploitation of beaver on Sandhill reduced the mean age and number of adults. The mean age of 2.9 years for the 11 completely trapped colonies in 1981 is similar to the 2.98 years for 11 completely trapped colonies in Alaska (Boyce 1974) but not with the 3.81 years for 11 completely trapped colonies previously unharvested in Newfoundland (Payne 1982). Nordstrom (1972) and Boyce (1974) found that untrapped populations contained more adults than trapped populations. A higher beaver density in untrapped populations results in reduced productivity and fewer beaver in the younger age-classes (Nordstrom 1972).

The average age of 2.2 years in 1982 after 1 year of harvest is similar to 2.57 years in Ohio (Henry and Bookhout 1969), and 2.35 years in Saskatchewan (Gunson 1970) from regularly harvested populations. Peterson (1979) found a mean age of 1.64 years for 41 completely trapped nuisance colonies in north-central Wisconsin, where size and age structure were influenced by intense year-round trapping.

MANAGEMENT IMPLICATIONS

Eliminating trap restrictions that prohibit trapping near the lodge would facilitate complete removal of nuisance colonies. Removal of an adult after freeze-up, but before the breeding season, will reduce pregnancy rates. Replacement of a dominant breeder by a subadult probably will result in smaller litters and lower survival of offspring. Beaver trapping in late fall-early winter in Wisconsin could increase trapping effort and beaver harvest

due to milder temperatures, open water or less ice, and more beaver activity around the lodge compared to later and longer beaver seasons. A harvest of more than 3.0 beaver/colony may be necessary in saturated populations to exceed capability for compensatory mortality and reproduction the 1st year, with perhaps lower harvests thereafter to reduce beaver populations.

Maintaining beaver populations at lower carrying capacity would lower the minimum breeding age and would prevent females from reaching ages of optimal productivity (Payne 1984b). Regular harvest without complete removal would maintain territories and prevent dispersers from recolonizing vacant colony sites. Maintaining conifers or advanced seral stages of vegetation along water would deter colony site selection, spacing, and reproduction (Boyce 1981a). A trapline system of harvest can be effective in achieving a high harvest of beaver (Payne 1980).

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Table 1. Cumulative percentages of beaver harvest and trapping effort on Sandhill Wildlife Area, Wisconsin, December 1981-82.

Date	Harvest		Trapnights	
	<u>N</u>	<u>%</u>	<u>N</u>	<u>%</u>
2	24	8.1	217	2.7
3	32	18.9	261	6.0
4	29	28.7	317	10.0
5	29	38.5	296	13.7
6	17	44.3	324	18.3
7	23	52.0	325	21.9
8	16	57.4	341	26.2
9	9	60.5	349	30.6
10	12	64.4	335	34.8
11	21	71.6	348	39.2
12	19	78.0	345	43.5
13	15	83.1	350	47.9
14	9	86.1	352	52.4
15	4	87.5	350	56.8
16	3	88.5	294	60.4
17	1	88.9	290	64.1
18	2	89.5	300	67.9
19	4	90.9	112	69.3
20	7	93.2	274	72.7
21	1	93.6	257	76.0
22	1	93.9	253	79.2
23	2	94.6	244	82.2
24	2	95.3	233	85.2
25	0	95.3	152	87.1
26	0	95.3	149	89.0
27	5	97.0	228	91.8
28	1	97.3	212	94.5
29	3	98.3	154	96.4
30	1	98.6	149	98.3
31	4	100.0	135	100.0

Table 2. Number of single, pair, and family beaver colonies trapped on Sandhill Wildlife Area, Wisconsin, 1981-82.

Year	Single		Pair		Family		N colonies trapped	N colonies present
	<u>N</u>	%	<u>N</u>	%	<u>N</u>	%		
1981	1	2.2	3	6.4	42	91.3	46	48
1982	2	5.4	6	16.2	29	78.4	37	38
1981-82	3	3.6	9	10.7	71	85.5	83	86

Table 3. Average colony size from beaver colonies completely trapped on Sandhill Wildlife Area, Wisconsin, 1981-82.

Colony Type	1981	1982	Both
Family			
No. beaver	39	21	60
No. colonies	7	4	11
Beaver/colony	5.6	5.2	5.4
Single and pair			
No. beaver	7	14	21
No. colonies	4	8	12
Beaver/colony	1.8	1.8	1.8
Combined			
No. beaver	46	35	81
No. colonies	11	12	23
Beaver/colony	4.2	2.9	3.0

STRUCTURE OF AN UNHARVESTED MUSKRAT POPULATION IN AN INFERTILE WETLAND

Muskrat (Ondatra zibethicus) populations that are not controlled can affect marsh dynamics and reduce the value for other aquatic wildlife. Mathiak and Lynde (1954) indicated that habitat deterioration, disease outbreaks, and low reproduction often are associated with insufficient harvest. Mathiak (1966) substantiated these findings on Horicon Marsh Wildlife Area in Wisconsin. Few studies have described unexploited muskrat populations. Even fewer have related food quality to population size or reproduction (Smith and Kadlec 1984). This study was undertaken to determine sex and age structure, and reproduction of a muskrat population unexploited for at least 19 years in an infertile wetland.

STUDY AREA

Sandhill Wildlife Area, in central Wisconsin, has a 2.5-m high deer proof fence enclosing 37 km². The area is managed by the Wisconsin Department of Natural Resources as an experimental and demonstration area with emphasis on wildlife habitat and managed hunting. No furbearer trapping occurred on the area since the state purchased the land in 1962; furbearer harvest records are unavailable before then. Habitat composition and forest management on Sandhill was

described by Kubisiak et al. (1980). The property has 419 ha of surface water including 16 impoundments, 39 km of drainage ditch and a 0.8-km segment of stream. The drainage ditches are remnants of the farming attempts of the early 1900's (Grange 1949). Drainage ditches and impoundments are the major sources of permanent water. Impoundments are 0.6-0.9 m deep; drainage ditches average 1.2 m deep. Annual freezeouts and winter-kill of fish occur commonly in many of the shallow impoundments. The area is drained to the east and south by the Wisconsin River drainage system. Baldassarre and Nauman (1981) described vegetation cover types of emergent and submergent species in 2 major impoundments on Sandhill, and found low marsh fertility.

METHODS

A trapline system for muskrats occurred on Sandhill during 1-12 November and 1-31 December 1981, 1982, and 1983. The November season was limited to the south half of Sandhill; 5 trappers received traplines designed to distribute muskrat habitat equally and provide adequate access. The December season included the southern and northern halves of Sandhill, and 3 more trappers. Trappers were reassigned trapping compartments during the December season to distribute the number of beaver (Castor canadensis) colonies equally.

Trappers reported daily at the Sandhill office the muskrat harvest, capture date, number of trapnights, and carcass identification number. Carcasses were tagged

through the tail with self-locking, numbered tags, and returned skinned the next day.

Tag numbers were attached to or placed with the skull and reproductive tract. Reproductive tracts were preserved in 10% formalin and examined for placental scars (McCann 1944, Sooter 1946, Gashwiler 1950). Accurate placental scar counts can be made on muskrats trapped in November and December (Errington 1963). Muskrats were sexed by internal examination of gonads (Errington 1937), and aged by zygomatic arch measurement (Alexander 1951) and fluting length of the upper 1st molar (Olsen 1959). Intrauterine and juvenile mortality to harvest was estimated by dividing the juvenile:adult female by placental scar:adult female ratio.

RESULTS

The muskrat harvest (2324 in 1981, 1464 in 1982, 512 in 1983) and number of trapnights (8488 in 1981, 5915 in 1982, 2567 in 1983) declined ($P > 0.05$) after 1981. Linear regression of number of trapnights and muskrat harvest resulted in a correlation coefficient of 0.999. A decline in muskrat pelt value (\$4.13 in 1981, \$2.69 in 1982, \$3.08 in 1983) (Pils 1983) may have influenced trapping effort for muskrats on Sandhill. The average harvest in open water and marsh habitat was 1.1 muskrat/ha.

Sex ratios of adults and juveniles favored males ($P < 0.05$) all years (Table 1). There was no difference in the percentage of juvenile males between years of harvest. There was a higher percentage ($P < 0.05$) of adult males in

1982 and 1983 than 1981. The juvenile and adult sex ratios in 1981 were not different; they were different ($P > 0.05$) in 1982 and 1983.

The harvest of 245 young/100 adults in 1981 was different ($P > 0.05$) from the 180/100 adults in 1983, but not different from the 198/100 adults in 1982 (Table 2). Placental scars averaged 9.5/adult female ($N=166$) for the 3 years. Intrauterine and juvenile mortality to harvest was 35% in 1981, 39% in 1982, and 41% in 1983 (Table 2).

DISCUSSION

Harvest

Variation in annual muskrat harvests has been related to availability of habitat, annual precipitation (Neal 1977), trapping season length and recruitment (Erickson 1981), muskrat density and geographical area (Harris 1952). The amount of open water and marsh habitat remained constant during the 3-year trapping period on Sandhill. Annual precipitation and temperature did not deviate from normal. Muskrat harvest on Sandhill was directly associated with trapping effort which probably was influenced by pelt value. Harvest effort often is treated as a direct function of mean pelt value in the harvest analyses for high-demand furbearers (Erickson 1981).

Beer and Truax (1950) reported a mean catch of 10.6 muskrats/ha in apparently more productive south and central Wisconsin marshes. A harvest of 23 muskrats/ha was not high enough to prevent overpopulation and habitat deterioration

in northwestern Iowa (Neal 1977). Underharvesting may result in extensive eat-outs that seriously reduce muskrat populations (Ferrigno 1967). Low populations of muskrats in some Louisiana marshes were attributed to previous overpopulation and undertrapping (O'Neil 1949). The low muskrat harvest on Sandhill may result from low density due to over-exploitation of habitat by muskrats in the absence of trapping for at least 19 years, and low marsh fertility (Baldassarre and Nauman 1981).

Sex Ratios

Dozier et al. (1948) found no differential sex-specific trapping mortality between fall and early spring muskrats over a 5-year period in Maryland. Likewise, Beer and Truax (1950) found sex ratios in fall and early winter to be representative of the actual population in Wisconsin marshes. A predominance of males can be expected in a muskrat population from the nestling age to the spring of their 1st breeding season (Errington 1963). Intra-specific strife, predation, and accidents due to increased movements are important factors in selective mortality in males during the breeding season (Beer and Meyer 1951), and may cause a more balanced adult sex ratio.

Spring breeding density seems directly related to adult male mortality (Errington 1963). Low breeding density on Sandhill may have reduced male mortality resulting in more adult males than females, especially in 1982 and 1983. Harvest in 1981 and 1982 may have reduced spring breeding

density and ultimately reduced adult male mortality. Neal (1968) found sex ratios were only slightly unbalanced in good habitat and strongly unbalanced in poor habitat with increased male mortality.

Age Ratios

Low age ratios on Sandhill occurred after at least 19 years of no harvest, and indicate low density compared to other more productive Wisconsin marshes. Beer and Truax (1950) reported a mean of 7.2 young/adult female (range 3.7-21.6) and Mathiak (1966) reported 7.8 (range 3.1-13.3) in southern Wisconsin. Errington (1963) suggested an inverse relationship between the population density and the ratio of young to adults in the fall population. Low age ratios, i.e. recruitment, tend to occur after years of light harvest, and high age ratios after heavy harvest (Errington 1963).

Annual muskrat reproduction on Sandhill did not fluctuate substantially and averaged 9.5 scars/adult female for the 3 years. Previous studies indicated a mean of 15 scars/adult female at similar latitudes (Gashwiler 1948). Harvest intensity did not appear to influence production. Trapping pressure appeared to influence juvenile survivorship rather than reproduction in Connecticut (Smith et al. 1981). Errington (1951) suggested that muskrat mortality is compensatory, and survival of young is inversely related to the spring breeding density. Neal (1968) and Danell (1978_{a,b}) indicated that muskrats living

in poor habitat have lower age ratios, shorter breeding seasons, produce fewer and smaller litters and probably have lower survival rates.

During winter 1981, tularemia (Francisella tularensis) was identified in beaver and muskrat on Sandhill. Decomposed carcasses were found after ice break-up throughout Sandhill. The higher age ratio and lower juvenile mortality in 1981 probably was a compensatory response to the added mortality. Tularemia outbreaks were not documented on Sandhill before 1981. Tularemia epizootics have been linked to conditions of over-population in muskrats (Parker et al. 1951, Ditchfield et al. 1960).

Soil nutrient levels of marshes on Sandhill are low compared to other more productive marshes in Wisconsin (Baldassarre and Nauman 1981). Water quality of 2 flowages on Sandhill is characterized by low nutrient levels and alkalinity less than 9 mg/l (Baldassarre and Nauman 1981). Linde (1969) defined unproductive marsh waters in Wisconsin as having an alkalinity less than 10 mg/l. Nutrient content of aquatic plants is thought to increase with increasing marsh nutrient levels (Boyd and Hess 1970). Ankney and MacInnes (1978) suggested greater reproduction in snow geese (Chen caerulescens) feeding on higher quality forage. Beaver feeding on trembling aspen (Populus tremuloides) have larger litters than those on willow (Salix spp.) (Huey 1956), and probably select higher nutritive foods (Jenkins 1978). Marsh fertility appears to limit reproductive success of muskrats

on Sandhill. More studies are needed to determine physiological responses of muskrats to higher nutritive quality vegetation.

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Table 1. Comparison of juvenile and adult sex ratios on Sandhill Wildlife Area, Wisconsin, 1981-83.

Year	Sample <u>N</u>	Males			
		Juvenile		Adult	
		<u>%</u>	<u>N</u>	<u>%</u>	<u>N</u>
1981	604	59.9	257	57.1	100
1982	447	57.5	171	68.0	102
1983	396	57.6	147	69.5	98

Table 2. Age ratios and mortality of muskrats trapped on Sandhill Wildlife Area, Wisconsin, 1981-83^a.

Age ratio	1981	1982	1983
<u>N</u> juveniles/adult female	5.7 (75)	6.2 (48)	5.9 (43)
<u>N</u> placental scars/adult female	8.8 (75)	10.1 (48)	10.0 (43)
Mortality rate ^b	0.35	0.39	0.41

^a Sample size in parentheses.

^b Intrauterine to November and December when trapped.

Appendix A. Trapping application used for the 1983 furbearer seasons at Sandhill Wildlife Area, Wisconsin.

INSTRUCTIONS:

1. No more than one application is permitted for each trapper applying in the random drawing.
2. List your name & address on this form. Be sure to include your 1982-84 Trapping License Number.
3. Return your completed application to: DEPARTMENT OF NATURAL RESOURCES, SANDHILL TRAPPING PERMIT, BOX 156, BABCOCK, WI 54413.
4. Applications must be postmarked by October 7, 1983 to be accepted for drawing.
5. No charge for this application.
6. Permits will be issued on a random drawing basis. The random drawing will be held at the Sandhill Headquarters on October 14, 1983 at 1:00 p.m.
7. Trapping seasons will be as follows:
*Muskrat, Mink, Raccoon - No bag limit. October 29, 1983 - November 8, 1983, December 3, 1983 - December 29, 1983.
 *Wet set or water set only for these species.
Beaver - No bag limit. December 3, 1983 - December 29, 1983.
8. All species not specifically mentioned above will be closed to trapping (includes otter, fox, coyote, etc.).
9. Trapping hours will be from 6:00 a.m. - 4:00 p.m. (CST).
10. Only authorized trappers will be allowed on the area during the trapping periods.
11. All current Wisconsin trapping regulations will apply.
12. Sandhill trappers will be expected to set and maintain a reasonable number of traps on an independent basis.

1983 SANDHILL TRAPPING APPLICATION

A controlled experimental furbearer trapping season has been established on the Sandhill Wildlife Area for the 1983 season. The objectives of the season will be to gather research information on furbearers, and, to assess trapper characteristics and techniques. Although trappers will be allowed to retain all fur trapped on the area, they will be required to work closely with research personnel on the area in the collection of furbearer data. We are asking you to answer the questions on the right side of this form. This part of the application is purely voluntary and will not affect your eligibility in the permit selection process. Season established pursuant to Section N.R. 10.22, Wisconsin Administrative Code.

1983 TRAPPING LICENSE NUMBER
NAME
STREET OR ROUTE
CITY, STATE, ZIP CODE

1. What is your age? _____
2. How many years have you trapped furbearers? _____
3. Are you a member of the Wisconsin Trappers Association? _____
4. What county(s) do you normally trap? _____
5. Of the following, which most closely approximates your last years trapping income? Check one.
 - Less than \$100.00 - More than \$100.00 but less than \$500.00
 - More than \$500.00
6. Have you ever attended a sponsored trapping clinic? yes no
7. Do you trap for - income?
 - sport?

Appendix B. Trapping contract used for the 1981-83 furbearer seasons at Sandhill Wildlife Area, Wisconsin.

TRAPPING CONTRACT FOR SANDHILL WILDLIFE AREA

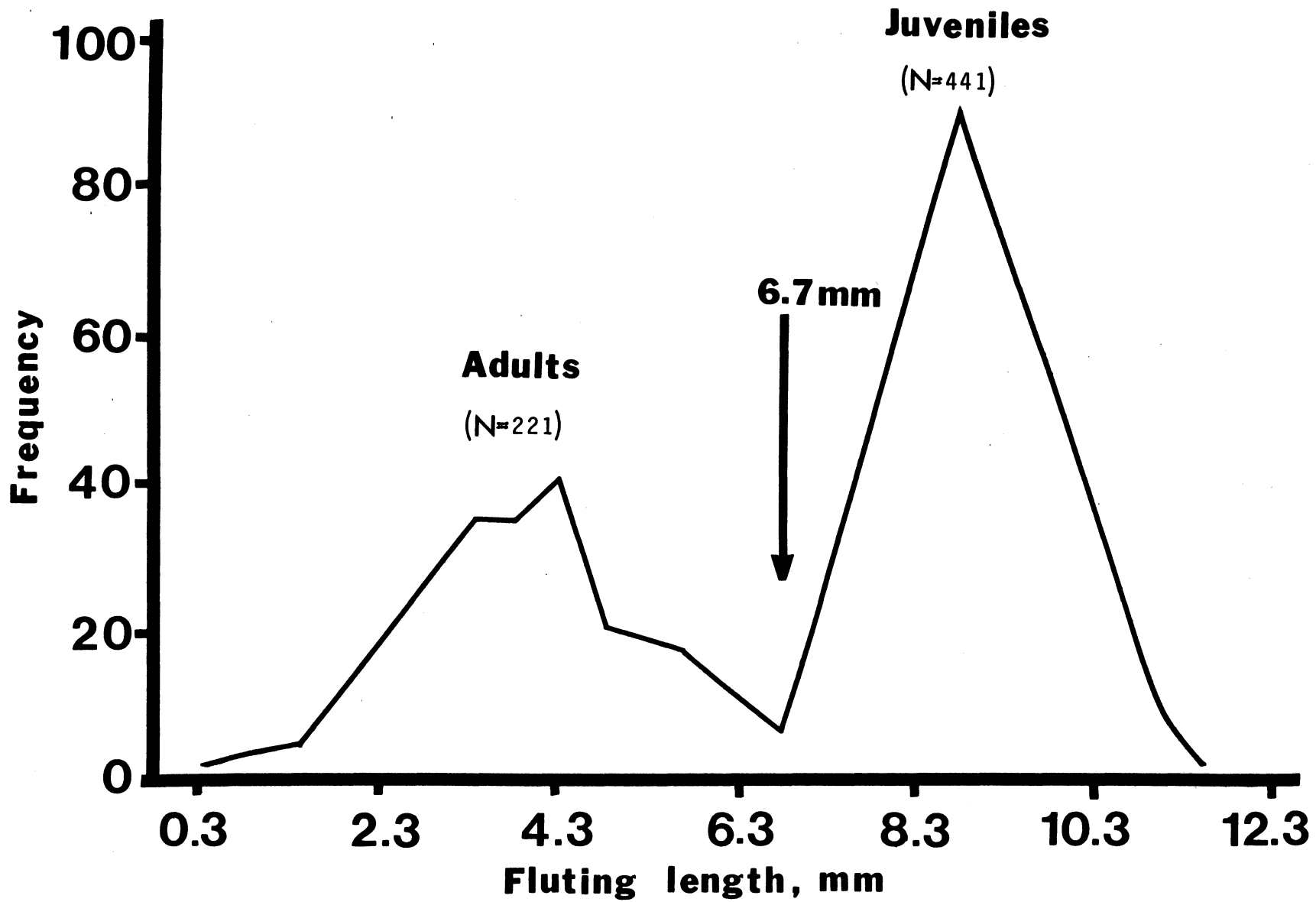
This contract is voluntarily entered into by and between the Department of Natural Resources, State of Wisconsin, hereinafter referred to as DNR and _____, hereinafter referred to as trapper, subject to and in consideration of the following terms and conditions:

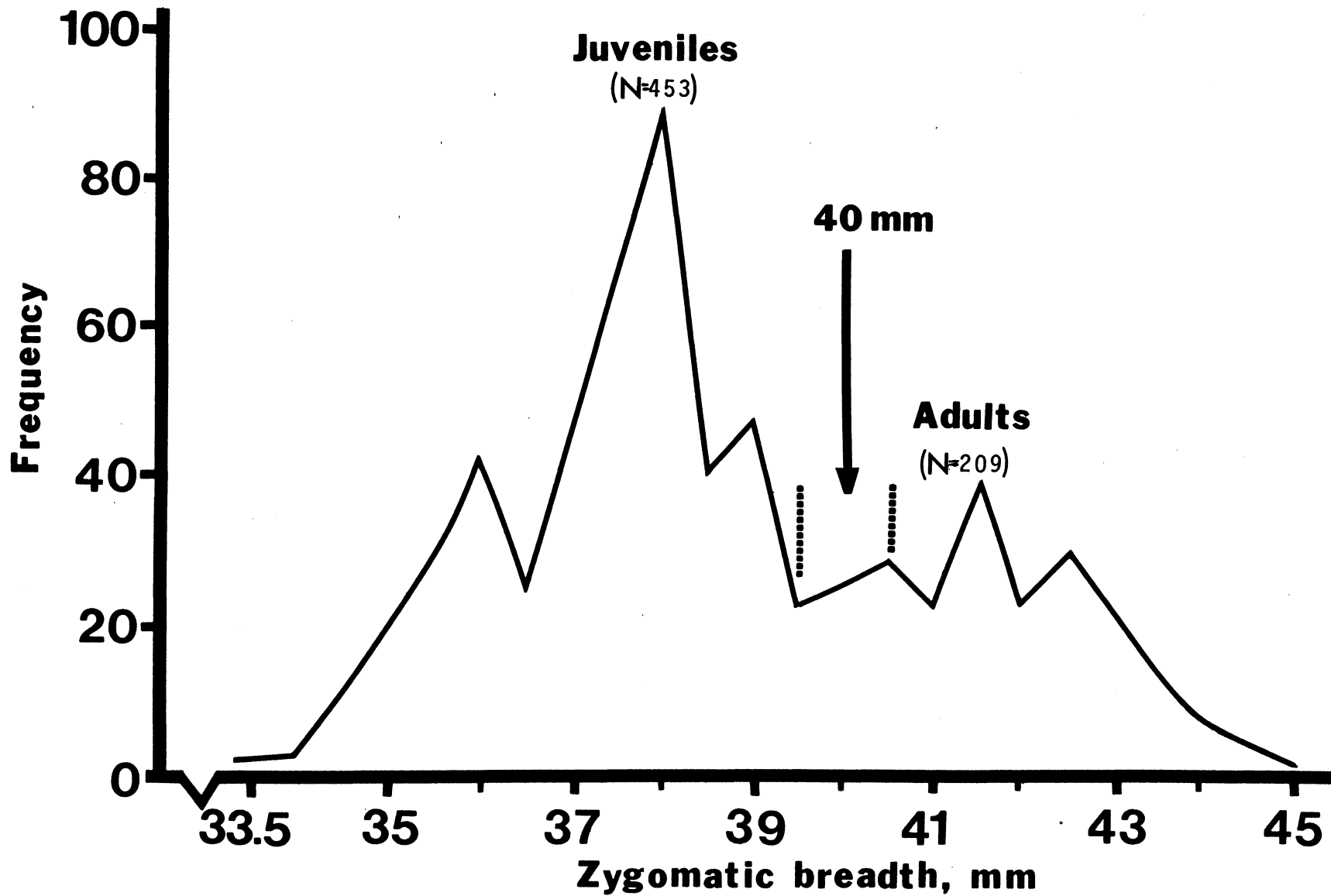
1. This contract shall cover the period beginning _____ and ending _____. The trapper may trap beaver, muskrat, mink and raccoon (water sets only). No trapping will be allowed on refuge area until _____.
2. In the event the DNR determines there is any default on the part of the trapper in the performance of this contract, this contract immediately terminates without notice.
3. The trapper shall have the right to trap animals authorized by this contract in Unit _____, which is described on the attached map made a part hereof by reference, within the boundaries of the Sandhill Wildlife Area in Wood County, Wisconsin.
4. The trapper during the period of this contract shall comply with all state laws and regulations pertaining to trapping. Violations of any trapping regulations will constitute a breach and terminate this contract.
5. All trap stakes shall be removed when traps are pulled up.
6. This trapping contract shall not restrict the DNR from carrying out wildlife management practices such as controlled burning, manipulation of water levels, etc.
7. The trapper under this contract is in the status of an independent contractor, and shall not be considered at any time to be an agent or employe of the DNR.
8. These trapping rights may not be transferred in whole or part.
9. The trapper assumes and agrees to protect, indemnify, and save harmless the Department, its agents, officers, and employees from and against any and all claims, demands, suits, causes of action, liability, costs and expenses arising out of any action or interaction of the trapper, its agents, officers and employees, regarding at least any property damage or personal injury, including death, and trapper agrees to defend the Department in any such cause of action, claim demand or suit.
10. The trapper agrees to abide by the following specific regulations, hereinafter made a part of this contract.
 - A. All trappers selected will be assigned designated areas or compartments to trap. They will be allowed to trap only in their assigned areas unless otherwise instructed.
 - B. Legal trapping methods and procedures shall be the same as specified in the 1981-82 Wisconsin Trapping Regulations pamphlet. All current Wisconsin trapping regulations will apply unless otherwise specified.

Appendix B. Continued.

- C. Access to assigned trapping areas will be worked out on an individual basis with each assigned trapper. Trappers will be expected to adhere to their assigned access routes. Touring or joy riding in areas other than those assigned is strictly prohibited.
 - D. The use of motor boats, snowmobiles, mini-bikes, ATV's, or ORV's or similar devices is prohibited.
 - E. Trapping hours will be from 6:00 A.M. to 4:00 P.M. Trappers will not be allowed on the area before 6:00 A.M. or after 4:00 P.M.
 - F. Only authorized, permitted trappers will be allowed on the area during the trapping periods. All trappers will be expected to operate on an independent or singular basis.
 - G. Trappers will be required to set and maintain a minimum of _____ traps and no more than 75 traps when trapping muskrat, raccoon and mink. The minimum number of traps must be set by the end of the second trap day of each season and maintained during the remaining open season.
 - H. Only wet-set and water-set trapping will be permitted for muskrat, mink and raccoon. Upland and dryland sets are strictly prohibited.
 - I. Trappers will be required to set and maintain a minimum of _____ traps and no more than 75 traps when trapping beaver. The minimum number of traps must be set by the end of the second day of the season and maintained during the remaining open season.
 - J. All traps must be checked at least once every 24 hours and animals removed.
 - K. Any dead, protected animals captured while trapping shall be turned in by providing location information for field pick-up to DNR at the Sandhill Headquarters.
 - L. All live, protected animals captured while trapping shall be released immediately.
 - M. Upon leaving Sandhill, trappers will be required to display any and all fur taken to the DNR at the Sandhill Headquarters for tagging and collection of research information.
 - N. All tagged carcasses shall be turned in to DNR at the Sandhill Headquarters after skinning.
 - O. Trappers will be prohibited from hunting while trapping on the area.
11. This contract may be terminated upon 24 hours oral notice by the DNR's superintendent of the Sandhill Wildlife Area.







Appendix E. Characteristics of trappers involved in trapping seasons at Sandhill Wildlife Area, Wisconsin, 1981-83.

	Year		
	1981	1982	1983
<u>N</u> Applicants	111	51	40
Oldest Applicant (years)	71	70	63
Youngest Applicant (years)	14	18	18
Mean applicant age (years)	37	36	36
Mean years trapping	18	20	19
Trapping motive (<u>N</u>)			
income	13	5	2
sport	49	6	21
both	49	40	17
Annual Trapping income (<u>N</u>)			
<\$100	7	3	0
\$100-\$500	37	12	21
>\$500	67	36	18

Appendix F. Muskrat harvest, number of trapnights, and harvest per trapnight on Sandhill Wildlife Area, Wisconsin, 1981-83.

	<u>Early season</u>			<u>Late season</u>			<u>Total</u>		
	1981	1982	1983	1981	1982	1983	1981	1982	1983
<u>N</u> harvested	1203	566	425	1121	898	87	2324	1464	512
<u>N</u> trapnights	3445	2334	2122	5043	3581	445	8488	5915	2567
Harvest per trapnight	0.35	0.24	0.20	0.22	0.25	0.20	0.27	0.25	0.20

Appendix G. Beaver harvest, number of trapnights, and harvest per 100 trapnights on Sandhill Wildlife Area, Wisconsin, 1981-83.

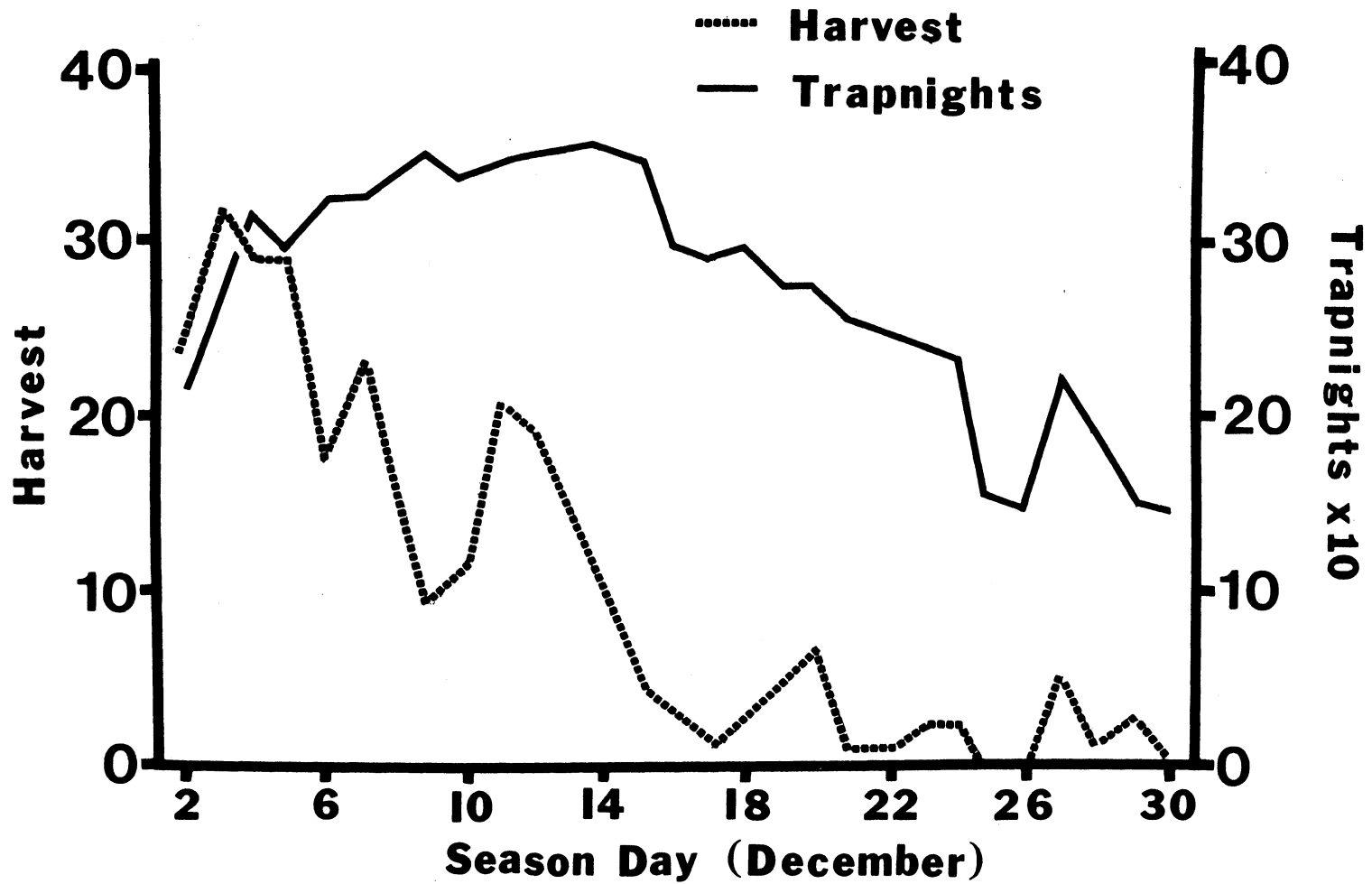
Year	<u>N</u> beaver harvested	<u>N</u> beaver trapnights	Beaver per 100 trapnights
1981	183	3870	4.73
1982	116	4314	2.69
1983	4	91	4.40

Appendix H. Number of beaver dams removed and drainage culverts opened relative to the number of active over-winter colonies and beaver harvest on Sandhill Wildlife Area, Wisconsin, 1979-83.

Year	<u>N</u> dams removed	<u>N</u> tubes opened	<u>N</u> active over-winter colonies	Beaver harvest
1979	137	155	UK	0
1980	115	111	UK	0
1981	302	142	48	183
1982	91	45	38	116
1983	34	21	18	4

UK= Unknown

Appendix I. Beaver harvest and trapping effort on Sandhill Wildlife Area, Wisconsin, 1981-82.



Appendix J. Time-specific life table of beaver trapped on Sandhill Wildlife Area, Wisconsin, 1981-82.

Age (years) x	N alive at start			Mortality rate q_x	L_x	T_x	Years life left e_x	Fecundity rate ^a m_x	$l_x m_x$
	Sample l'_x	Per 1000 l_x	N dead d_x						
1981									
0.5	62	1.000	0.323	0.323	0.8385	2.4350	2.435	0.000	0.000
1.5	42	0.677	0.306	0.452	0.5240	1.5965	2.357	0.000	0.000
2.5	23	0.371	0.177	0.477	0.2825	1.0725	2.891	0.000	0.000
3.5	12	0.194	0.049	0.252	0.4435	0.7900	4.072	0.875	0.170
≥ 4.5	43	0.693	0.145	0.209	0.3465	0.3465	0.500	1.105	0.766
Total	182	2.935	1.000	0.341	2.4350	6.2405	2.126		$R_0=0.936$
Mean >0.5	120	1.935	0.677	0.350		3.8055	1.967		
≥ 3.5	55	0.887	0.194	0.219		1.1365	1.282		
1982									
0.5	67	1.000	0.836	0.836	0.5820	1.2310	1.231	0.000	0.000
1.5	11	0.164	0.045	0.274	0.1415	0.6490	3.957	0.250	0.041
2.5	8	0.119	0.029	0.244	0.1045	0.5075	4.265	1.000	0.119
3.5	6	0.090	0.000	0.000	0.2240	0.4030	4.478	1.167	0.105
≥ 4.5	24	0.358	0.090	0.251	0.1790	0.1790	0.500	1.844	0.660
Total	116	1.731	1.000	0.578	1.2310	2.9695	1.715		$R_0=0.925$
Mean >0.5	49	0.731	0.164	0.224		1.7385	2.378		
≥ 3.5	30	0.448	0.090	0.200		0.5820	1.299		

^aAge-specific fecundity rate based on placental scars refers to previous year's reproduction, they are listed for the previous year.