Muskrat population studies at Horicon Marsh, Wisconsin. Number 36 1966

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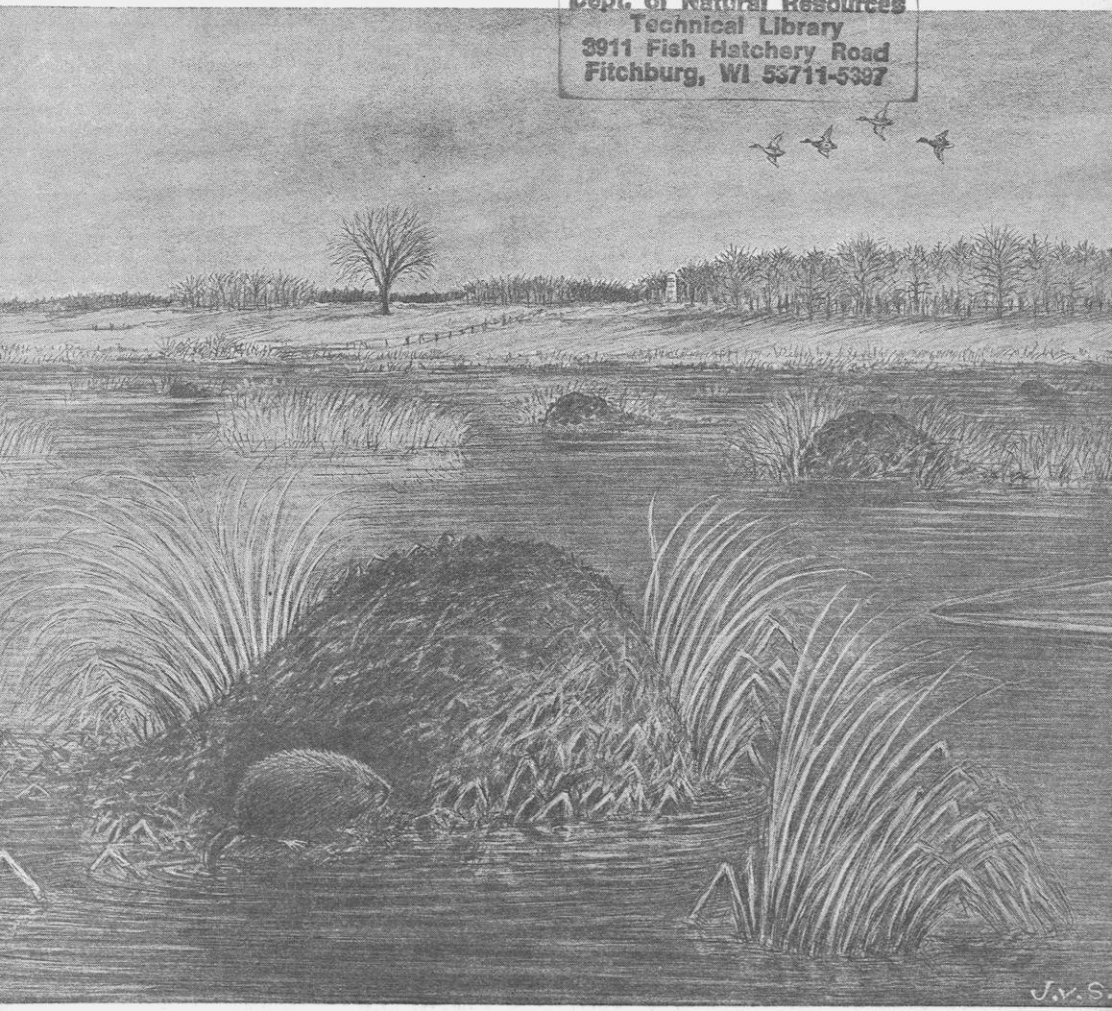
MUSKRAT POPULATION STUDIES
At Horicon Marsh, Wisconsin



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MUSKRAT POPULATION STUDIES AT HORICON MARSH

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Wayne C. Truax was leader of the Fur Research Project from 1947 until June of 1948 when he became manager of the Horicon Marsh Wildlife Area. Some of our studies could not have been made without his cooperation as Marsh manager and the cooperation of succeeding Marsh managers Harry Stroebe and James G. Bell. Robert Dobbratz of the Marsh staff gave substantial assistance by recording harvest data and searching thousands of trapped muskrats for ear tags.

Many members of the Wisconsin Licensed Muskrat and Beaver Farmers gave their time for field trips and shared their knowledge of muskrat management to help in the development of this study.

Finally, to the share-trappers of Horicon Marsh who cooperated in so many ways, our sincerest thanks. Separation of muskrat catches by trapping units, providing muskrats for examination, skinning muskrats at the office for breeding studies, handling diseased animals, and tolerance of our time-consuming pelt examinations were a few of the ways in which the share-trappers provided vital help to the Fur Project. Their spirit is probably best exemplified by one trapper who, on a winter day, responded to our plea for a live muskrat by bringing one back to the office in his lunch box.

Edited by James B. Hale and Ruth L. Hine

ABSTRACT

Research on muskrat populations was conducted from 1946 to 1963 on the 10,857-acre state-owned portion of Horicon Marsh, Wisconsin. The objective of this research was to gather biological data which would form a scientific and practical basis for muskrat management in the state. Muskrat population biology was studied mainly by following the fate of more than 6,000 muskrats ear-tagged as kits.

The earliest recorded litter birth-date was April 16, while May 10 was the mean date of peak litter production. Litter sizes ranged from 1 to 12 with a mean of 7.3. Precocial breeding by Horicon muskrats was negligible. Average weights were obtained for nine age classes of muskrats ranging from 100 to 950 days of age.

There was an average of 58 percent males in 460 complete litters examined. Likewise, there were 58 percent males among the 6,207 kits which were litter-tagged. Among 43,696 pelts of trapped immature muskrats, there were 57 percent males, indicating no apparent change in sex ratio from birth until mid-winter. There were practically equal numbers of males and females among 12,307 pelts of trapped adult muskrats. Age ratios obtained from 10 trapping units for five years varied widely between units and years, making questionable the value of age ratios as production indicators.

Movement data were obtained for 1,579 individual muskrats. Only 5 percent were considered to have made significant movement from the point of tagging and release. This 5 percent is believed to represent the part of a muskrat population responsible for repopulating isolated and unoccupied habitats. Tag recoveries indicated that a mortality of 87 percent from all causes occurred during the first year of life. Ninety-eight percent of a year class is removed by the end of the second trapping season. Only one fourth-year recovery was found during this study.

Major die-offs due to Errington's disease were experienced at Horicon in 1946 and 1953. Tularemia was known to be present at times because several trappers contracted the disease after handling muskrats.

A 20-year share-trapping program at Horicon Marsh resulted in a harvest of 267,756 muskrats. Gross revenue to the State of Wisconsin exceeded $217,000, of which about ¼ was disbursed to local governments in lieu of school taxes. This annual intensive trapping had very little effect on the muskrat population trends in comparison to natural controls such as disease, freeze-outs, and drought.

Underharvesting is more of a problem than overharvesting. Low pelt prices and greatly increased development of wetlands for other

wildlife indicate a greater need to develop muskrat control methods than to stimulate muskrat production.

Muskrat research on Horicon Marsh points toward one policy: muskrats must be adequately harvested. Harvest regulations must be kept flexible to assure harvests in the face of wide yearly variations in muskrat numbers, water conditions, and weather during trapping seasons.

Muskrat management has been greatly stimulated on private marshes by Wisconsin's fur-farm laws which encourage marsh development for fur production.

CONTENTS

INTRODUCTION

The muskrat has been a leading furbearer in Wisconsin, as well as in the United States, for many years. From 1948 through 1964, the estimated muskrat harvest for Wisconsin totalled 8,423,000, an average of more than 500,000 muskrats annually. The large numbers harvested kept the total income to trappers high, despite the relatively low value per individual pelt.

Several decades ago, when muskrat pelts were worth several dollars apiece, many far-sighted individuals bought marshes just for muskrat production. It was not uncommon for some of these men to recover their investment in one or two years through the sale of muskrat pelts. Special features of the Wisconsin fur-farm laws provided the incentive to purchase marshes and practice intensive management for muskrat production. Considerable ditching, diking, and other management practices were undertaken to maintain or increase production of muskrats.

There were many varieties of management, however, on private and public lands. Practices often seemed to have little scientific justification, even where the owner had a sincere desire to produce muskrats. For example, trapping ceased when disease was noted, or was omitted for a year in hopes of building up a very large crop the next year, or was done only in the spring of years when pelts seemed to be prime.

Similarly, governmental regulation of trapping in Wisconsin has often followed the lead of a minority of the state's trappers dissatisfied with the status quo and therefore most vociferous in any particular year at the time regulation changes were being considered. Special season regulations sometimes permitted better harvests when needed; at other times, regulation changes which would have salvaged a largely unutilized muskrat crop were not put into effect.

There was need for more information on muskrat biology and management methods, and many licensed fur farmers exerted a continuing demand for such information. At the same time, an accelerated wetland acquisition program by the Wisconsin Conservation Department created a parallel demand for improved techniques to be used in the management of public lands. To help meet these objectives and to gather biological data which could form a scientific and practical basis for muskrat management in Wisconsin, a fur research project was activated by the Conservation Department on October 1, 1946. Wayne C. Truax was leader of the project until June of 1948 when the author assumed charge.

Research on muskrat populations was concentrated on the 10,857-

acre state-owned portion of Horicon Marsh in Dodge County, Wisconsin, where conditions were ideal for investigating the numerous factors affecting muskrats. The area was large; it contained varied types of muskrat habitat ranging from bluejoint marsh to deep-water cattail marsh. Trapping could be regulated through the share-trapping program. Shop facilities were available for developing equipment. Lastly, there were substantial numbers of muskrats with which to work.

In addition to the work conducted at Horicon, managed marshes all over the state were inspected. These consisted mainly of private fur-farms and state or federally operated wildlife areas. Thus many types of management for muskrats were studied first-hand. Some inspections were activated by reports of disease or unknown factors depressing local muskrat populations.

A considerable amount of research and management information has come out of these studies, and findings on habitat management through level ditching, the role of refuges, growth and litter production and pelt patterns have been published (Mathiak and Linde, 1954 and 1956; Dorney and Rusch, 1953; Linde, 1963). This report presents a large series of population data, part of which formed the basis of the published bulletins, and several new concepts which strengthen management practices based on harvest considerations.

METHODS

Muskrat population biology was studied mainly by following the fate of individual animals ear-tagged as kits and subsequently recovered during trapping seasons. Muskrats for tagging were obtained by opening thousands of muskrat houses to capture and examine muskrat kits. More than 6,000 kits were tagged and released. They were sometimes captured in the nest, although often the more active kits escaped into plunge holes. It was then necessary to demolish most of the house to expose all of the plunge holes, and catch the kits as they surfaced for air. Relatively few kits were caught swimming outside the house. Demolished houses were partially rebuilt to provide shelter for kits until the mother could repair the house or move the kits to some other suitable house. As kits were caught by hand, they were placed in a pail until they could be measured, tagged, and released.

For aging purposes, the tail length of one kit per litter was recorded. Kits were aged according to tail-length criteria of Dorney and Rusch (1953). The smaller kits were sexed by visual examination, but with the larger, more heavily furred kits, palpation was necessary to

Open water areas in Horicon Marsh tend to be taken over by white water lilies, a good muskrat food.

determine the presence or absence of the os penis (Baumgartner and Bellrose, 1943).

In 1947 and part of 1948, all kits, regardless of size, were tagged with numbered fingerling tags (Aldous, 1946), but the smallest kits showed a very poor rate of return. Thereafter, tags were largely limited to use on kits with tail lengths measuring at least 65 mm — a criterion indicating that they were at least 12 days of age. Kits were tagged in all years from 1947 through 1957 except in 1952. Locations

of tagging were recorded according to the share-trapping units into which the marsh was arbitrarily divided.

Most recoveries of ear tags were made when trapped muskrats were brought by share-trappers to the checking station for examination. A few additional recoveries were made from winter runners or miscellaneous muskrats found dead on the marsh. Harvest information was recorded by day and trapping unit.

Ear-tag loss occurred to a small extent. Several times kits were recaptured which had freshly notched right ears, but the tags were missing. Because the tag loss seemed confined to certain litters and involved kits too small to tear out the tags themselves, the greatest tag loss must result from adults tearing or biting out the tags. A few tags were undoubtedly lost because of improper application. Haste during application, friskiness of the kits, or exceptionally heavy fur about the ears sometimes resulted in tags being clinched too close to the edge of the ear and subsequently lost.

To gain some idea of the magnitude of tag loss, kits were toe-clipped and ear-tagged at ages of 12 days or greater by Dorney and Rusch (1953) during their growth study in 1950. All of the muskrats harvested in their special study area were examined for evidence of toe-clipping and tag loss, and six cases of tag loss were found among 88 recaptured kits (6%). The intensive nature of the Dorney and Rusch study resulted in far more handling of the kits than took place during this study. Our recovery rates have not been corrected to allow for tag loss as measured by this sample.

The share-trapping programs which provided much of our study data were worked out in cooperation with the game manager in charge of Horicon Marsh. Aerial surveys of marsh conditions were used in some years to aid in assignment of trapping units to assure a good distribution of trapping pressure. Share-trapping regulations required trappers to work only in certain units as directed. Only one trapper, or a trapper and his helper, worked in one unit at a time. Each trapper was allowed to use 125 traps, or 50 more than were permitted under the general state trapping regulations. Use of stop-loss or killer-type traps was encouraged and good pelt preparation was stressed. Because of low muskrat populations and decreased trapper interest, trapping units were consolidated from the original 56 to 23 larger-sized units in 1958.

Pelts were sexed and aged on fur-division days using the techniques developed by Buss (1941), Applegate and Predmore (1947), Shanks (1948), and others. Upon request, trappers kept pelts from trapping units separate until furs were divided, permitting us to get the information for special units. In certain years, the state sold its share of

pelts at auction. Before selling, the pelts were graded and lotted by a professional fur grader. This made possible the determination of relative values of pelts of different grades and the relative changes in grade composition as the trapping season progressed.

Most tagged muskrats recovered during the trapping season were weighed to the nearest ounce.

The extent of precocial breeding was investigated through examination of uteri of litter-tagged immature female muskrats trapped during the season. The presence of placental scars was taken as evidence of breeding, although there was no way to determine whether any litters were actually added to the marsh population.

Captive muskrats and their young were kept in the project office for nearly two years to more closely observe their habits.

Reports of diseased muskrats were investigated in many parts of the state, and diseased animals were collected when possible and sent to Conservation Department pathologists for autopsy. A considerable number of muskrats were live-trapped for use in disease studies being conducted by state or university pathologists.

POPULATION BIOLOGY

Population Characteristics

Breeding Habits

Litter-tagging was undertaken in eleven of the years from 1947 to 1960. The earliest litter recorded was born April 16, 1955 (Table 1). April 24 was the average birth-date for all earliest litters. Autopsy of approximately 100 female muskrat carcasses during the second week of April in 1952 failed to reveal any indication of pregnancies.

Of all years when litter-tagging was done, 1951 was the only one in which no April litter was recorded. Of course, only a few of the earliest litters could be found when working in such a large area. And, since litter-tagging was usually not started until the greatest number of litters were large enough to tag, some of the earliest litters undoubtedly were never captured. Most very late litters were widely scattered and thus missed because too much effort was required to locate them in the lush new vegetation.

Extra manpower in 1950 made it possible to keep a crew litter-tagging through the summer until litter production practically ceased. In this one year, birth dates were obtained for 730 muskrat litters, exclusive of those reported in the growth study by Dorney and Rusch (1953), and are presented in Figure 1. A small amount of duplication may exist among these dates, because those kits that were too small

Typical broken marsh area at Horicon which is most productive of muskrats, and in which most kits were litter-tagged.

to tag when first caught might have been captured and recorded a second time when larger. However, there was so much area to be worked that little duplication was believed to have occurred.

The lack of sharp monthly birth peaks in Figure 1 (excepting the initial peak in mid-May) is not surprising, since upwards of 5,000 acreas of marsh were searched to locate the 730 litters. Synchronization of first breeding over the entire marsh is not likely because of the many habitat variations in the marsh with consequent variations in

TABLE 1

Litter Production Dates for Horicon Marsh Muskrats

Year	No. Litters Aged	Earliest Litter	Litter Production Peak
1947	74	April 28	May 8
1948	171	April 24	May 14
1949	471	April 20	May 28
1950	730	April 28	May 15
1951	143	May 2	May 20
1952		No Litter-Tagging	
1953	149	April 18	May 3
1954	119	April 20	May 3
1955	132	April 16	April 28
1956	139	April 29	May 10
1957	179	April 21	April 29
1958		No Litter-Tagging	
1959		No Litter-Tagging	
1960	94	April 28	May 10
	Average	April 24	May 10

frost penetration. Fuller (1951) concluded that first matings coincided with the first few days of open water in the spring. Needless to say, appearance of open water varies considerably over Horicon Marsh, being influenced by water currents, depth of ice penetration over winter, and density of emergent vegetation. The open areas may be free of ice several weeks before areas supporting dense stands of emergent vegetation.

Occasional litters are born from September to November, for small kits are sometimes taken in the trapping season. On November 3, 1960, a Horicon trapper caught a large female muskrat containing seven well-developed embryos. This would have been a November litter if carried to full term. The extent of late breeding may vary considerably from year to year.

Of 7,397 pelts taken in November, 1949 and graded for auction by a professional grader, 298 were placed in one lot classified as "badly damaged kits, and mice" — 199 were "kits" or very small pelts, and 33 were extremely small pelts, which were called "mice." The "mice" must represent very late breeding. Another 13 were graded as "mice" from the next fur division of 1949, consisting of 6,292 December and January pelts. The actual percentage of these extremely small pelts would be somewhat higher in the wild, since trappers sometimes throw the "mice" away rather than bothering to skin such small and worthless furs.

Recovery of litter-tagged muskrats during the first trapping season after tagging provided the opportunity to investigate precocial breeding by known-age muskrats. In the early years of the study, carcasses of many immature female muskrats previously litter-tagged were autopsied in search of evidence of precocial breeding. Unfortunately, no record was kept of numerous autopsies which yielded only nega-

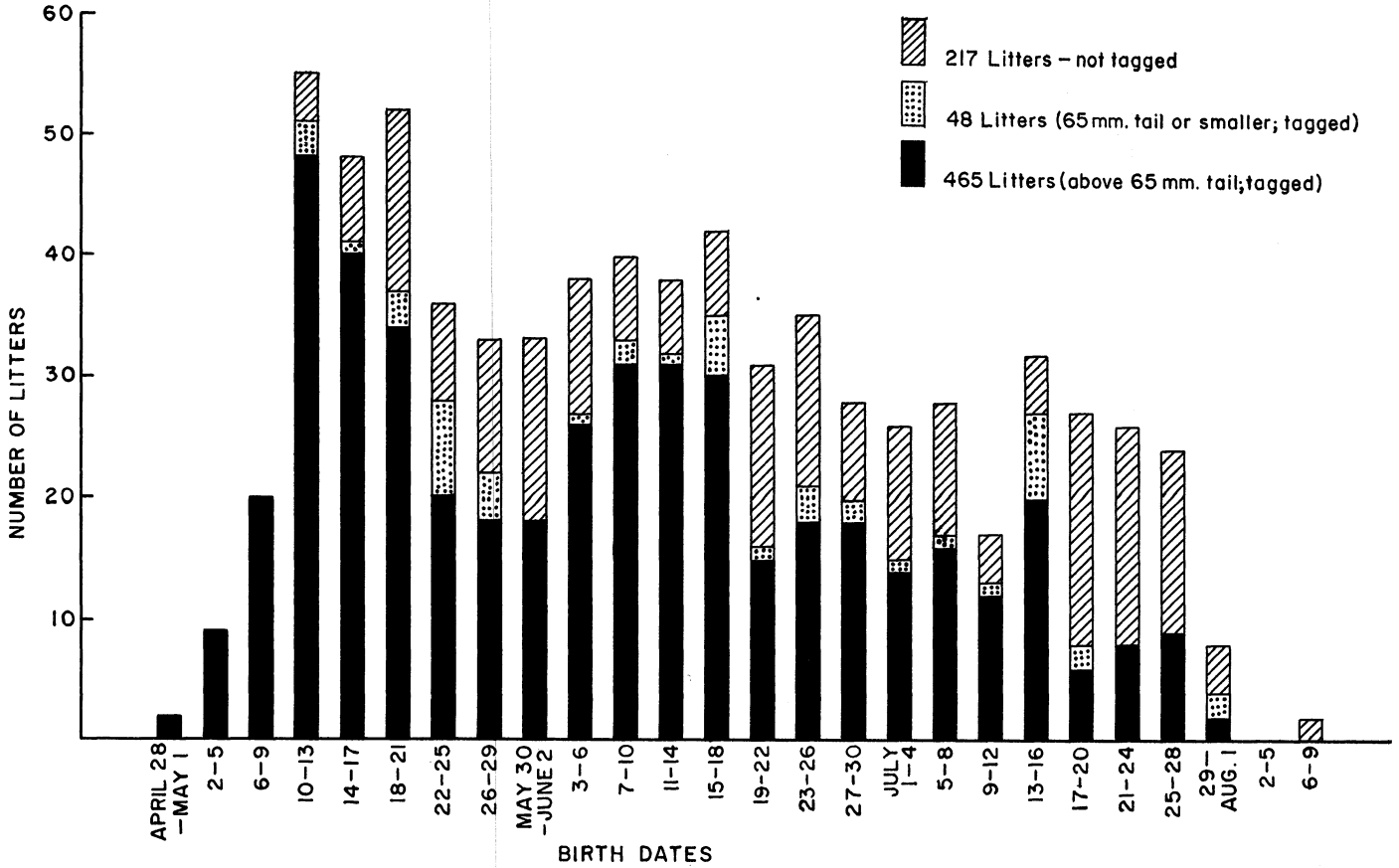


Figure 1. Birth Dates of 730 Muskrat Litters Handled in 1950

Litters were most easily captured where the houses were in fairly open water.

tive information. For several years it appeared as if precocial breeding in this area was only a trapper's myth.

Our first positive evidence of precocial breeding was found in 1954 when four litter-tagged immature muskrats were found to possess placental scars. One positive case of precocial breeding was found in 1955. Seven instances were found in 1956. Since three of these females came from one litter and two were members of another, this represented known precocial breeding in four individual litters. This breeding characteristic may be linked to a hereditary factor.

During the 1957 trapping season, 41 tagged immature female muskrats were autopsied, and no signs of precocial breeding were found. April birth dates were found for 40 percent of the litters tagged in 1957, but for only 3 percent of the litters tagged in 1956. Because birth dates were earlier than average in 1957, more precocial breeding might have been expected, yet none was found. By comparison, 7 out of 41 immature females (23%) had bred in 1956, a year with later-than-average birth dates.

Data for the 12 recorded cases of precocial breeding are given in Table 2. One of these (born April 16, 1955) was from the earliest-born litter we recorded. The average birth date was May 3 and the average age when trapped was 184 days. These precocial breeders were of good size, averaging 2 pounds and 9 ounces when trapped. The number of placental scars ranged from 3 to 10 and averaged 6 scars for the females in which scar counts were recorded. Evidence for

TABLE 2

Precocial Breeding Records for Muskrats at Horicon Marsh

Year	Birth Date	Date Recovered	Age in Days at Recovery	Weight in Lbs.-Oz.	No. of Placental Scars
1954	April 30	October 28	181	2-8	8
	April 29	October 27	181	2-6	4
	May 1	November 3	186	2-8	present
	May 8	November 3	179	2-9	present
1955	April 16	November 1	199	2-8	6
1956	May 7	November 15	192	3-0	8
	May 8*	November 11	187	2-5	6
	May 8*	November 3	179	2-11	6
	May 8*	November 3	179	2-12	6
	May 6**	November 3	181	2-15	3
	May 6**	November 5	183	2-11	10
	May 7	November 3	182	2-4	5
Mean	May 3	November 3	184	2-9	6

*Same litter.
**Same litter.

precocial breeding is based only on the presence of placental scars. We have no evidence that any young were actually produced or that young, if born alive, ever survived to the trapping season. The incidence of precocial breeding is so low that it has essentially no effect on muskrat populations in this area. Errington (1961) reports 1.5 percent as the rate of precocial breeding among nearly 5,000 immature muskrats examined in Iowa. His study areas have a somewhat warmer climate than ours and could have a higher rate of precocial breeding because of longer breeding seasons.

Litter sizes are summarized in Table 3. During litter tagging, when it was certain that all the kits in a house were captured before any escaped to the plunge holes, the litter was recorded as being "complete."

A minimum litter size results from this method of calculation, because (1) some litters may have been split between houses so that two small litters would be recorded instead of one larger one, (2) some litters may have been handled before all members of the litter were born, (3) some kits may have escaped from the nest unobserved, and (4) mortality may have taken place prior to handling. Thus the mean litter size of 7.3 is probably somewhat below the true value.

TABLE 3

Size of Complete Muskrat Litters, 1947-57

Size of Litter	No. of Litters	Total Kits
1	1	1
2	1	2
3	5	15
4	17	68
5	39	195
6	74	444
7	107	749
8	107	856
9	74	666
10	21	210
11	10	110
12	4	48
Total	460	3,364

Mean Litter Size: 7.3

Yearly mean litter size ranged from 6.6 to 7.9 (Table 4). However, average litter size showed relatively little variation between 1947 and 1957, despite the fact that sample sizes varied considerably. Unfortunately, no litter size was determined for 1952, the high point for muskrat populations in recent years.

Errington (1954) reported changes in muskrat litter size to conform generally to cyclic changes in grouse and hare populations. His data for complete litters, however, were largely based on placental scar counts and are probably not comparable to litter sizes obtained in this study from handling of complete litters. Personal judgment is a considerable factor in "reading" of placental scars, and there is doubt that scar counts are of sufficient validity to warrant making them. Errington (1953, 1954) says "The possibility is further recognized that, even in Iowa fall specimens, some of the placental scars assigned to early spring may have been laid down the previous year. Spring and summer specimens occasionally show a gradual fading of scars that could not have been laid down during the current breeding season."

TABLE 4

Sex and Size of Complete Muskrat Litters

		Sex of Litters			Size of Litters	
Year	No. of Litters	No. of Males	No. of Females	Percent Males	Total Kits	Average Per Litter
1947	17	63	49	56	112	6.6
1948	44	175	172	50	347	7.9
1949	78	312	244	56	556	7.1
1950	148	606	425	59	1,031	7.0
1951	36	163	98	62	261	7.3
1953	17	84	47	64	131	7.7
1954	28	137	83	62	220	7.9
1955	22	88	78	53	166	7.5
1956	40	178	125	59	303	
1957	30	147	90	62	237	7.9
	460	1,953	1,411	58	3,364	7.3

Observations on behavior of penned adult and kit muskrats modified considerably our ideas of the relationship of males to females and young during the breeding season. Past impressions have been of intolerance of males by females when young were present. In the pens, however, the males took an active part in caring for the young, and were also observed to help with nest building. Errington (1963) found males to be more tolerant than females toward young in the breeding season, and observed males taking care of young in the wild.

On one occasion, a male muskrat took a kit out of an attached bath tank. The kit was unable to negotiate the ramp leading from the tank to the cage. A few minutes later, the kit moved toward the water tank again. The male was nearby and curved his front leg across the passageway to deliberately prevent the kit from reaching the water. Then he picked up the kit with his teeth and carried it into the nesting box. On the same day, the female rescued a kit in the water by submerging in front of the ramp, enabling the kit to clamber out.

On July 20, a female muskrat which had six kits appeared to be weak and almost dead. One kit was nursing at this time. I decided to transfer the kits to another cage containing a pair of adults and three slightly smaller kits. I balanced one of the kits on the end of a ruler and held it near the entrance of the other nesting box. The male sniffed this kit and did not seem to be antagonistic. The kit soon crawled into the nest chamber. Then I put four more kits into the cage. The male immediately carried the four strange kits into the nest chamber where they were soon accepted by the female. When I put the last kit into the cage, it crawled into the nest chamber by itself. The female nursed the transferred kits a short time later.

On July 29, one of the smallest kits was out alone in the cage. The adult male approached and smelled it, but left it alone. The kit was either sleepy or somewhat sick as it looked very listless. Then I took an iron bar to scrape uneaten corn out of the cage, and the male came again and carried the kit back into the nest box.

On the same day, the female seemed to be bothered by the heat and the task of nursing nine young. She went in the bath tank with one kit hanging on and nursing, and just lay in the water with the kit submerged for approximately one minute. Then the male jumped in, grabbed the female by the side, and tried to drag or help her out of the water. She then left the water with the kit still attached.

Such behavior may at least partially explain the size differences found in kits in some houses. While relatively uncommon, size differences have occurred within litters which were not attributable to differential growth rates or to consecutive litters by the adult female.

Sex Ratios

There was an average of 58 percent males in the sample of 460 complete litters examined from 1947 to 1957 (Table 4). This unbalanced sex ratio is thought to closely approximate the actual sex ratio at birth. The data on complete litters are mostly from relatively young kits, since the older kits become, the less chance there is to capture all members of the litter in the nest.

During the same ten years, 6,207 muskrat kits were ear-tagged. Again, there were 58 percent males in this larger sample (Table 5). Since this sample contains many more older kits than were found in the complete litters, this indicates that there is no differential mortality affecting the kits through the period when they are small enough to be caught by the methods used when litter-tagging, and that male and female kits are caught with the same relative ease.

The third and largest sample of sex ratio data was obtained by sexing pelts on fur division days. Accuracy of the techniques for sexing and aging pelts has been demonstrated by Linde (1963). During the early years of the study, when muskrat populations were high, sex and age data were obtained from selected trapping units. In later years, when the total harvest dropped quite low, sex and age data were taken from the entire state share of the pelts. In 1959, when only about 800 muskrats were trapped, all pelts were examined to increase the sample size. The percentage of immature males ranged from 54 to 64, and averaged 57 percent (Table 6). This is nearly identical to the 58 percent found while litter-tagging, and indicates that there is no differential mortality between sexes of immatures from the time of litter-tagging to the fall harvest.

Over 12,000 pelts of adult Horicon Marsh muskrats have been classified according to sex. The over-all sex ratio in adults is 50 per-

TABLE 5

Sex Ratio of Muskrats at Time of Litter-Tagging

Year	Total No. of Kits	Males		Females	
		Number	Percent	Number	Percent
1947*	221	120	54	101	46
1948	367	216	59	151	41
1949	1,068	600	56	468	44
1950	1,762	1,009	57	753	43
1951	295	163	55	132	45
1953	495	281	57	214	43
1954	499	306	61	193	39
1955	500	295	59	205	41
1956	500	301	60	199	40
1957	500	299	60	201	40
	6,207	3,590	58	2,617	42

*Data from Truax (1947).

TABLE 6

Muskrat Sex and Age Ratios in Fall and Winter Harvests

Year	Total Muskrats Examined	Immatures			Adults			Young Per Adult Female
		Male		Female	Male		Female	
		Number	Percent	Number	Number	Percent	Number	
1947*	4,755	2,132	56	1,694	458	49	471	8.1
1948	12,091	5,355	56	4,249	1,259	51	1,228	7.8
1949	6,639	2,733	55	2,194	831	49	881	5.6
1950	3,259	1,277	57	973	485	48	524	4.3
1951	4,023	1,782	54	1,509	379	52	353	9.3
1952	2,684	1,378	59	956	174	50	176	13.3
1953	4,478	2,104	57	1,574	418	52	382	9.6
1954	2,798	1,267	56	994	265	49	272	8.3
1955	2,710	1,257	58	922	250	47	281	7.8
1956	3,874	1,910	60	1,258	364	52	342	9.3
1957	3,979	1,766	59	1,227	518	53	468	6.4
1958	2,755	1,054	64	592	571	51	538	3.1
1959	798	345	55	279	94	54	80	7.8
1960	1,160	516	56	399	110	47	135	6.8
Total	56,003	24,876	57	18,820	6,176	50	6,131	7.1

*Data from Truax (1948).

cent (Table 6), which is a considerable departure from the unbalanced sex ratio of the immatures (57%). The excess immature males must be lost some time after the first trapping season and prior to the second.

Beer and Truax (1950) found an unbalanced sex ratio of 55 percent males, during fall, winter and early spring based on over 89,000 muskrats reported in the literature from many localities. Errington (1963) also found the sex ratio of newly born muskrats to be unbalanced in favor of the males.

Sather (1958), Beer and Truax (1950) and others report that excess males are lost during the spring break-up periods. Increased movement and fighting at this time contribute to the losses. Muskrats moving through unfamiliar territory are particularly vulnerable to predation and accidents. Extent of fighting is indicated by the large percentage of pelts taken during spring trapping that are damaged from cuts. A check of 1,169 muskrat pelts in April of 1952 showed 40 percent to have one or more holes, largely the result of fighting. Some of the damage apparently occurs, however, when trapped muskrats are attacked by passing muskrats. Most of the damaged pelts were found when trapping started at break-up time. The percentage of damaged pelts decreased as the population was thinned out by trapping.

Data from the 1951-52 trapping season suggest mortality also later in the year. During the spring trapping period from April 1-15, 1952, 1,169 muskrats were trapped, and 55 percent were males. It was not

possible to age these muskrats from the pelts. The sex ratio of the 1951 fall and winter population from which the spring sample was taken, obtained from data in Table 6, was 54 percent males. The spring-trapped sample apparently shows that this trapping was not selective for sex and that the sex ratio of the untrapped population was still unbalanced at the conclusion of the spring trapping period. These data suggest that the loss of excess males took place after the spring break-up period.

It is interesting to note the remarkable constancy from year to year of both the immature and adult sex ratios (Table 6). There is no significant difference between years among adults. Although there were four years with significant divergence among immatures (1951, 1956, 1957 and 1958), this is probably not biologically significant.

Age Ratios

The number of young per adult female in the harvest is often considered an indication of the relative rate of productivity. A high age ratio may represent good management because it means high productivity, while low age ratios show something is wrong, since there are only a few young for each adult female. Different ways of interpreting aging data are given by Alexander (1958). In the present study, an attempt was made to ascertain the relation of age ratio changes to changes in population levels of muskrats.

Age ratios for the muskrats trapped in ten selected trapping units over a period of five years are presented in Table 7. The random variations between units and years strongly suggest that the Horicon Marsh muskrat population consists of many sub-populations. No reasonable explanation is apparent for the age ratio changes from year to year, sometimes occurring in adjacent units which to all appearances consist of comparable habitat. Sample sizes are generally ade-

TABLE 7

Muskrat Age Ratios in Trapping Units, 1949-53 Trapping Seasons

	1949		1950		1951		1952		1953	
Trapping Unit No.	No. 'Rats	Young/ Adult Female	No. 'Rats	Young/ Adult Female	No. 'Rats	Young/ Adult Female	No. 'Rats	Young/ Adult Female	No. 'Rats	Young/ Adult Female
6	737	4.2	300	1.8	665	12.0	279	9.8	617	8.8
14	Refuge	Refuge	Refuge	Refuge	444	7.8	432	14.3	811	11.2
15	901	6.7	504	4.8	794	8.0	339	9.0	525	7.0
17	612	7.3	338	5.0	311	7.8	159	15.4	748	11.0
21	554	4.2	253	4.1	204	9.2	90	5.0	183	7.7
22	574	6.8	177	3.4	401	8.1	267	49.0	441	8.4
39	1,211	7.5	849	4.9	419	13.6	408	12.4	368	13.4
45	899	4.0	349	4.6	361	10.4	325	15.8	528	15.9
53	418	6.7	196	7.5	143	9.0	189	18.9	0	—
56	733	5.2	293	4.6	281	9.5	196	16.1	257	5.3
Totals	6,639	5.6	3,259	4.3	4,023	9.3	2,684	13.3	4,478	9.6

quate, except in a few cases such as Unit 22, where in 1952 we found 49 immature muskrats per adult female in the harvest. This obviously constitutes a sampling deficiency. However, even where the sample size is greater than 200 per unit, a change of only a few adult females would have a considerable effect on the apparent age ratio.

The better trappers were assigned to these special trapping units, resulting in a consistently high rate of harvest year after year. The inconsistencies in Table 7 therefore represent pretty much the actual variations in age ratios which probably existed between these units. If such variation is indeed normal, then predictions or postulations of population behavior based on age ratio data of muskrats are of doubtful value, especially so when only portions of larger areas are sampled.

An attempt was made in 1949 to see if immatures were caught more easily than adults. A father-son team of trappers worked in Unit 56 and segregated each day's catch. They used 125 traps and worked the entire unit continuously during the trapping period. The catch totalled 733 muskrats from the 89-acre area.

There is no apparent consistent difference in the rate at which the sexes are caught within each age class (Table 8). Neither does there seem to be much correlation between age and rate of catch. However, if the percentage if immatures is calculated on a cumulative basis, there is a gradual rise in the percentage of immatures in the harvest. This would seem to indicate that adults tend to be trapped sooner than the immatures when steel leg-hold traps are used. This phenomenon was not observed when live-traps were used to take the harvest in a level ditching study (Mathiak and Linde, 1956).

The adults might tend to be trapped sooner just because of the size factor. A large muskrat should snap some traps set rather deeply or heavily over which a smaller muskrat might pass unscathed. In

TABLE 8

Sex and Age of Muskrats from Horicon Trapping Unit 56, 1949

	November							
Calendar Period	2-4	5-7	8-10	11-13	14-17	18-24	Total	Percent
No. of immature males	33	53	37	52	81	34	290	55
No. of immature females	47	41	29	48	47	28	240	45
Total immatures	80	94	66	100	128	62	530	
No. of adult males	27	15	16	14	16	12	100	49
No. of adult females	25	19	15	16	18	10	103	51
Total adults	52	34	31	30	34	22	203	
Total no. of muskrats	132	128	97	130	152	84	733	
Percent immatures	61	73	68	77	79	74	72	
Cumulative percent immatures	61	67	67	70	71	72		

other words, catchability might depend somewhat on size, with half-grown, smaller muskrats tending to be caught later than the big muskrats. The weights of the animals were not taken, so we do not know if there actually is a correlation between size and trapability, or if there might actually be an age factor causing adults to be trapped somewhat more easily.

Trappers in this area usually set their traps "hard" or "heavy." With "light" sets, they find a large increase in the number of snap-offs.

To investigate age ratios as productivity indicators, the age ratios from the fall and winter harvests (Table 6) are presented in Table 9 for comparison with the total numbers of muskrats harvested in the corresponding years. The Horicon Marsh muskrat harvest showed a general increase from 1943 to 1952, a general decline to 1959, and then a rising trend again to 1963, when a summer draw-down coupled with drought conditions drastically reduced the amount of muskrat habitat. All indications are that these harvest figures reasonably reflect the actual trends in population levels.

The highest age ratio coincides with the year of the highest harvest (1952). The lowest age ratio of 3.1 in 1958 may have actually coincided with the lowest population level although the harvest did not hit the low point until a year later. However, the intervening years show poor correlation of age ratio changes with population changes. Nine of 13 yearly changes in age ratios (1948, 1949, 1952, 1954, 1955, 1956, 1957,

TABLE 9

Muskrat Harvest, Horicon Marsh Wildlife Area

Year	Total Harvest	Young Per Adult Female
1943	9,297	—
1944	4,167	—
1945	1,016	—
1946	8,243	—
1947	9,535	8.1
1948	24,654	7.8
1949	29,678	5.6
1950	18,739	4.3
1951	36,577	9.3
1952	36,848	13.3
1953	24,186	9.6
1954	16,682	8.3
1955	6,695	7.8
1956	3,892	9.3
1957	4,889	6.4
1958	2,973	3.1
1959	802	7.8
1960	5,467	6.8
1961	10,973	—
1962	10,885	—
1963	1,558	—
1964	6	—
21-Year Total	267,762	

1959, 1960) show a negative correlation with population changes, while in only four years (1950, 1951, 1953, 1958) was there a positive correlation (Table 9).

With the exception of 1952, age ratios were less than 10 young per adult female. In contrast, Errington (1961) reported age ratios of 12-15 to be not uncommon in the better Iowa habitats. Beer and Truax (1950) found eight muskrat age ratios greater than 10 on six Wisconsin marshes, although the average on these areas was 7 young per adult female.

If large year-to-year variations in age ratios are normal for muskrat populations, as our data indicate, then changes as found at Horicon are independent of total populations and have no real value as measures of productivity or management practices. Age ratio values become even less reliable if samples are too small or poorly drawn from the muskrats being sampled.

Movement

An intensive check for ear tags was made of nearly all muskrats harvested from 1947 to 1957 on the state-owned portion of Horicon Marsh. Of the 6,207 muskrats tagged, 1,579 recoveries were obtained (Table 10). Points of recovery were usually known by trapping units, but sometimes only within a small group of units.

Recoveries taken in the same unit or in the unit adjacent to the one in which they were tagged have been combined in Table 10, since neither group is considered to involve significant movement. There are several reasons why: (1) Kits were often tagged close to the boundaries between units and it would be just a matter of chance in which unit the muskrat would be trapped. (2) Geographic orientation within the marsh is difficult, so that the tagger or the trapper might have had some doubt as to exactly where he was working. (3) Trappers were sometimes operating in several units during the same period. The catch from each unit was supposed to be kept separated until checked for tags by personnel at the checking station, but mix-ups may have occurred. (4) Movement of as much as half a mile might be involved if a muskrat were to move the maximum distance within a unit. In Figure 2, it might appear as if much longer moves were possible between adjacent units. This is quite unlikely, however, because tagging was usually confined to small portions of the larger units. For example, the litters tagged in Unit 41 were caught only in the southwest corner of this big unit. Similarly, tagging in Unit 11 took place only along the eastern edge of the unit.

There was so little difference between male and female movement rates (Table 10) that discussion will concern only the combined data.

TABLE 10

Recovery Rates and Movement of Litter-Tagged Muskrats

Year Recovered After Tagging	No. Recovered in Same or Adjacent Unit	No. Recovered in Distant Unit	Total Recoveries Number	Total Recoveries Percent
MALES				
First	758	23	781	88
Second	74	12	86	10
Third	13	3	16	2
Fourth	0	0	0	0
Total males	845	38	883	
Percent	96	4		
FEMALES				
First	575	21	596	86
Second	79	11	90	13
Third	8	1	9	1
Fourth	1	0	1	Tr.
Total females	663	33	696	
Percent	95	5		
COMBINED SEXES				
First No.	1,333	44	1,377	87
Percent	97	3	—	—
Second No.	153	23	176	11
Percent	87	13	—	—
Third No.	21	4	25	2
Percent	84	16	—	—
Fourth No.	0	1	1	Tr.
Grand total No.	1,508	71	1,579	—
Percent	95	5	—	—

In the 1,377 first-year recoveries, 97 percent were made in the same or adjacent units and only 3 percent in distant units. The second-year recoveries showed a higher rate of movement since these muskrats had been subjected to one spring dispersal period. Still, nearly 59 percent were taken in the same unit as tagged, another 28 percent were taken in adjacent units, and only 13 percent moved to distant units. Even among the third-year recoveries the large majority of animals were taken in the same or adjacent units.

The 71 movements to distant units for all years (5 percent of the total recoveries) represent the "pioneering" animals which invade new or unoccupied habitats. This is a very important characteristic since much habitat which produces muskrats periodically becomes vacant due to drought, freeze-outs or other catastrophes. Without the pioneering muskrats, the very high fur harvests in favorable periods when practically all habitat capable of producing muskrats is occupied would not be possible.

Only two tagged muskrats were recovered away from the marsh. One was a runner picked up in winter as a road kill several miles east of the marsh. The other was also a runner and was killed in the city of Horicon. Others may have occurred, but because of the small size

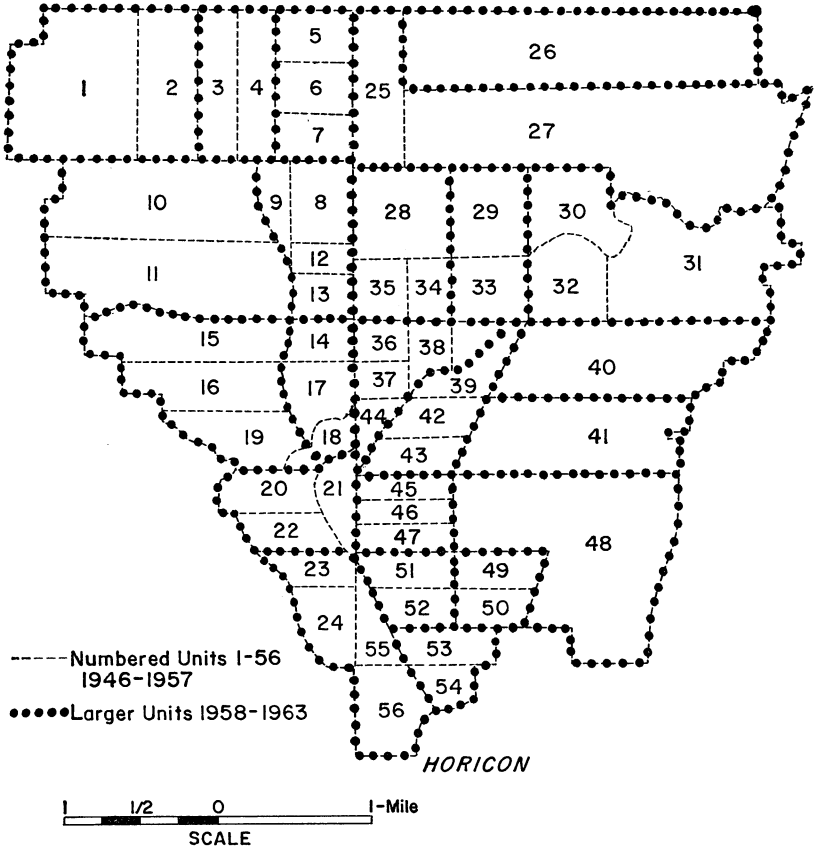


Figure 2. Trapping Units Horicon Marsh Wildlife Area.

of the ear tags, there is not much chance of tags being noticed on muskrats taken away from the marsh.

No tagged muskrat was ever reported from the federally owned northern section of Horicon Marsh. This could be accounted for primarily by the fact that very little of our litter-tagging was done close to the federal boundary. Although no special effort was made to have federal share-trappers look for tags in their catch, I believe that if any tagged muskrats had been noticed, the refuge manager would have been notified.

Three major types of movement are found in muskrat populations. The spring shuffle is well known (Spruegel, 1951). Our extensive tagging on Horicon Marsh, however, indicates that many muskrats spend all of their lives in a relatively small area. Whole populations do not move around during the spring shuffle, for returns of muskrats in the second and third years after tagging show that three-quarters

of them are taken within the same unit as originally tagged or in adjacent units (Table 10).

These data may be influenced by the fact that Horicon muskrats have been subjected to heavy trapping pressure every year, thus probably reducing intra-specific strife to a minimum. Also, litter-tagging was largely concentrated in the best muskrat habitat (where the most kits could be caught with the least effort) and animals in these areas were subjected to the least stresses of weather extremes or food shortages.

A second conspicuous movement of muskrats is in late summer and fall if marginal muskrat habitats dry up completely. These movements have been noticed at Horicon, but do not show up in our recovery data because so little tagging was done in areas subject to fall drying. Tagging in such areas was not warranted because it was almost impossible to catch kits unless there was a fair amount of open water around the houses. Late fall movements initiated by drought probably do little to restock vacant habitats. The major effect is more likely a concentration of muskrats in already occupied better habitats, plus considerable losses while the muskrats are travelling overland. Large-scale movements are often detected by the number of road-kills seen along highways. This phenomenon was observed all through the summer of 1963 in the vicinity of Horicon Marsh when water levels were far below normal.

Areas outside of the heavily-trapped, state-owned portion of Horicon Marsh may contribute a higher rate of movement for restocking because of lower harvest efficiency (Errington, 1940). Undertrapping of many areas is common because of posting restrictions, inaccessibility, too few muskrats to warrant trapping, or lack of interest on the part of the landowner or trapper. Social intolerance in an undertrapped population could easily result in more movements and help account for the rapidity with which vacant habitats are restocked. Certainly, when heavy rainfalls create areas suitable for muskrats, the muskrats seem to find these areas in a hurry, even though they may have been without water or muskrats for several preceding years.

The third type of movement, by winter runners, often is the most conspicuous of all. When ice depths become so great that all the food resource is sealed in frost, muskrats eventually become hungry enough to chew out of their houses and leave in search of food. For a few days they may forage around in the vicinity of their house, but failing to find nourishing food above the ice, they depart, roaming erratically until they succumb to cold, predators, or are killed from other causes. In very shallow-water marshes, a frost depth only 16 inches may be enough to cause starvation.

When temperatures are so low as to freeze out muskrats, there usually is no open water to which they can move. Therefore winter runners are short-lived. This type of movement contributes nothing to spreading or restocking the species. The problem of winter runners becomes most severe when high muskrat populations are subjected to very cold weather without the presence of an insulating cover of snow. These runners may become quite a nuisance, getting into buildings, window wells, scaring people, etc. In the winter of 1943-44, share-trappers took 4,178 winter runners just on the state portion of Horicon Marsh. Probably as many more were taken on the federal portion and within a few miles of the perimeter of the marsh, mainly around farm buildings.

Longevity and Mortality Rates

The large number of muskrats tagged as kits over a period of years and in a variety of habitat types permits an evaluation of life expectancy. Table 11 shows the number of muskrats litter-tagged and recovered by years. We did not litter-tag in 1952. The total recovery from each tagged year-class varied from a low of 17 percent in 1948 to a high of 39 percent in 1954. The years 1951-55 had total recovery rates averaging 38 percent, compared to an average of 21 percent for the two years preceding and the two years after this period. The average return by trapping of all tagged muskrats was 25 percent. Natural factors must account for the fate of the other 75 percent.

The number of muskrats that survived three winters is very low. We found only one fourth-year recovery in all the years of our study. This muskrat was tagged on May 18, 1954 and recovered on November 15, 1957 at a point not more than one-half mile from its birthplace. Apparently this old female muskrat spent her entire life in a very small section of the marsh.

There seems to be no correlation between the annual variations in total recovery rates for tagged year classes and population, size, sex ratio, or age ratio changes during the same years. Although recovery rates were consistently high from 1951 through 1955, the Horicon muskrat population was undergoing a major decline. The annual trapping harvest dropped 30,000 during these years (Table 9). Nearly all tag recoveries were made during trapping seasons and efforts to locate tagged muskrats were comparable from 1949 on.

Recovery rates shown in Table 10 can also be used to determine mortality rates for an average muskrat year-class. There was nothing in our trapping or other field experience to indicate that the behavior of tagged muskrats was different than the behavior of untagged muskrats; therefore we assume that all muskrats are equally vulnerable to trapping and that nontrapped muskrats have the same mor-

TABLE 11

Muskrat Kits Tagged and Recovered by Years, 1947-57

		Recoveries After Tagging									
		First Year		Second Year		Third Year		Fourth Year		Total	
Year	No.	No.	%	No.	%	No.	%	No.	%	No.	%
1947	221	22	10	16	7	2	1	—	—	40	18
1948	367	45	12	15	4	3	1	—	—	63	17
1949	1,068	168	16	25	2	4	T	—	—	197	18
1950	1,762	321	18	43	2	6	T	—	—	370	21
1951	295	105	36	4	1	—	—	—	—	109	37
1953	495	164	33	23	5	1	T	—	—	188	38
1954	499	175	35	17	3	—	—	1	T	193	39
1955	500	175	35	9	2	3	1	—	—	187	37
1956	500	88	18	18	4	5	1	—	—	111	22
1957	500	114	23	6	1	1	T	—	—	121	24
	6,207	1,377	22	176	3	25	T	1	T	1,579	25

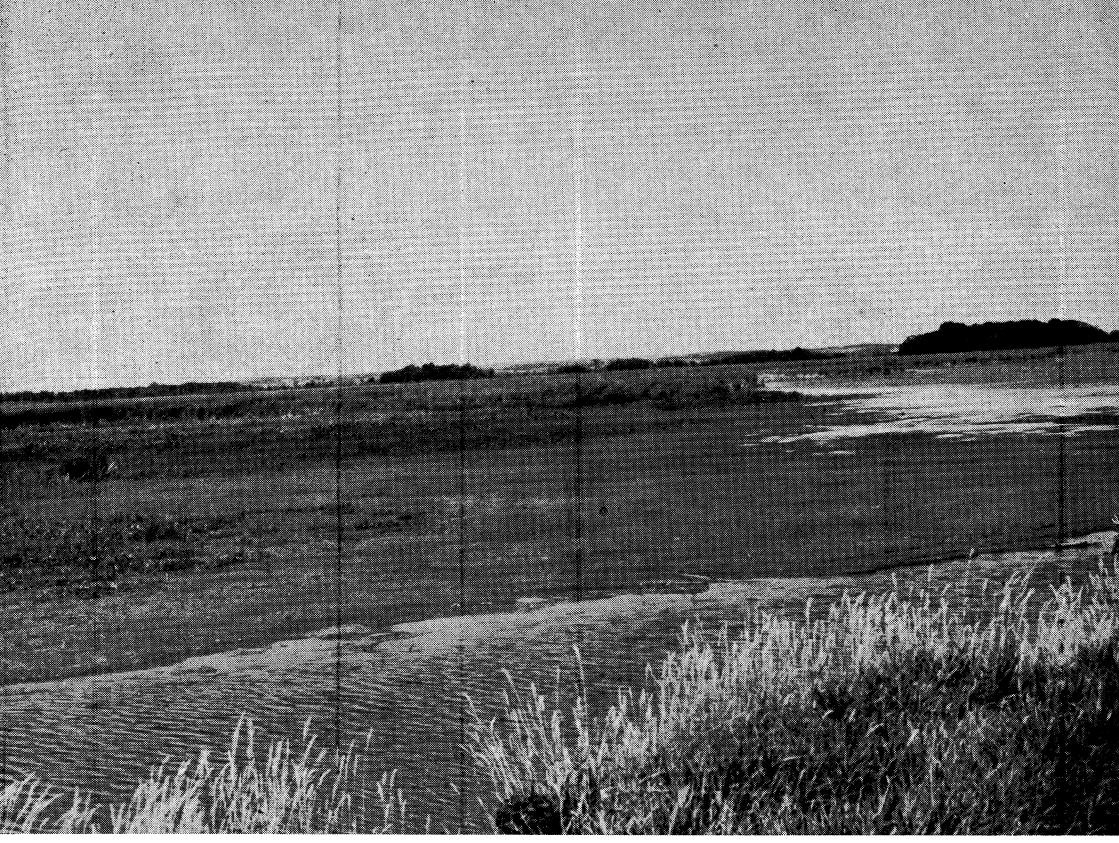
tality rates from all causes as trapped muskrats. Thus the muskrats in the average year-class for the period of our study disappeared at the rate of 87 percent the first year, 11 percent the second year, and 2 percent the third year. There are annual variations around this average, but for all biologically significant purposes it would seem that the muskrat population had a complete turnover in 2 years.

These high mortality rates emphasize the need for annual trapping seasons to prevent loss of a fur crop to natural causes, and that muskrat populations in good habitat such as Horicon Marsh can sustain themselves in the face of heavy trapping pressure. Trapping is obviously a major annual mortality factor since in most years trappers removed 80 percent or more of the available muskrat crop.

MORTALITY FACTORS

Disturbance

Members of litters were sometimes widely scattered during the process of catching kits. There may have been cases of abandonment, especially when only one or two kits were captured and the house was thoroughly demolished in order to expose the plunge holes. Predators digging into a house would also have a tendency to scatter the young muskrats. Litters were known to have been moved to nearby houses because of disturbance. It is just a question of whether the adults find all of the young scattered about. As indicated earlier, our observations of penned muskrats show that losses from this cause might not be too serious because of the extent of parental solicitude shown



Summer water draw-downs can be detrimental to muskrats.

by both parents or even other adults which might come in contact with lost or misplaced kits.

Predators

The raccoon is thoroughly at home in marsh areas at all times of the year. Muskrat houses may be used for rearing their young or as winter dens. Evidence of raccoon predation on young muskrats was noted quite often during litter-tagging operations. Apparently the raccoon can hear or smell young muskrats in the nest, for the usual sign is to find a hole in the house leading directly to the nest. Nesting material is often pulled out of the house as if the raccoon just scooped the nest and kits outside before eating the young.

Raccoon predation often was found concentrated near wooded islands. Litter-tagging was usually futile near these areas where raccoons had been active, although the adult muskrats did not desert the area. It was not uncommon to find houses being repaired for another litter with only the pile of nesting material on the outside of the house to show that predation had taken place.

No evidence was obtained to show that the raccoon preyed on adult muskrats. Raccoons were at times a nuisance to muskrat trappers be-

cause they damaged muskrats caught in traps or got into traps themselves, too often escaping with the trap. The share-trappers did not take the pains necessary to make their many muskrat sets strong enough to hold the few accidentally caught raccoons.

Mink also dig into muskrat houses in search of kits, but apparently not as frequently as the raccoon. Mink occasionally use muskrat houses for rearing young and use them very frequently for winter dens. Many houses are entered in winter in search of food, but when a house has a heavily used den, the trapper has a sure catch.

Mink not only enter muskrat houses, but also swim out under the ice away from the house. Horicon trappers have taken mink in winter in muskrat feeder houses which could only be reached by swimming underwater from a nearby main muskrat house. One trapper on a fur farm took several mink at underwater entrances to muskrat bank dens using wire funnel traps.

Mink and other predators show much interest in muskrat houses in winter but, as often as not, they are interested in the meadow mice which are common inhabitants of muskrat houses the year around. Mink can efficiently catch winter runner muskrats. They will drag a dead runner as much as a mile to get it back to the home den. Killing of winter runners can hardly be considered harmful predation since these muskrats are doomed to an early death anyway because of inadequate food and lack of protection from the cold.

In most cases, mink predation does not seem to be a serious factor as far as overall muskrat production is concerned. An exception was noted in 1957 when a situation was found in which mink may have depressed a muskrat population. The marsh in question (not Horicon) was visited in winter when there was a good tracking snow. Only a few muskrat houses were present and everyone of these had been drilled by mink. The mink population appeared to be higher than the muskrat population. Most likely this local muskrat population was practically annihilated by spring. The marsh was operated primarily for duck shooting by a private club and subjected to very little if any mink trapping pressure. Errington (1961) found that apparent mink predation often was only a salvaging of muskrats which had died of disease.

The red fox is a common inhabitant of the marsh in winter. Fox tracks often lead from house to house, but we have seen no evidence that they dig into the houses in pursuit of muskrats. Most of their investigation and digging into muskrat houses is concerned with the meadow mice living in the same houses. Runner muskrats will be tracked and killed by foxes in winter. Foxes may also get in the habit of eating muskrats caught in steel traps.

Snowy owls present in small numbers during some winters can readily take runner muskrats when available. The winter of 1945-46 was characterized by many winter runners and many muskrats dying of disease in late winter and early spring. Snowy owls stayed some weeks after the spring break-up, probably because there were so many dead or dying muskrats available for food.

A very large heron rookery has been located on the state-owned portion of Horicon Marsh for many years. Nests of great blue and black-crowned night herons number in the thousands. Muskrat kits of even fairly large size could easily be subdued by either species. Partially eaten kits were found under the heron nests in only one year, but there was no way of telling if the kits were killed by the herons or found dead. Heron predation on muskrats could have been very serious in 1959 when nearly all of the fish of the marsh were winter-killed. Food for the herons was so scarce, however, that the rookery was abandoned for one year, and very few herons remained on the marsh during the litter-rearing period.

Large snapping turtles are common, though seldom seen except during the egg-laying period. Numerous clutches of snapping turtle eggs found in muskrat houses indicated that the turtle population was high. We trapped 20 snapping turtles in 1949 to investigate turtle food habits during the muskrat litter-rearing season. No evidence was found of muskrats being eaten by the turtles.

Commercial turtle trappers operated on the marsh during several summers and took many turtles in short periods of warm weather. In 1959, a report was investigated that muskrat remains were being found in many turtles taken by a commercial trapper. Examination of a series of turtle intestinal tracts furnished by the trapper again showed an absence of muskrats. Bullheads, carp, crayfish, and white waterlily leaves were the main food items.

During two years of intensive litter-tagging, 70 clutches of snapping turtle eggs were found in muskrat houses. Average size of clutch was 44, which is a minimum figure since some nests had been partially destroyed by predators. The largest clutch contained 85 eggs. We never found the eggs of other species of turtles in muskrat houses as reported by Johnson (1925).

The presence of snapping turtle eggs in houses did not seem to bother muskrats. Sometimes some of the eggs dropped into muskrat runways but were not eaten or removed by the muskrats. Turtle eggs in muskrat houses are quite safe from predators compared to eggs laid on shores or ditch-banks where the mortality rate is extremely high. Large snapping turtles are much more abundant in Wisconsin waters than would seem possible based on sight observations. Only

when snapping turtle trapping programs are undertaken is there proof of the numbers present. Reduction of snapping turtle numbers does not seem a necessity in muskrat management.

Large northern pike capable of eating muskrat kits have been abundant in nearly all years of this study. Little is known of their relation to muskrats. However, because of their numbers, they might constitute the major threat to muskrats on this marsh.

Great horned owls occur in relatively small numbers in and around the marsh. Their effect on muskrats is believed to be negligible. Some fur farmers having poorer muskrat habitat surrounded by wooded areas believe the horned owl to be a serious predator of muskrats. This belief stems from the fact that relatively large numbers of owls can be trapped in the muskrat habitat where other types of prey are scarce.

Disease

Many muskrats were autopsied by Conservation Department and University of Wisconsin pathologists. Some muskrats suspected of being diseased had deteriorated before being found and could not be submitted for diagnostic procedures. Others found dead or dying had been victims of trauma or mechanical injury, according to the autopsy findings. As would be expected in a short-lived species, some animals die without any abnormal symptoms. Still others exhibit symptoms of several pathogens, making it impossible to determine which condition arose first or contributed most to the downfall of the animal.

Pasteurellosis, hepatitis, uremic poisoning, pneumonia, and degeneration of heart or liver were found occasionally in Wisconsin muskrats but did not occur with enough frequency to have any significant effect on local populations. The two diseases found to be of importance were tularemia and Errington's disease.

Tularemia was not found to be a killer of large numbers of muskrats, although it is important because of the seriousness of the disease when contracted by humans. A die-off of muskrats occurred at Horicon Marsh in early spring of 1946. Severe wintering conditions followed by exceptionally high spring floods concentrated the weakened muskrats along the edges of the flood waters. Fighting and other bodily contacts between muskrats were frequent and conditions were just right for a disease outbreak. Soon dead muskrats were being found in large numbers, and the tularemia organism was isolated from some of the carcasses. However, the main cause of the mortality was believed to be Errington's disease.

One state worker and one trapper hired to skin salvaged muskrats contracted tularemia on Horicon Marsh. In Dodge County alone

there were six cases of tularemia reported to the Wisconsin State Board of Health in 1946. Another was a trapper at nearby Beaver Dam who contracted tularemia after handling muskrats during the same period.

During the period when muskrats were dying at Horicon, a beaver was found floating dead in the water. When autopsied by the research pathologist, the internal organs showed an extremely severe case of tularemia. Apparently this small colony of beaver was completely wiped out for no fresh beaver sign was found on the marsh during the next 15 years.

Large numbers of muskrats have died in Wisconsin and other portions of North America with symptoms similar enough to be diagnosed generally as "Errington's disease." Despite a great deal of research, there remains a lack of agreement as to the exact nature of this disease.

The disease came into prominence when Errington (1946) reported on his investigations concerning a new disease very lethal to muskrats in his Iowa study areas. Errington and his co-workers tried to isolate and identify the agent causing this disease without success.

Symptoms of the disease vary with one or more of the following being recognizable. The lower intestine, colon, and cecum may be hemorrhagic to varying degrees. The liver may or may not be necrotic or covered with pale yellowish spots. Often, all the muskrats dying at one time in a small area will have practically identical symptoms. However, muskrats dying in the same area several months later may have a somewhat different set of symptoms. The hemorrhagic cecum is the most obvious and most often found symptom when Errington's disease is involved. When the colon and rectum are highly hemorrhagic, the fur in the anal region may be tinged with blood. This is the only external symptom which helps disclose the presence of Errington's disease. Sometimes hermorrhages in the lungs are more conspicuous than those of the intestinal tract. Detailed descriptions and characteristics of the disease in the wild are reported in Errington's last books (1961 and 1963).

McLeod (1950) believed that a virus was involved in the muskrat die-off with which he was working in Manitoba. K. G. Flakas, the Wisconsin Conservation Department game pathologist from 1950-54, postulated (pers. comm.) that several infectious agents might be involved, thus accounting for variations in symptoms from time to time. He also was unable to isolate the causative agent of the disease killing large numbers of muskrats in Wisconsin.

Lord (1952) ran elaborate tests and experiments in an effort to discover the cause of Errington's disease. He reported failure in the at-

tempt to associate any virus with Errington's disease. He did, however, isolate an anaerobic bacterium of the genus *Clostridium* which he was able to link with the disease. He was able to photograph and culture the bacterium and also transmit the disease by means of the cultures. Muskrats dying from the cultured materials exhibited typical Errington's disease symptoms and were found to contain the *Clostridium* organism in the hemorrhagic areas.

The disease apparently does not affect other animals. Muskrats have been used as a food for ranch mink for many years. Undoubtedly, many carcasses of diseased muskrats were fed to ranch mink in the last 15 years without any noticeable adverse effect on the mink.

Errington's disease likewise seems to constitute no threat to humans. Many trappers, wildlife workers, and others who have handled hundreds of pelts and carcasses of afflicted muskrats without taking special precautions showed no ill effects that could be traced to this disease. Human contact with diseased muskrats was especially great in 1953 when trapping interest was still high, the muskrat population was high, and there were many animals dying of Errington's disease during the fall trapping season. Trappers usually salvaged pelts from animals found dead if the hair was not already slipping. Other diseased animals were trapped in various stages of infection; some of these animals probably had not yet developed gross symptoms of the disease. Removal of muskrats while in the early stages of infection certainly helped delay spread of the disease and resulted in a larger harvest than would have been possible if trapping had been delayed until the pelts were prime.

Errington's disease was believed to have been the major cause of the muskrat die-off at Horicon in the spring of 1946, although during the same period tularemia was identified in some of the muskrats and in one beaver. Many muskrats were collected and burned in hopes of controlling disease.

The value of destroying only part of the infected animals is open to question. With so many muskrats dying over a large area, it is doubtful if even 10 percent of those dying from the disease were found. Muskrats dying in houses, bank dens, and in thick vegetation remained as sources of infection for other muskrats.

Errington (1961) found that bank dens once used by diseased muskrats remain as sources of new infection for many years. We similarly found cages having previously housed diseased muskrats to be infectious to other muskrats introduced into these cages months later. Lord (1952) tried disinfecting cages with chemicals without success. He then recommended use of heat to sterilize cages. If strong chemical

disinfectants won't kill the *Clostridium* spores, it is obvious that infection could persist for a long time in the wild.

Floods in conjunction with high wind action provide one of the best means of reducing or eliminating infections. Muskrat houses often collapse when flood waters rise high enough. The vegetation of the house and any infected materials inside are then scattered by wave action. Waves also oxygenate the water and should thereby provide an environment less favorable to the development of anaerobic bacteria.

Marsh managers need not worry about floods being detrimental to muskrats because of this beneficial action in regard to disease control. Healthy muskrats are very adaptable and can usually adjust quickly to flood conditions. Any goal of stable water conditions is therefore of questionable value. Certainly in many areas, large muskrat populations have developed despite recurring floods. Conversely, areas with very stable water levels do not tend to exhibit better muskrat-producing abilities than areas subject to floods. Winter floods could be catastrophic if the water rose high enough to inundate muskrat houses and the weather turned extremely cold while the muskrats were without food or shelter.

Underharvesting

Underharvesting of muskrats on local areas within Wisconsin is a much more prevalent condition than overharvesting. Although underharvesting may lead to an expanding population, an underharvested population will often suffer extensive losses from disease, winter weather and emigration, and will damage habitat and water-control structures.

Reasons for underharvesting vary:

1. Fur farmers sometimes stopped trapping upon finding dead muskrats in their marshes. These men felt trapping would reduce the population excessively since losses were already occurring. This procedure is not biologically sound. If disease is discovered, it is better to trap extra heavily. Trapping will remove some of the diseased animals, remove others before they have a chance to become infected, and slow the spread of the disease by reducing the number of contacts between diseased and healthy muskrats.

2. Trapping of a good population one year may be deferred in hopes of getting a larger harvest the next year. In most cases, the next year's population was actually lower than that of the first year.

3. Trapping of a heavy muskrat population may be deferred in hopes of opening up dense stands of emergent vegetation. This policy is most often followed at national wildlife refuges where more small openings for ducks are desirable. However, when a high population

is not trapped, the likelihood of large losses from disease and other factors increases. In the long run, therefore, more openings may result from the attempt to maintain a stable population through an annual trapping program rather than trapping in intermittent years.

4. Unfavorable weather can sometimes slow or almost prevent harvest. A freeze-up before the trapping season opens is especially bad and practically stops trapping before it can start. Most Wisconsin trappers won't trap through the ice, partly because restrictive laws greatly reduce the possibility of a profitable operation and partly because of transportation problems and unfavorable weather and ice conditions which make trapping undesirable or difficult.

Fortunately, early trapping is possible on many of the better muskrat areas through the Wisconsin fur-farm laws and special regulations in effect on several large state and federal wildlife areas.

5. Low fur prices discourage trapping with the result that many areas may not be trapped. Other areas will be trapped only as long as the daily catch remains high enough to warrant running the trapline.

Intraspecific Strife

Considerable losses occur from fighting among the muskrats themselves. This may involve attacks of adults against adults, adults against young, or even larger young against smaller young. Kits with fresh slash wounds were captured occasionally during litter-tagging. The aggressiveness of young kits was readily observed when captured litters were confined to a pail prior to the actual tagging. Captured kits seem to have a compulsion to attack anything moving within range of their sharp teeth.

Errington (1961) found that intolerance of muskrats to one another tended to vary between periods of years. Muskrats exhibited the most tolerance in the years closest to the highs of the cycle and the least tolerance in the years about the low of the cycle. We did not work closely enough with individual muskrats to detect differences in tolerances.

MANAGEMENT IMPLICATIONS

Harvest Considerations

Wisconsin has experimented with many types of trapping seasons. Completely satisfactory regulations have not yet been found, and changes are still being made every few years. A major difficulty is the need to set seasons before it is possible to know what the muskrat crop will be. A second problem is the tremendous influence weather may have on the trapping effort. Modifying seasons after they are

Late fall trapping at a large muskrat house. The stake is set in deeper water to insure drowning.

once set is difficult, although weather conditions may be so adverse as to prevent more than a token harvest.

Modern administrative machinery is not geared to changing regulations quickly. This is especially true when the loss from insufficient trapping will not be obvious, and it is easy to assume that there is no waste when muskrats are underharvested.

The 1961 trapping season in Wisconsin is a case in point. Although the state was zoned for trapping in 1961, all the opening dates were so late as to discourage trapping of muskrats. A mistaken belief that pelt prices were still very low contributed to a statewide apathy toward trapping, especially since little open water trapping was likely. The net result was a gross underharvest of muskrats throughout the state. Attempts to obtain a statewide spring trapping season were unsuccessful except in the Mississippi River area. Here a spring season was obtained on the basis of suspected presence of Errington's disease in the river muskrats. The Mississippi River trappers were able to take a good harvest in the special spring season. Many licensed fur farmers in other parts of the state also conducted a successful spring trapping season because they knew their fall harvest was too low.

Many thousands of muskrats could have been taken in the rest of the state during the same period if the season had been opened. Spring trapping can be a special tool to use when insufficient numbers of muskrats are taken during the fall and winter trapping period. This

tool was used with notable success on Horicon Marsh where seven spring trapping seasons have been used to reduce excessive numbers of muskrats.

For some years, Wisconsin alternated beween open and closed muskrat seasons. This was based on a widespread belief that a closed season automatically insured a bumper crop the next year. Ignored were the many factors which affect the welfare of muskrats and the inherent ability of muskrats to increase rapidly when conditions are favorable. This system of alternating seasons has been abandoned.

Muskrat densities may vary greatly from year to year and also in different habitats within a single year. Trapping laws cannot be expected to be changed to suit individual situations, even if it were possible to detect these population variations long before the trapping seasons.

A general principle should be followed, therefore, of setting seasons which can usually be expected to give an adequate harvest on the more heavily populated areas. Such areas exist within our state each year despite some years in which populations are generally low over the state. Low fur prices have cut down trapping pressure to the point where overtrapping of muskrats in the better habitats is not likely. Overtrapping in poor habitats is more possible. Should overtrapping occur, natural restocking can be expected to replenish the breeders.

The need for closed seasons to produce bumper crops has been amply disproved by the large statewide harvests under consecutive open seasons in the early 1950's. Next, statewide seasons opening on November 1 were tried. Due to a difference of about three weeks in average freeze-up dates between northern and southern Wisconsin, the state was zoned and the season was opened before November 1 in the far north in order to have open-water trapping.

From 1956 to 1960, the state was zoned as follows: North of highway 64, October 20 to December 19; south of highway 60, November 5 to December 19; while the central zone ran from October 28 to December 19. In addition, there were special regulations for lands within the national wildlife refuge along the Mississippi River and a few counties in which a special long dry-set season was permitted.

Although a majority of the trappers seemed to favor these zoned, early opening seasons, some opposition arose because early-trapped mink were almost worthless. The vociferous dissatisfied swung the pendulum so that openings were made later, from November 1 in the northern zone to November 15 in the southern zone. These seasons were in effect in 1961 and 1962. The poor harvest of 1961 has already been described.

There was a general, hard freeze late in October of 1962, but warmer weather returned and open water was present most of the time until late November. Ice did hamper and discourage trapping, despite the open water since most everyone expected the permanent freeze-up to occur at any time in November. Trappers are loath to get caught with a lot of traps out at freeze-up time since it can be very difficult to recover the traps after the ice is thick enough to support walking. Therefore it is believed that the 1962 harvest was also too low despite the lateness of the freeze-up.

If mink and muskrats were not so closely related in habits, setting of trapping seasons would be much simpler. Any trap set for muskrats can also catch a mink since there seem to be no places used by muskrats not also used at times by mink. Even muskrat feeder houses are visited by mink when the only access to the feeder house is by travelling under the ice from the main muskrat house. Mink also use underwater entrances of muskrat bank dens.

Delaying the mink season till mink were closer to prime would mean that any mink caught by accident in muskrat sets would be illegal and a total waste. Wisconsin has therefore continued to have concurrent mink and muskrats wet-set seasons.

Periodic occurrence of winter runners in considerable numbers was the basis for a special dry-set season for muskrat and mink in 1946 in a block of counties near Lake Winnebago. This season extended from the end of the regular trapping season until March 15. It permitted the salvage of many muskrats which would have died shortly anyway.

This extra long season did not prove detrimental to the mink or muskrats in this block of counties. Should extra protection be desired for mink, regulations could permit the taking of runner muskrats by means other than trapping. This would give the mink complete protection during special seasons for runners. Trapping every runner muskrat would do no harm at all, but since mink can also be trapped with dry sets, the mink could conceivably be reduced too much.

The greatest danger to overtrapping mink comes from a relatively small number of trappers usually referred to as "culvert trappers." These trappers may have one or more of the following characteristics: (1) they operate out of the larger cities; (2) they operate long traplines, often extending into half a dozen or more counties; (3) they may use more than the legal limit of 75 traps (enforcement of this regulation is very difficult); (4) they make sets almost exclusively where creeks and ditches cross roads; (5) they often violate trapping or trespass laws in order to catch their furs; (6) they do not own land, pay taxes on wild land, or otherwise do anything to produce a fur

crop; (7) when operating several long traplines, they may not check traps daily, an undesirable method of trapping; and (8) by using these methods, they obtain a disproportionate share of the wild fur crop.

Recommendations

Muskrat research on Horicon Marsh points toward one policy: muskrats must be adequately harvested. With wide yearly variations in muskrat numbers, water conditions, and weather during trapping seasons, adequate annual harvests are not likely unless regulations are flexible. Chronically low fur prices have eliminated to a considerable extent the need to preserve muskrat breeding stock by means of restrictive regulations. Should fur prices collapse entirely in the future, regulations may have to be relaxed or even eliminated to preserve the interest of trappers. Assuming, however, that muskrat pelts will continue to bring an average of 80 cents or more, and that general trends in statewide muskrat populations can continue to be determined, the following recommendations for statewide muskrat and mink management are made on the basis of our investigations:

1. Muskrat and mink should continue to be trapped in joint seasons.

2. Muskrat and mink seasons should be held annually because (a) some local areas commonly have high muskrat populations even though most other areas may have generally low populations during the same period; (b) the muskrat mortality rate is so high that excessive losses result when one or more trapping seasons are skipped; (c) natural factors such as drought or freeze-outs can be expected to frequently reduce muskrat numbers prior to the next trapping season; (d) low fur prices have been the rule for some years so that trapping usually ceases long before muskrat numbers are reduced too low (It follows that quotas are not needed nor are pre-season population estimates needed to set quotas or trapping regulations.); (e) untrapped or grossly undertrapped populations are much more subject to major losses from disease; and (f) Wisconsin has so much muskrat habitat that many muskrats probably never are exposed to the hazards of trapping. Refuges specifically for muskrats therefore are not needed.

3. Muskrat seasons should be early enough to allow on the average about a week of open-water trapping. If the bulk of the muskrat crop is not taken prior to freeze-up, the chances for an adequate harvest, especially with a fixed statewide season, are remote. Zoning therefore is desirable.

4. On public lands managed primarily for waterfowl, it may be undesirable to have uncontrolled trapper activity during hunting hours. The muskrat resource can still be utilized without measurable

damage to the waterfowl program by limiting the number of trappers and their mode of operation through a permit trapping season. This is preferable to prohibiting trapping altogether, especially where muskrats are abundant.

5. State law and administrative procedure should be modified as necessary so that additional trapping can take place to remove obvious surpluses. Gross undertrapping in fall and winter can occur due to factors such as (1) very low fur prices; (2) a very high muskrat population with extensive muskrat habitats occupied; and (3) unfavorable weather factors such as high winds, very early freeze-up and abnormally heavy and early snowfalls. Further special seasons quite frequently are needed in a hurry when freeze-out conditions cause large numbers of winter runners. An alternative to the latter proposal would be an annual statewide season for taking muskrats by means other than trapping from the end of the trapping season to March 1.

6. As a sole means of taking muskrats, spring trapping is not advisable because (1) there may be large losses before spring due to freeze-out or disease; (2) spring pelts are often past their prime; (3) spring pelts tend to be heavily damaged by cuts from fighting among the muskrats themselves, resulting in the customary drastic markdown in selling price; and (3) once in a while spring break-up will be much later than usual, causing additional loss in pelt quality.

7. On larger marshes, usually publicly owned, special efforts should be made to trap extra heavily when drastic draw-downs are planned for the next summer. This should include spring trapping in addition to the heavy fall and winter trapping.

8. Greater use of the provisions of the fur-farm law should be encouraged (Sections 29.375 and 29.58, Wisconsin Statutes). The fur-farm laws not only permit better muskrat management, but in so doing, they insure dedication of many of our better wildlife habitats to production of wildlife. It would also help the problem of when to set mink trapping seasons; on licensed farms, owners could trap early or in spring, when conditions require it. All state-owned marshes should be managed as fur farms. This would allow more efficient control where muskrat damage to dikes is a major problem.

9. Small, man-made water areas are increasing rapidly in numbers. This trend is expected to continue at an accelerated pace in future years. Dikes are commonly used to create new water areas which include fish ponds, duck hunting areas, and water areas to beautify estates. Owners of these water areas very often have absolutely no interest in muskrats. Muskrats do, however, cause damage mainly in digging in dikes and banks. Eventually leaks and total water loss may

result unless time-consuming and costly repairs are repeatedly made.

Here again, rules and regulations should be changed to permit sensible and practical control. There is no justification for having state employees check every complaint and spend much time and effort to collect muskrats taken in control work. These water areas benefit so much other wildlife that their development should be encouraged, even to the point where muskrats can be controlled when necessary.

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APPENDIX A

Aging Table for Muskrat Kits
(Adapted from Dorney and Rusch, 1953)

Tail Length (Mm.)	Age in Days	Tail Length (Mm.)	Age in Days	Tail Length (Mm.)	Age in Days	Tail Length (Mm.)	Age in Days
26	1	62	11	99	21	137	31
27	1	63	11	100	21	138	31
28	1	64	11	101	21	139	31
				102	21	140	31
29	2	65	12				
30	2	66	12	103	22	141	32
31	2	67	12	104	22	142	32
		68	12	105	22	143	32
32	3					144	32
33	3	69	13	106	23		
34	3	70	13	107	23	145	33
35	3	71	13	108	23	146	33
		72	13	109	23	147	33
36	4						
37	4	73	14	110	24	148	33
38	4	74	14	111	24		
39	4	75	14	112	24		
		76	14	113	24		
40	5						
41	5	77	15	114	25		
42	5	78	15	115	25		
43	5	79	15	116	25		
		80	15	117	25		
44	6						
45	6	81	16	118	26		
46	6	82	16	119	26		
		83	16	120	26		
47	7	84	16				
48	7			121	27		
49	7	85	17	122	27		
50	7	86	17	123	27		
		87	17	124	27		
51	8	88	17				
52	8			125	28		
53	8	89	18	126	28		
54	8	90	18	127	28		
		91	18	128	28		
55	9	92	18	129	29		
56	9			130	29		
57	9	93	19	131	29		
58	9	94	19	132	29		
59	10	95	19				
60	10			133	30		
61	10	96	20	134	30		
		97	20	135	30		
		98	20	136	30		

APPENDIX B

Weights of Known-Age Horicon Marsh Muskrats

Age Class (Days)	Average Age (Days)	Sample Size	Weight Range (Oz.)	Average Weight (Lbs. - Oz.)	
MALES					
100-119	112	15	22-36	1-13	
120-139	132	19	26-41	1-15	
140-159	150	33	21-45	2-4	First fall and winter
160-179	172	100	31-46	2-6	
180-199	188	147	30-55	2-8	
200-219	207	33	33-50	2-9	
273-350	324	28	33-53	2-12	April trapped
485-621	556	66	38-60	3-2	Second fall
910-950	935	4	48-57	3-4	Third fall
FEMALES					
100-119	113	18	23-34	1-12	
120-139	131	19	19-45	1-13	
140-159	149	35	22-45	2-1	First fall and winter
160-179	172	66	29-45	2-5	
180-199	188	104	27-50	2-7	
200-219	207	25	32-46	2-6	
261-354	310	22	31-63	2-10	April trapped
482-612	547	54	40-57	3-1	Second fall
906-943	925	5	47-58	3-5	Third fall

APPENDIX C

Muskrat Populations and Trapping at Horicon Marsh

Share-trapping Program

A dam was built on the Rock River in the City of Horicon in 1930 for the purpose of controlling water levels on Horicon Marsh. It was not until 1943 that authority to begin regulating the water was finally received. In anticipation of greatly increased muskrat harvests, a share-trapping program was started in 1943 and continues, with modifications, until the present time.

The share-trapping program found favor with the trappers because they were assured of a good trapping area without competition or fear of having furs or equipment stolen. Waterfowl hunters possibly benefited because trapping was delayed in some areas until the freeze-up. Trappers actually caused little real disturbance to hunters since usually only one trapper worked a given trapping unit. Our observations showed that trappers often flushed ducks which otherwise would not have been seen by hunters. This was especially true on week days when few hunters were out.

The state marsh was divided into 56 trapping units (Fig. 2), the corners of which were marked with five-gallon cans mounted on double-length steel fenceposts. After muskrat numbers and prices had drastically declined, trapping interest also declined and the original 56 units were consolidated in 1958 into 23 larger trapping areas. This greatly simplified the record keeping, both for the trapper and the state.

In the first year of share-trapping, the trappers merely brought in each day's catch. After being divided half and half, the state's share was skinned and stretched by a crew of prisoners commuting from the state prison at Waupun. In succeeding years, the trapper was required to take care of all the pelts and the state took its share of the dried pelts only on fur division days.

From 1943 to 1952, all muskrat and mink were shared 50-50. The division rates were changed in 1953 to favor the trapper and thus counteract the discouraging effect of very low fur prices.

Table 12 summarizes division rates as they existed during the share-trapping program. From 1953 on, the trappers retained all the mink for themselves. From 1953 to 1956, the trappers were given two-thirds of the muskrats after the freeze-up. Otherwise, many would have quit trapping after the freeze-up when the lower catches in combination with the low fur prices would have made trapping uneconomical under a 50-50 division. This arrangement continued until 1957 when the trapper began receiving two-thirds of the muskrats

TABLE 12

Chronology of Share-Trapping Regulations
Horicon Marsh Wildlife Area

1943	First year of share-trapping on state land. Muskrat and mink divided half and half. All other furs to trapper. The state had to skin, stretch, and dry its share of the furs.
1944-52	Divisions remained the same, but the trappers processed the state's share of the furs.
1953-64	Trappers allowed to keep all of the mink.
1953-56	Muskrats divided half and half until freeze-up. After freeze-up, the trapper received two-thirds of the muskrats.
1957-64	All muskrats divided two-thirds to trapper and one-third to state. No longer a daily check of trappers; instead they report periodically.
1945-53	An oversupply of trapping applicants. Trappers selected by means of a drawing conducted by the Bureau of Purchases.
1954-64	An undersupply of trapping applicants. The marsh manager could assign trappers without holding a drawing.

during the entire trapping season. The share-trapping program barely survived as is shown by the number of trappers participating (Table 13). A moderate increase in fur prices coupled with a great increase in the number of muskrats in 1961 probably kept muskrat trapping in Wisconsin from collapsing completely.

The share-trapping system of harvesting muskrats proved highly valuable to the fur research project. It made possible a nearly complete control of the trapping effort. With the cooperation of the marsh manager, the time, intensity, and distribution of trapping effort could be varied to fulfill various research needs. Daily examination of the catch was possible, and detailed harvest records were kept for each trapping unit. The share-trappers proved very cooperative in giving extra services to help the research effort. Starting in 1959 trappers filled out daily catch sheets, and were no longer required to submit each day's catch for examination.

Development of the Horicon Marsh muskrat population and the related share-trapping effort on state-owned lands is summarized in Table 13. With the exception of a few of the early years, intensive trapping was the rule, with essentially all muskrats being taken that the trappers were able and willing to take under existing conditions of weather, water, market, and population level. Even greater harvests would have been possible if trapping in some areas had not been delayed until duck hunting was terminated for the year by ice formation. Under-ice trapping usually does not take as large a percentage of the available crop as fall, open-water trapping. Too often, ice or snow effectively prevent the desired cropping intensity when trapping is delayed until after the freeze-up. Early deep snows, for instance, might prevent all trapping after the freeze-up. There are other areas, of course, in which open-water trapping is virtually impossible be-

TABLE 13

Trapping Season Information and Harvest Horicon Marsh Wildlife Area

Year	Trapping Season	No. of Units	No. of Trappers	Harvest			
				Muskrat	Mink	Raccoon	Opossum
1943	Nov. 15-Jan. 25, 1944	20	18	9,297	101	—	—
1944	Nov. 1-Dec. 31, 1944	25	22	4,167	140	19	—
1945	Dec. 15-Feb. 1, 1946	42	37	1,016	250	4	—
1946	Nov. 1-Jan. 20, 1947	56	32	8,243	172	40	3
1947	Nov. 1-Feb. 25, 1948	56	34	9,535	110	12	10
1948	Nov. 1-Jan. 8, 1949	56	32	24,654	78	33	3
1949	Nov. 1-Jan. 20, 1950	56	31	29,678	89	17	6
1950	Nov. 1-March 15, 1951	56	33	18,739	90	28	10
1951*	Nov. 1-April 15, 1952	56	30	36,577	30	5	1
1952*	Oct. 28-April 7, 1953	56	20	36,848	28	3	1
1953*	Oct. 25-April 15, 1954	56	24	24,186	64	19	18
1954*	Oct. 25-April 15, 1955	56	16	16,682	24	14	10
1955	Oct. 25-March 5, 1956	56	12	6,695	18	15	22
1956	Oct. 28-Dec. 14, 1956	56	8	3,892	6	3	3
1957	Oct. 28-Jan. 31, 1958	56	6	4,889	48	—	—
1958	Oct. 28-Feb. 22, 1959	23	7	2,973	123	19	11
1959	Oct. 28-Dec. 5, 1959	23	2	802	90	33	10
1960**	Oct. 28-April 15, 1961	23	6	5,467	24	24	5
1961**	Nov. 1-April 20, 1962	23	14	10,973	18	—	—
1962*	Oct. 25-April 15, 1963	23	16	10,885	70	15	6
1963	Oct. 28-Feb. 27, 1964	23	5	1,558	26	16	3
1964***	Dec. 15-Jan. 31, 1965	0	5	6	115	22	21

*Years with a general spring trapping season.
**Spring trapping in limited areas to control dike damage.
***Trapping directed primarily at mink.

cause of travel difficulties. Here trapping is automatically delayed until enough ice forms to permit foot or car travel.

Income from sale of the state's share of pelts is given in Table 14. Over $200,000 had been gained by the state by 1960. Costs of administering the program have not been tabulated, but these costs have not been great. Of net income received by the state, 25 percent has been turned over to the Dodge County treasurer who distributes this money to the county and towns as a payment in lieu of school taxes on the state-owned land. Payment to each town is proportional to the percentage of state-owned land in each town.

A summary of the trapping season in relation to the muskrat population level, marsh conditions and weather is presented for each year from 1943 through 1963 in the following section.

Chronology of Muskrat Population and Trapping Seasons

1943. The summer water-level gauge readings averaged only 74.30. The Horicon dam gates were open all summer and water levels on the marsh were actually regulated by the dam downstream at Hustisford. By September, the reading was down to 73.02. Water-gauge

TABLE 14

Gross State Revenue from Share-trapped Muskrats
Horicon Marsh Wildlife Area

Year	Number Sold	Total Revenue	Avg. Price Per Pelt
1943	4,853	$ 12,957.51	$2.67
1944	2,083	4,780.90	2.30
1945	477	1,140.00	2.39
1946	4,120	11,371.20	2.76
1947	4,101	12,587.00	3.07
1948	12,954	23,315.93	1.80
1949	14,837	22,699.36	1.53
1950	5,989	12,782.79	2.13
1951	21,508	36,092.94	1.69
1952	18,429	31,341.72	1.70
1953	10,023	13,245.15	1.32
1954	7,220	13,520.32	1.87
1955	3,367	4,409.53	1.33
1956	1,810	1,887.41	1.04
1957	1,828	1,440.42	0.79
1958	967	928.32	0.96
1959	(No sale this year)		0.92*
1960	1,977	1,529.52	0.77
1961	2,630	3,366.40	1.28
1962**	3,434	5,252.99	1.53
1963***	1,558	2,414.90	1.55
1964	(No sale this year)		
	124,165	$217,064.31	$1.75

*From trappers.
**Includes 1,358 pelts from 1961.
***Pelts from 1962; 1963 pelts not sold yet.

readings are related to a bench mark near the dam at an assumed elevation of 100 feet. At the low reading of 73.02, the state marsh was essentially dry except for ditches, old river channels, and some old, deep peat burns in the Burnett Ditch area.

Permission was obtained to close the gates of the Horicon dam on October 2 and begin raising water levels. The water had been raised to 73.98 by December.

In this first year of share-trapping, 5,119 muskrats were trapped, mostly through the ice. Later the ice became so thick that many muskrats were frozen out of their homes. The share-trappers took an additional 4,178 winter runners from December 28 to January 25. Runner muskrats became very prevalent and were quite a nuisance on the highways and around buildings. Permits were issued to the public to kill runners, and over 1,500 were killed away from the marsh. Most of these originated on both state and federal portions of the marsh.

1944. Water levels averaged only slightly higher this year as incomplete purchase of marsh lands precluded additional flooding. The muskrat population had not recovered from the 1943 winter losses

and only 4,167 were trapped. The mink harvest reached 140. The dry portions of the marsh were, of course, more suitable for mink than muskrats.

1945. Trapping did not start until December 15, at which time the marsh was covered with ice. Cold weather soon stopped muskrat trapping. The trappers found that they could make more money trapping mink, which brought an average price of over $26. A record number of 37 trappers took a record number of 250 mink, which amounted to 1 mink for about 40 acres of marsh. The low muskrat harvest of 1,016 did not mean the total population was low. Poor conditions for trapping muskrats plus a high population of valuable mink meant that most of the trapping effort was diverted to mink trapping.

1946. The highest water of the year occurred on March 18 when the gauge read 76.6. The rising flood waters caused most muskrat houses to collapse and sink. The homeless muskrats were forced to move to ditchbanks and the edges of the marsh. Here many contacts and much fighting took place, favoring the spreading of disease which caused many deaths, especially in the first half of April.

Probably most of the muskrats lost to disease, fighting and emigration consisted of surplus animals not harvested in the poor 1945 muskrat trapping season. With trapping starting on November 1 in 1946, the catch again was up, with 8,243 muskrats being taken. This was a good catch considering the fact that summer water levels were still relatively low and good muskrat habitat was limited in extent.

1947. Although trapping started on November 1, an early freeze-up soon terminated open-water trapping. Regulations were amended to permit trapping in feeder houses, which allowed chopping a hole in the ice next to a feeder house and setting a trap in or under the feeder with the use of a shoulder-length rubber glove. Feeder house trapping has been used with success every winter, for clear ice is not necessary to locate sets. Two factors eventually may limit feeder trapping in any one season: (1) ice depths of 10 inches or more require too much effort to chop through the ice and also make it difficult to reach far enough under the ice to set the trap; and (2) excessive snow depths may make it impossible to find feeder houses in which to make sets.

Summer water levels averaged 6 inches higher than in 1946, and the improved muskrat habitat resulted in an increased population. The harvest of 9,535 muskrats was considered inadequate for this year, but it was all that the trappers could get under the unfavorable conditions.

1948. Water levels remained essentially as they were in 1947. A late freeze-up and a long period of open-water trapping permitted

the first of the large harvests. The total of 24,654 muskrats trapped resulted in good incomes to the trappers and a record income of $23,315 to the Conservation Department.

1949. This was the first year when water levels averaged over the 75.00 mark during the summer months. Water levels had now reached the point where summer levels averaged .87 feet higher than in 1943 when manipulation of the dam was first undertaken. The acreage of good muskrat habitat increased rapidly as water levels were gradually increased. Twenty-one days of open-water trapping followed by under-ice trapping until January 20 brought the muskrat harvest up to 29,678. This figure could not have been reached had not feeder-house trapping been permitted.

1950. Ice formation stopped open-water trapping on November 10 even though open-water conditions returned for a few days later in the month. Trappers are loath to get caught with too many traps set out at freeze-up time. Snow appeared early and much drifting occurred, resulting in greatly curtailed car travel on the ice, slow freezing and hazardous foot travel in the bog areas, and obscuring of feeder houses.

The net result of these conditions was a harvest much lower than desirable. Only 18,739 muskrats were taken although the harvest probably should have been 30,000. Only a few diseased muskrats were found during the summer. The muskrats seemed to have recovered from the 1946 epidemic.

1951. Water levels hovered near the 75.00 mark during the summer months. The muskrat population was high and well distributed over the marsh. Trapping conditions were generally unfavorable, but due to the high level of the population, the harvest reached 29,873 muskrats by March 15. Even this was not considered adequate and a spring season was opened to trapping from April 1 to 15, enabling the trappers to take an additional 6,704 muskrats.

1952. Trapping conditions remained favorable throughout the winter. Even then, a spring season was deemed necessary and the total catch rose to a new high of 36,848. Trapping interest was down and only 20 trappers were responsible for the high catch. An abundance of muskrats on other areas helped depress interest in the Horicon share-trapping program. In 1951, it required 30 trappers to take approximately the same number of muskrats.

Muskrats were spread out to the edges of the marsh. They seemed to be in generally good health despite the heavy concentration in some areas. The statewide muskrat population was following the same trend and close to a million muskrats were trapped during this peak season.

1953. The summer populations of muskrats was high and it appeared as though another big harvest was in prospect. Drought conditions through the late summer and fall resulted in a decrease in available water areas which intensified the competition for the remaining water areas by an already very high population of muskrats.

Trouble was evident as early as August when dead muskrats were being found in many parts of the state as well as at the marsh. Many of the dead muskrats were found to have symptoms typical of Errington's disease. The die-off continued right into the trapping season when it was not uncommon for trappers to find muskrats in the last stages of dying or to find fresh carcasses where there had been none the day before.

Undoubtedly many muskrats were salvaged by the earliness of the trapping season. If trapping had been delayed until mid-winter, the number of muskrats alive would have been much smaller than was the case in late October.

1954. January of this year had many sub-zero days with little snow cover at the time. The ice thickened quickly and the food normally available to many muskrats became imbedded in the ice. Runner muskrats became numerous. The share-trappers were able to take 2,462 of these runner muskrats. This was only a small portion of the muskrats lost because of the freeze-out. Many other runner muskrats were taken by predators or died of exposure and lack of food.

A heavy, drifting snow on January 26 practically ended the harvest of runner muskrats. Transportation was difficult and the insulating effect of the snow materially slowed ice formation so that new groups of muskrats were not frozen out by thick ice.

A few diseased muskrats were found in 1954, but no great numbers such as were seen in 1953. Small numbers of dead muskrats were found during the winter and spring trapping seasons. Clusters of houses at which no muskrats could be trapped indicated that more muskrats were dying of disease than were being found.

Trapping effort was high in 1954, with trapping starting on October 25 and terminating April 15, 1955. The harvest dropped to 16,682, about 8,000 below the 1953 harvest. Contributing to the decrease were: Fewer trappers, reduction in breeding stock and probably lower productivity due to the previous winter freeze-out, and some deaths still from disease.

1955. Water levels were deliberately lowered about 9 inches during the summer months in order to stimulate the growth of emergent aquatic vegetation. The acreage of muskrat summer habitat was therefore considerably lower than it had been for several years. By

mid-September, much of the state-owned marsh was dry except for shallow water in the ditches and old river channels.

The trapping season ran from October 25, until March 5, yet only 6,695 muskrats were taken by the 12 trappers. Of the total, 572 were runner muskrats taken during the period January 19 to March 5. A general lack of snow accompanied by low temperature resulted in thick ice formation and consequently the nearly complete elimination of muskrats from the shallow water sections of the marsh.

1956. Another drawdown was attempted this year, but frequent rains kept the water above the desired levels. Average pelt prices dropped below the dollar mark for the first time in many years. Low pelt prices and a reduced supply of muskrats combined to discourage trapping on the marsh. Only 8 trappers took part in the share-trapping program. The harvest dropped to 3,892 muskrats, the lowest since 1945.

1957. The muskrat population continued at a low level. Most shallow water areas were again dry during the summer months. Very low pelt prices further reduced trapper interest. For the first time, the share-trappers were given two-thirds of all the muskrats. Still, only 6 trappers trapped the state marsh. Two of these trappers took 3,870 of the 4,889 muskrats taken altogether. Trapping terminated January 31, 1958 because the catch became too small to make the effort worthwhile. The average price per pelt dropped to 79¢ to which can be added about 10¢ per carcass sold for mink feed. The real value per pelt is considerably lower after all expenses are deducted. These may include trapping license, trap tags at 10¢ each, trap loss, breakage and depreciation, car and motor boat expenses. The final deduction is the payment of income taxes, if necessary. It is no wonder that trapping activity declines when pelt prices become very low.

1958. Muskrat prices, the population level, and trapper interest continued at a low level. The net result was a low harvest of 2,973 muskrats of which about 200 were winter runners. Seven trappers started on October 28, but only two continued after the freeze-up and stayed with the job until trapping finally stopped on February 22, 1959. Diseased muskrats were not conspicuous. The likelihood of finding diseased muskrats was lowered because of the relatively few muskrats living on the marsh.

1959. Muskrat sign was hard to find during the summer months. The scarcity of muskrats was emphasized by the fact that most wild rice plants were not clipped. In previous years, utilization of wild rice by muskrats was very heavy. The marsh was opened for trapping, despite the apparent scarcity of muskrats, to see if the trappers could locate more muskrats than were believed present. Two trappers

worked the marsh and were able to take only 802 muskrats. The trappers were free to move wherever they wished, but no good concentrations of muskrats were found.

1960. Water levels were very high during the year, especially in the summer months. A surprisingly large amount of muskrat sign became evident in the spring, indicating that trapping of the low 1959 population had done no harm. There probably had been more muskrats present in 1959 than were estimated, but the unseen muskrats were believed to have been living in unusual numbers in very dense stands of cattail where they could neither be seen nor trapped.

Prices were at their lowest level in over twenty years. The average price was about 77¢, which was too low to provide much incentive. Nevertheless, 6 trappers took 5,467 muskrats, a 6-fold increase over 1959. Spring trapping accounted for several hundred muskrats, but this trapping was limited to subimpoundments to reduce damage from tunneling muskrats.

1961. Daytime sightings of muskrats were conspicuously higher this year. A high muskrat population became even more obvious when a great many muskrats were seen while nightlighting for ducks. Getting an adequate harvest this year promised to be a problem.

Trapping during three periods resulted in a take of 10,973 muskrats. About one-third of the total was taken during each trapping period. The second was the winter period when much of the take consisted of runner muskrats. To further reduce the population, the third period of trapping was run from March 29 to April 20, 1962. A special effort was made to take all muskrats possible because of the planned drastic drawdown of water levels during the summer months. Although 14 trappers took part in this year's trapping, the bulk of the muskrats, amounting to 87 percent, were taken by just 5 of the trappers. The highest catch per trapper was 2,910 muskrats. Trapping conditions must be pretty good for even a good trapper to take this many muskrats in one season in competition with the others.

Prices rose somewhat with the trappers receiving 93¢ per pelt and the state $1.28. This price increase was enough to re-create a heightened interest in the trapping of wild furbearers.

1962. Water levels were deliberately kept low throughout the summer, greatly reducing the quantity of good muskrat habitat. Despite the high intensity of the 1961 trapping effort and lack of water in the summer of 1962, the muskrats developed a remarkably high population.

The outstanding feature of the year was the fact that thousands of muskrats persisted in areas without surface water. Tunnels were dug as much as 2 feet deep to reach water. Many muskrats remained in

the dry areas even at freeze-up time. The harvest rose to 10,885. Of these, about 1,200 were runners and 3,545 were taken in a spring trapping season. The spring trapping was a salvage operation because of a planned drastic water drawdown in 1963.

1963. The marsh became even drier than in 1962. Drought conditions intensified the effect of the drawdown. Essentially there was no open water from summer through the winter except in the Main Ditch, a few side ditches, and portions of old river channels. This year the muskrats did not thrive in the dry portions of the marsh. The population remained low. Road-killed muskrats were quite common around the marsh throughout the summer. Only 1,558 muskrats were taken during the trapping season. Of these, about 71 were winter runners.

A lack of snow during the winter coupled with very low water levels resulted in poor wintering conditions. Consequently, the muskrat population at Horicon is thought to be at the lowest point in 20 years.

1964. Muskrat populations at an all-time low. Drought conditions for several years plus severe wintering conditions reduced the population to a point where trapping was not advisable.

APPENDIX D

Scientific Names of Plants and Animals Mentioned in Text

PLANTS (After Fassett, 1940)	
Bluejoint	*Calamagrostis canadensis*
Cattail	*Typha latifolia* and *T. angustifolia*
White water lily	*Nymphaea odorata*
MAMMALS (After Jackson, 1961)	
Muskrat	*Ondatra zibethicus*
Mink	*Mustela vison*
Raccoon	*Procyon lotor*
Red fox	*Vulpes fulva*
Meadow mouse	*Microtus pennsylvanicus*
Beaver	*Castor canadensis*
BIRDS (After Gromme, 1963)	
Snowy owl	*Nyctea scandiaca*
Great blue heron	*Ardea herodius*
Black-crowned night heron	*Nycticorax nycticorax*
Great horned owl	*Bubo virginianus*

FISH, ETC. (After Hubbs and Lagler, 1941)

Carp	*Cyprinus carpio*
Northern pike	*Esox lucius*
Bullhead	*Ameiurus* sp.
Crayfish	*Cambarus* sp.
Snapping turtle	*Chelydra serpentina*

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