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MUSKRAT GROWTH AND LITTER PRODUCTION

STATE CONSERVATION COMMISSION OF WISCONSIN

TECHNICAL WILDLIFE BULLETIN NUMBER 8
Game Management Division
WISCONSIN CONSERVATION DEPARTMENT
Madison 1, Wisconsin
1953

MUSKRAT GROWTH AND LITTER PRODUCTION

by

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Pittman–Robertson Project 15-R

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1 9 5 3

ACKNOWLEDGMENTS

Cyril Kabat and Harold A. Mathiak contributed many helpful suggestions during the course of this study. Arlyn F. Linde assisted in collecting the field data. Charles W. Lemke and Donald R. Thompson of the Pittman–Robertson Game Survey Project (25–R), and James H. Torrie and Robert G. D. Steele of the University of Wisconsin assisted in the statistical analyses. Joseph J. Hickey and Robert A. McCabe of the University of Wisconsin's Department of Wildlife Management, and Ruth L. Hine assisted in reviewing the manuscript.

Edited by James B. Hale

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INTRODUCTION

To determine the success of a breeding season, it is necessary to know the number of young produced, when they are produced, and their relative survival rates. For muskrats *(Ondatra zibethica)*, one method used to estimate the number of young produced is to count litters in muskrat houses throughout the breeding season. Litters varying in age from newly born to 30 days old are commonly handled when muskrat houses are opened. To calculate the birth dates of these litters and their relative survival rates, it is essential that accurate aging criteria be developed. Thus a knowledge of muskrat kit growth rates is needed to determine the success of a muskrat breeding season.

Errington (1939) was able to develop growth curves for nestling muskrats in Iowa by recording the weight and total length of kits of known age. However, adult muskrats trapped in the fall on Horicon Marsh in Wisconsin (Truax 1948a) are considerably heavier than adult muskrats trapped in Iowa (Errington *op. cit.*). Therefore, since the growth rates of Horicon Marsh muskrats appeared to be more rapid than those of Iowa muskrats, a local growth study was undertaken in the spring of 1950 to age accurately kits handled on Horicon Marsh. This study also provided a method for estimating the birth dates of immature muskrats trapped in the fall, and other related data on production, survival, and movement.

THE STUDY AREA

The study was conducted on the southern portion (10,000 acres) of Horicon Marsh which is located in Dodge county near Horicon, Wisconsin and is managed by the Wisconsin Conservation Department primarily for muskrats and waterfowl. This section of the marsh is divided into 56 trapping areas of various sizes. The muskrats in each trapping area are harvested in the fall by private trappers, the total fur catch being divided between the state and the trapper on a 50–50 basis.

In selecting a trapping area for an intensive growth study, two factors were considered. To permit adequate sampling in a single breeding season, it was essential that the trapping area should have a high muskrat breeding density. Second, the emergent cover had to be interspersed with enough open water to make it easy to locate the muskrat houses and to capture the older kits that are able to swim out of the houses and hide in heavy emergent cover.

Thus Trapping Area 50, containing 69 acres, was selected for the study. In 1950 the area had a high muskrat population living in scattered clumps of cattail *(Typha latifolia* and *T. angustifolia)* and bulrush *(Scirpus validus)* interspersed with open water. Along the eastern edge of the area adjacent to the upland was a fairly heavy stand of bur-reed *(Sparganium eurycarpum)*. In May, the water was about two feet deep in the bur-reed fringe and three to four feet deep around the cattail and bulrush clumps.

During the fall trapping season of 1949, 10 muskrats were harvested per acre in Area 50. During the 1950 breeding season, we estimated the breeding population to be 51 adult females.

A considerable amount of fluctuation in water levels occurred in the summer of 1950 in Area 50. In May and June, the water level remained quite stationary, but during July, heavy rains raised the level 1.2 feet in a few days. By the end of August, the water had receded to the May level.

Area 50 was too large to locate every muskrat house accurately on a field map. The area was therefore subdivided into 36 sections. Twenty-four of the sections were 300 feet by 300 feet, while twelve located along the edges of the area were irregular in size. All of the section corners were marked by a numbered tin can placed on a steel fence post. With this system it was easy to cover-map, plot houses, and determine the distances that marked muskrats had moved.

PROCEDURES

Handling Interval

We opened every muskrat house and feeder house in Area 50 at approximately ten-day intervals throughout the entire breeding season. This allowed for the handling of a maximum number of newly-born kits without causing a great deal of disturbance to the breeding muskrats. The first of the periodic checks for litters in Area 50 was made from May 8 to 12, 1950. Every muskrat house and feeder house was opened and their location plotted on a field map. During subsequent 10-day checks litters of known age that had been previously handled were not disturbed, but were rehandled at the most desirable interval for growth data. We made the last check of all muskrat houses in Area 50 on September 8. When time permitted we searched other trapping areas adjacent to Area 50 for newly-born litters to get more growth data. Area 52, lying west of Area 50, was intensively searched from June to the end of August.

The term "rehandled" as used here will refer only to marked muskrat kits caught by hand in muskrat houses; "recovered" will refer to previously-marked muskrats killed during the fall steel-trapping season.

Measurements Taken

All muskrats kits captured during the growth study were weighed to the nearest gram with a spring gram scale. To avoid any unnoticed stretching of the spring in the scale, it was checked once a week with standard weights. The tail lengths of handled muskrat kits were also recorded for growth information. For convenience in the field, we measured the tail length from the anus to the tip of the last vertebra. This measurement was easily taken by suspending the kit by the tail with one hand and laying the ruler alongside the tail. Measurements were taken to the nearest millimeter. Total-length measurements were not taken since they tend to be inaccurate and too time consuming with struggling kits.

Kit-Marking Methods

Kits were marked by toe-clipping and/or ear-tagging with fingerling tags. The toe-clipping system used in this study is shown in Figure 1. The major part of the clipping was confined to the ten rear toes since the front feet of the muskrat are used extensively in securing food and in digging burrows. With this particular toe-clipping system, it was possible to have a consecutive series of litter numbers from 1 to 499. For example, a muskrat bearing number 166 would have toe 100 clipped on its left front foot, toes 50 and 10 clipped on its right rear foot and toes 5 and 1 clipped on its left rear foot $[100 + (50+10) + (5+1)] = 166$. Ear tags were used only on kits weighing 70 grams or more since it has been shown that kits tagged when less than 70 grams in weight have low rates of recovery (Mathiak 1949a).

La Crosse cuticle clippers were used to remove the toes for marking. On kits up to 5 days of age, the toes were so short and so tightly packed together that it was necessary to clip each toe as close

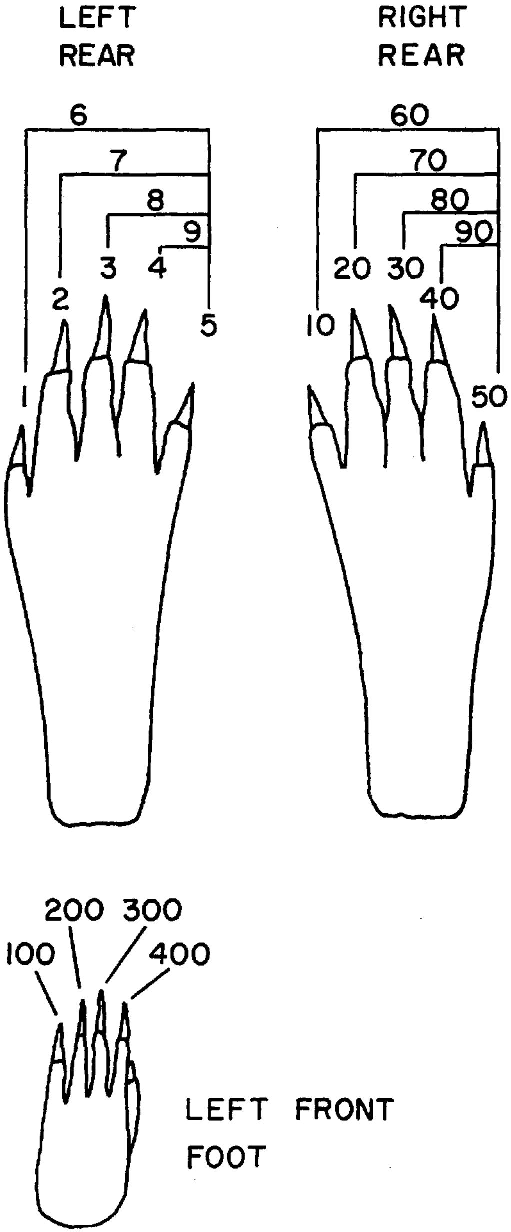


Figure 1
Toe-clipping Code for Kits

to the foot as possible. After the toes had become elongated, each toe was clipped off at the first joint. Muskrats with toes clipped in this manner generally had about ¾ of the clipped toe remaining after reaching adult size.

A tincture of ferric chloride was applied to each clipped toe stub to cauterize and sterilize the wound. Ferric chloride was especially useful in preventing blood loss in small kits. After kits reached 14 days of age, very little bleeding took place when their toes were clipped at the first joint. A total of 635 nestling kits were toe-clipped with this system. Only one kit of the 263 kits rehandled had a slight infection in a clipped toe. Fall recovery of this kit showed that the infected toe was completely healed.

Some of the litters that were toe-clipped at 1–5 days of age had regenerated toenails when rehandled. Toe numbers 3, 5, 30, and 50 (Figure 1) showed the greatest amount of regrowth. Undoubtedly the toenail regrowth was due to their small size at birth and to the difficulty in clipping them deeply enough. No confusion resulted, however, since the new toenail was abnormal in shape and size. This regrowth was later eliminated by using toe numbers other than 3, 5, 30, and 50 on newly-born kits.

When the immature toe-clipped muskrats were steel-trapped in fall, some additional nail regrowth was also discovered. Generally the same toe numbers that were observed to regrow toenails in the kits were the ones that showed regrowth in the trapping sample. The feet of every trapped muskrat were carefully examined for deformed, discolored, or shortened toenails. Because most of the handled muskrats had more than one toe clipped and many were ear-tagged, it is unlikely that any toe-clipped muskrats were missed due to the regrowth of toenails.

Toes mutilated in a steel trap can be readily separated from a toe-clipped muskrat since a freshly-mangled toe is bloody or unhealed. Adult muskrats with toes lost from a previous trapping season were not confused with immature muskrats since their age can be determined in the fall by examining their gentalia. (Baumgartner and Bellrose 1943).

Toe-clipping was therefore a very useful technique for marking kits too small to ear-tag and was also satisfactory for identifying marked kits in the fall trapping season, providing care was taken in examining each trapped immature animal.

Live-Trapping and Steel-Trapping

After muskrat kits are weaned—at 30 days or less (Errington 1939)—it rapidly becomes more difficult to rehandle them in muskrat houses. Therefore, live traps were used to get growth data for weaned kits. Both National live traps and family live traps (Snead 1950) were used during the months of August, September, and October. To gather information from marked kits caught in steel traps, Dorney accompanied the trapper assigned to Area 50 from November 2 through November 9.

RESULTS

Movements of Muskrat Kits

From previous litter-tagging experience, it was known that litters may be moved by adults to a different muskrat house following their handling (Truax 1947b). In order to rehandle adequate samples of marked kits, it is important to know the distance these litters may be moved and the probability of their movement.

Muskrat kits are moved two ways by the adult female. If an adult female is disturbed in a muskrat house while her young are nursing, she may swim out of the muskrat house with one or more of her kits hanging tightly to her teats. Not infrequently the entire litter is thus moved. This type of movement has been recorded by other workers (Errington 1939, Smith 1938). Movement of kits on the female's teats can be easily recognized in the field by finding young kits with wet fur in atypical breeding locations, or by finding a muskrat litter scattered from the nest to the plunge-hole when the breeding house is opened. Kits moved in this manner usually will be deposited by the adult female on top of a nearby feeding platform or inside a feeder house. (A feeder house can be defined as a single-chambered muskrat house less than two feet in diameter.) In this study the age range of kits moved on the female's teats was 2 to 11 days. Teat movement is, of course, not planned by the adult female and may well be called "fright movement".

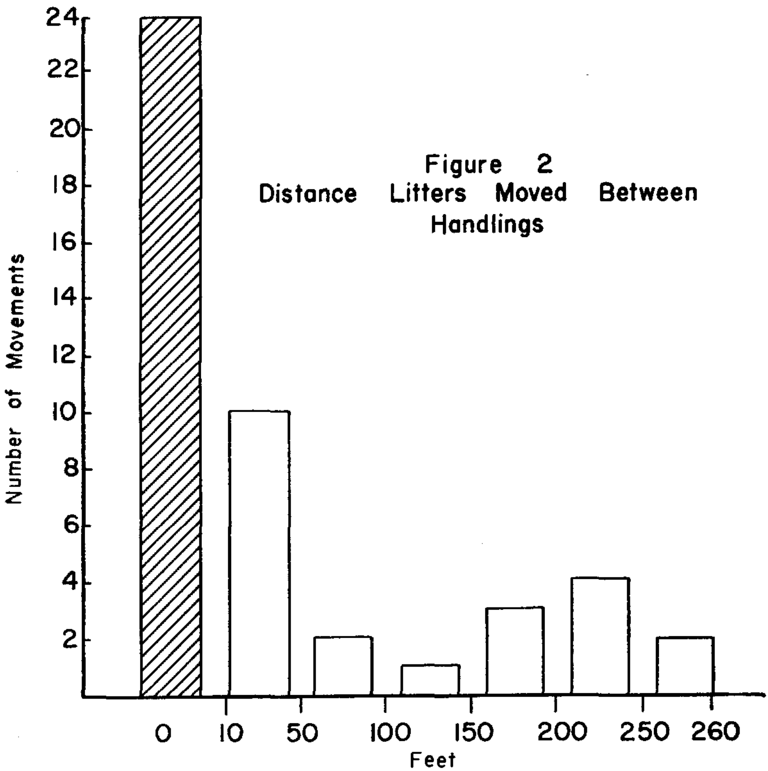
The other way in which kits may be moved is by the adult female carrying them in her mouth (Lang 1925). It is probably safe to assume that all movement of nursing litters following their handling is of this type. Data from a sample of 22 litters that were moved following their handling in Area 50 indicate that kits as old as 23 days may be moved varying distances in this way. For example, on

June 3, four kits 23 days old were rehandled from litter number five. On June 8, two kits from this litter were rehandled in a newly-built muskrat house 175 feet from the original home lodge. Two more kits, undoubtedly from the same litter, were seen in this house at the same time but were able to escape handling.

Kit movement may take place immediately after a litter is handled. We toe-clipped eight kits nine days old at noon on May 24. One hour later, we found seven of the marked kits from this litter in a feeder house 50 feet from the original lodge. They were very wet, indicating the recency of movement. We immediately reopened the original lodge, but the last kit could not be found.

Three other litters were known to have been moved to new houses in less than one day. Two of these litters were moved to newly-constructed, semi-open feeder houses while the third litter was moved to an open nest built on a feeder platform.

The distances litters 1–30 days old were moved between successive rehandlings are shown by a frequency histogram in Figure 2. The



oldest litter at first handling in this sample was 21 days of age. The data are probably not distorted by litters moving away from Area 50 since none of the 59 nursing litters handled around the edges of Area 50 had been marked inside the area. Movements known to have occurred due to females carrying the young on their teats are not included in Figure 2. For those litters rehandled more than once, each rehandling is recorded as one occurrence. Litter number 84, which had the greatest number of movements, is represented in the histogram three times since the litter was found in three new locations. Litters rehandled in the same lodge are recorded as an individual occurrence of no movement.

Assuming a litter has remained alive, it is readily apparent that the chance of rehandling a marked litter in the original lodge is about 50 per cent. Ten of the 22 litters were moved less than 50 feet from their original lodge. In many cases the distance a litter was moved appeared to be governed by the location of the nearest muskrat lodge that was in repair. Occasionally, to accommodate the newly-moved litter, complete new lodges were built on feeding platforms, or abandoned lodges were rebuilt. The longest litter movement found in this sample was 260 feet. Errington and Errington (1937) recorded the movement of dependent young by adults up to 60 yards following disturbance. Therefore, if an area of marsh about 300 feet around the original house is searched, it should be adequate for locating moved litters.

Movements of Immature Muskrats

During the first eight days of the fall steel-trapping season (November 2–9) Dorney examined all muskrats caught in Area 50 as they were removed from steel traps. In this way it was possible to determine the exact distance marked muskrats had moved since they were last handled as kits. A more extensive study on immature muskrat movement covering many trapping areas and conducted over a period of years will be published by the Wisconsin Fur Research Project (15–R) at a later date. The movement data from our intensive study are recorded in Table 1.

After investigating reports by Mathiak (1950a) and Takos (1944) on the movement of marked muskrats, we assumed the home range of a muskrat in fall to be 300 feet or less. Using this assumption, 38 or approximately two-thirds of the 56 immature muskrats did not move from the home range in which they were born. It appears that for

Area 50, the May-born kits dispersed more widely than did any other age group. However, the small size of the samples prevents further generalization.

Table 1

Movements of Marked Immature Muskrats from Location as Kits

	Month of Birth					
	May	*June*	*July*	*August*	*September*	*Total*
No. of Kits Marked	165	84	61	30	8	348
Movement in Feet:						
0–299	16	7	7	7	1	38
300–399	1	--	1	--	--	2
400–499	2	--	--	2	--	4
500–599	1	1	--	--	--	2
600–699	--	1	--	--	--	1
700–799	4	--	1	--	--	5
800–899	1	--	--	--	--	1
900–plus	3	--	--	--	--	3
Total Number Moved	28	9	9	9	1	56
Per Cent Moved More Than 300 Feet	43	22	22	22	0	32

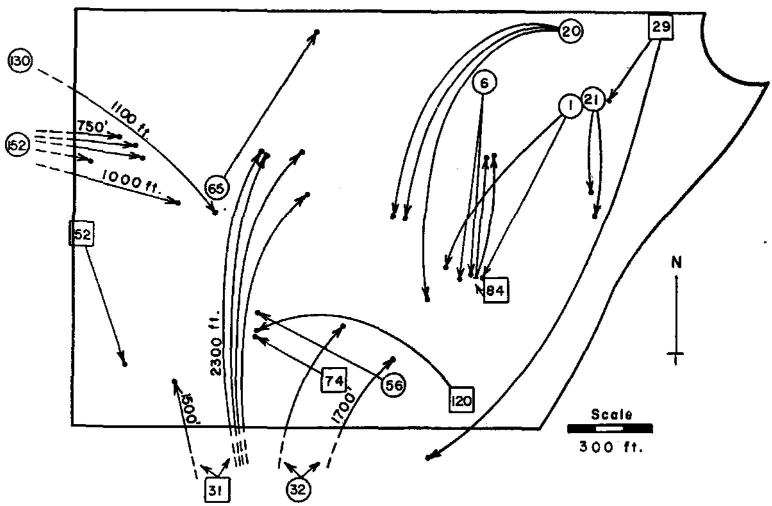
One of the August-born kits that had moved 420 feet was found sitting on a muskrat house on November 6, badly cut in the hind quarters. Whether or not this movement was the result of physical eviction is unknown. The movement data probably are not distorted by the voluntary movement of immature muskrats out of Area 50, since only one marked muskrat was recovered 100 feet outside Area 50. The surrounding areas were heavily trapped.

All immature muskrats that moved more than 300 feet were plotted individually on a map shown in Figure 3. Marked kits that moved into Area 50 are also recorded on this map. The distances moved within Area 50 are accurate to approximately 15 feet, while those for movements from adjacent areas into Area 50 probably are accurate to about 100 feet. It is readily apparent that a general movement of immature muskrats took place into the western portion of Area 50 from the surrounding marsh.

General movement into this portion of Area 50 was substantiated by the increased amount of muskrat sign. Few breeding houses had been present in this portion of Area 50 during the summer. This dearth of breeding houses may have been largely due to the excessive water depths, particularly during the July floods, as well as to the almost complete absence of emergent cover until the middle of June. During September it became apparent that large numbers of muskrats were using the scattered emergent cover for feeding. Also, a great many more muskrat houses were being built in this portion of Area 50 than could possibly be accounted for by the thinly-distributed resident population. Thus field observation and evidence from marked kits indicated that this portion of Area 50 was attractive to muskrats in the fall. It appears likely that this general movement may have been due to the low density of resident muskrats plus the preference of muskrats for wintering in deeper water.

Figure 3

Movements of Immature Muskrats from Location of Last Handling as Kits to their Location When Steel-Trapped in Fall



Legend:

2 One or more of litter trapped less than 300 feet from original lodge.

2 All of litter trapped more than 300 feet from original lodge.

Enclosed numerals are litter numbers.

Only movements greater than 300 feet are plotted.

Figure 3 also indicates that in some cases part or all of a litter appeared to move as a group to a new fall location. It is not probable that these group movements represent extended feeding trips outside normal home range. If these muskrats were making long feeding trips from their home lodge they should have been trapped in all directions from their home lodge rather than in one localized area.

The trapping pressure was uniformly distributed throughout Area 50 during the eight trapping nights when these movements were recorded. The trapper in Area 50 set 80 per cent of his traps on muskrat houses to catch muskrats building on their lodges. It is more likely that muskrats trapped while house building are within their home range.

It is quite possible that in the case of litters 52, 21, and 74, the short movements shown in Figure 3 may not represent a change in home range. However, it seems unlikely that four of the six recoveries of litter 31 almost half a mile from their original home range were merely the result of coincidental feeding trips to the same location. Rather, the data suggest that in some cases a litter or part of a litter may tend to move as a group to a new location. Carter (1922) also recorded the group-movement of two adults and four of their half-grown young into an unpopulated marsh in August.

Kit-Aging Criteria and Rehandling Success

Accurate growth information for kits was obtained by determining as accurately as possible when a litter of muskrats had been born. To establish some criteria for determining the age of young muskrat kits, a pregnant female was placed in a pen and closely observed. This female gave birth to at least six kits within a 3-day period. In contrast to this protracted birth period the greatest difference in age detected in wild litters was approximately one day. Apparently confinement may have caused this atypical three-day interval. It was clear that aging a litter to the nearest day can be an artificial classification.

Using the pen-raised kits, one litter that was rehandled within a few days after birth, and a few young litters clearly showing kits of different ages, the following aging criteria for young muskrats were developed.

Newly-born kits less than ten hours old have a placenta and/or a fresh cord attached. Often kits of this age have fresh cuts on their bodies. Their dorsal surface is light grey, and they are inactive. One-day-old kits have the placenta removed and an umbilical scab present. Occasionally a portion of the dried umbilical cord may still be attached. Two-day-old kits have an umbilical scab present and their dorsal surface is somewhat darker. Many of the two-day-old litters could be clearly differentiated from the three-day-old litters since one or more members of the litter were about one day old. Three-, four-, and five-day-old kits have an umbilical scab present. They were differentiated mainly on the basis of their weight and tail length. Data from one six-day-old litter indicated that the umbilical scabs begin to drop off at this age. For this reason, the only litters used for kit-growth information were those with umbilical scabs present.

Since no litters older than five days were used as a starting point for developing the 1- to 30-day growth regressions, no serious errors in back-dating should have occurred. Those litters having birth dates that could be determined to the nearest day will be called known-age litters.

Table 2

Frequency Distribution of Known-Age Litter Rehandling

Number of Times Rehandled	*Number of Litters Handled*
1	12
2	11
3	7
4	1
Total	31

Table 2 shows the number of times the known-age litters were rehandled. In general these litters were rehandled at about ten-day intervals until the litter was 25 days of age. Although it would have been possible to rehandle these known-age litters at more frequent intervals, we felt that a smaller sample of kits that was disturbed a fewer number of times would yield more accurate growth information. After a litter was 25 days of age a rehandling attempt was made about once every three days until the litter was too old to catch in the muskrat house.

For workers who may attempt to rehandle a large series of young kits, it may be well to report here the probability of success that was found for rehandling known-age litters. During the entire breeding season, 59 known-age litters were handled (some outside Area 50). In every case, considerable effort was expended to rehandle these litters. However, it was only possible to rehandle 31 of the 59 litters; hence only about half of the young litters could be found a second time.

Growth Regression for Muskrat Kits

The tail-length and weight regressions derived from rehandling known-age kits from 1 to 30 days of age are shown in Figures 4 and 5. The confidence limits for regression at the 95 per cent level are also plotted in these figures. All litters that contained newly-born kits were considered as one day old. In Table 3 the standard deviations and means for both tail length and weight are recorded by one-day intervals. These means tail lengths and weights were used to calculate the regressions. The number of kits handled in each one-day class is also shown.

Table 3

Standard Deviations and Means for Tail Lengths and Weights of Muskrat Kits

		Tails (mm.)		*Weights (gms.)*	
Age in Days	*No. of Kits*	*Mean Length*	*Standard Deviation*	*Mean Weight*	*Standard Deviation*
1	70	28.5	2.15	23.0	2.56
2	58	31.4	1.77	26.1	3.31
3	16	34.6	2.25	31.4	2.45
4	32	38.5	2.37	35.6	2.98
5	15	41.3	2.25	40.3	3.20
6	12	42.3	5.16	37.0	2.58
7	0	-----	-----	-----	-----
8	8	49.5	2.27	49.6	4.69
9	14	51.4	2.20	50.6	2.65
10	0	-----	-----	-----	-----
11	14	63.1	2.57	67.6	4.09
12	20	63.7	4.89	71.9	8.65
13	6	62.0	1.79	71.0	2.00
14	15	77.8	5.63	86.9	2.45
15	12	77.3	5.71	97.8	2.46
16	3	84.3	2.55	102.7	3.08
17	12	88.2	8.00	113.5	17.71
18	2	92.5	13.45	118.5	16.28
19	10	95.4	3.23	112.2	1.82
20	9	98.0	10.83	121.8	14.87
21	18	105.9	8.28	131.4	12.42
22	9	108.7	8.12	140.1	9.08
23	10	112.0	6.02	150.2	8.52
24	2	116.5	14.87	163.5	33.24
25	1	(117)	-----	(164)	-----
26	2	109.5	3.61	141.5	9.22
27	6	128.3	5.64	173.0	18.01
28	3	125.3	3.81	188.7	6.12
29	1	(125)	-----	(245)	----
30	2	135.5	2.24	235.0	35.36
Total	382				

One known-age litter (number 30) showed definite signs of malnutrition. The fur of the kits in this litter was very coarse, and their general appearance was strikingly different from all other litters handled. Their growth rates were extremely slow, and since kits showing this type of growth can be easily separated from normal kits by appearance, this litter was not included in the growth regression, but was plotted separately in Figures 4 and 5.

An analysis was made of the effect of sex, litter size, and period of birth on the average weight of known-age kits. The method of ranking paired replicates as described by Wilcoxan (1950) was used for all these analyses.

Figure 4
Regression Tail Length and Age of Muskrat
Kits

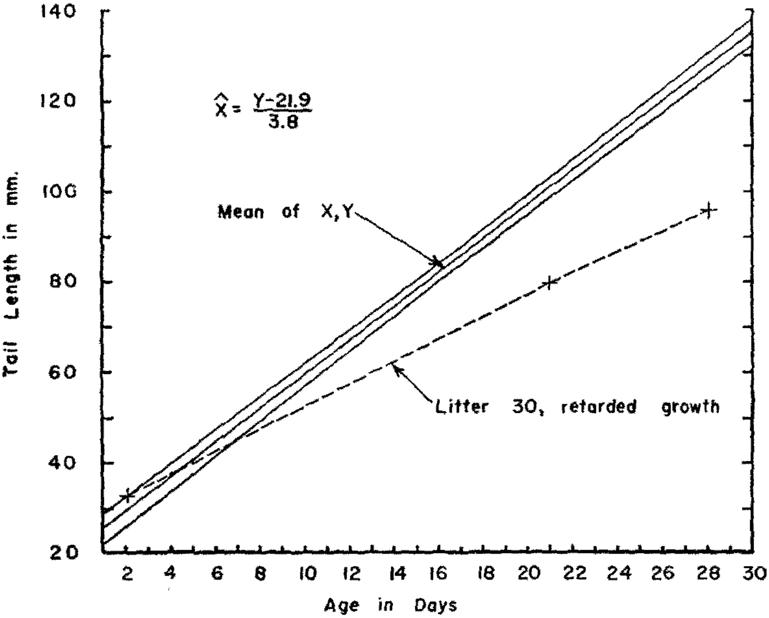
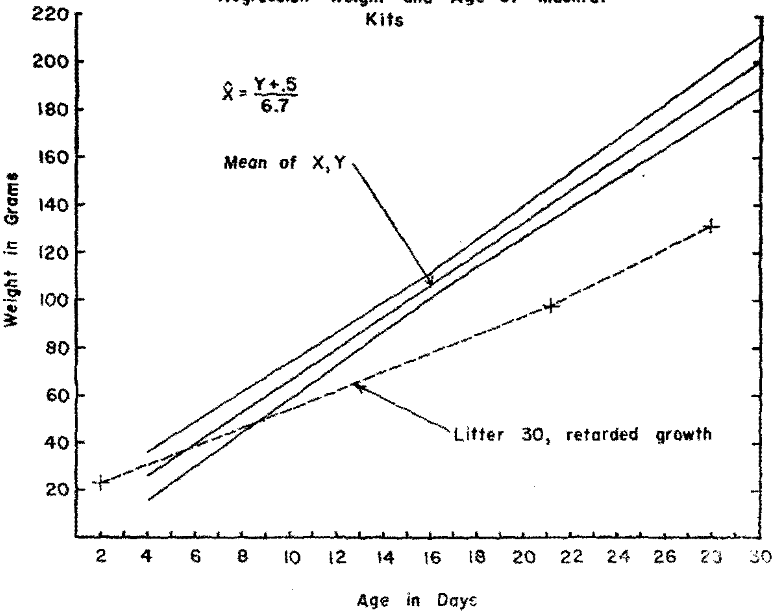


Figure 5
Regression Weight and Age of Muskrat
Kits



The average weight differences between litters born in May, June, and July were not statistically significant. The weight differences between members of small and large litters were also not significant. This analysis was based on litters from 1 to 6 kits and 7 to 10 kits in size. However, the sample for this analysis was small since it was restricted to those litters which were known not to have suffered enough mortality between handlings to change from the large- to the small-litter group.

The weight differences between male and female muskrat kits was significant (P. $<$ 5 per cent). The female kits had the highest rate of weight gain. Since most litters contain both sexes, the distortion in back-dating kits by using an average growth curve would be very slight.

The regression confidence limits for tail lengths in Figure 4 show that tail length is an accurate indicator of muskrat kit age. Since tail-length measurements are easier to obtain in the field than weights, kit aging should preferably be based on tail length.

Growth Regression for Immature Muskrats

The Wisconsin Fur Research Project (15–R) has been ear-tagging muskrat kits and recovering them during fall trapping seasons since 1947 (Truax 1947a, 1948b, and Mathiak 1949b, 1950b). This has made available a total of 556 steel-trapped muskrat weights for growth analysis. The age of each marked muskrat trapped in fall was determined by first aging its litter using the tail-length regression criterion shown in Figure 4. With an approximate birth date established, the age of the muskrat when trapped was then calculated. Since most of the litters were marked when they were from 12 to 25 days of age, the back-dating error was quite small.

On Horicon Marsh the trapping season starts on November 1 and often lasts into January. This means that many ages are present among the marked muskrats caught. One of the purposes of developing a growth regression for immature muskrats was to back-date muskrats trapped in the fall. Since the largest samples of muskrats are usually trapped during the first two weeks in November, the data for the growth regression were restricted to muskrats steel-trapped throughout November. However, to make a complete weight-age regression it was necessary to include weights of previously marked litter-handled and live-trapped muskrats for the period from 31 to 99 days, since very few muskrats of these young ages are trapped in November. A total of 78 per cent of the weights from muskrats varying in age from 31 to 99 days were live-trapped and litter-handled muskrats. All other weights were from marked muskrats killed in steel traps in November.

Before the growth data for 1947 through 1950 could be combined into one regression, it was important to know whether or not growth rates for the four years were identical. First, weight data were grouped by ten-day classes from 31 to 199 days of age. Weights from 1950 made up 83 per cent of the sample; 1949, 13 per cent; 1948, 2 per cent; and 1947, 2 per cent. Because it was impractical to analyze the weight differences for muskrats trapped in 1947 and 1948 due to their presence in such small numbers, only the 1949 and 1950 weight groups were analyzed (*t* test).

The weight data were broken into six ten-day age classes including a sex breakdown. One hundred and twenty-two from 1950 were compared with 45 from 1949. Of these six paired classes, only one pair showed a significant difference between the weights of the two years. We assumed that this difference was due to a 1-in-20 chance sampling. On the basis of this evidence, all four years were combined in calculating the growth regression.

To determine whether a muskrat of the same numerical age trapped during different portions of November was of the same average weight, we made an analysis of variance comparing these groups. November was divided into four periods. A total of 13 analyses was run on ten-day age classes stratified by period. Only one of the 13 analyses had a probability less than 5 per cent. Since only one group showed a significant difference for period trapped, we assumed that this difference was due to a 1-in-20 chance sampling. The period in November in which a muskrat had been trapped was therefore considered unimportant.

A test of significance was next applied to male and female weights. For 15 paired ten-day age classes, four showed a significant difference between the sexes. When the mean weights for male and female muskrats were compared by ranking paired replicates as described by Wilcoxan (1950), the probability level was one per cent. It seems likely, therefore, that male and female weights do differ. In any case, the sexes were separated in the regression analysis.

Weight distortion due to wet fur was not large since all weights were taken when the muskrat was reasonably dry. When an 800-gram dry immature muskrat was put in water and then dried by shaking and wringing, its weight increased about ten grams. This amounts to a distortion due to wet fur of less than two per cent.

Tail lengths were not used for aging immature muskrats since a muskrat's tail shortens after death. The tail length of a freshly killed muskrat was 242 mm. Five hours later, the tail had decreased to a length of 222 mm. More extreme shrinkage was noted when the live-trapped tail length was compared with the steel-trapped tail length after a muskrat had been dead for more than five hours. Trappers bring in muskrats that have been dead varying lengths of time, so that tail shrinkages may be greater than ten per cent. We felt that this sampling variability was too great for use as an aging technique. Thus weights from trapped muskrats appear to be more reliable than do tail lengths. This is in contrast to the aging method for live kits where tail lengths are preferable to weights.

Table 4

Standard Deviations and Mean Weights in Grams for Male and Female Immature Muskrats 31 to 199 Days of Age

	Male			*Female*		
Age Range in Days	*No. of Wts.*	*Mean Weight*	*Standard Deviation*	*No. of Wts.*	*Mean Weight*	*Standard Deviation*
31– 39	4	218	14.0	6	185	17.5
40– 49	7	266	22.3	3	279	23.4
50– 59	1	368	-----	4	361	42.7
60– 69	3	375	13.0	2	348	81.3
70– 79	2	564	75.7	4	522	173.1
80– 89	8	541	66.8	2	512	159.1
90– 99	3	656	17.0	2	625	1.0
100–109	11	806	58.6	12	714	79.6
110–119	13	845	106.1	20	829	85.9
120–129	12	800	118.9	13	834	189.0
130–139	31	903	108.8	21	801	111.8
140–149	31	936	139.5	36	880	127.7
150–159	34	1,012	132.0	25	989	91.7
160–169	37	1,041	118.5	32	1,015	99.5
170–179	60	1,059	94.4	33	983	104.7
180–189	42	1,081	94.5	25	1,061	80.1
190–199	10	1,108	104.5	7	1,092	107.4
Total	309			247		

In Table 4 the means and standard deviations for male and female immature muskrat weights are tabulated. Figure 6 shows the curvilinear weight regressions for male and female immature muskrats from 31 to 199 days of age. Using this regression, the age of a fall-trapped immature muskrat can be calculated if its weight is known.

It is important to point out that this weight-age regression for immatures does not necessarily represent the average summer and early fall weights of immature muskrats of a given age. If the age of a weaned muskrat in summer or early fall is desired, it would only be safe to use the mean weights for muskrats 31 to 99 days old (Table 4) since these mean weights were taken primarily before the steel-trapping season started in November.

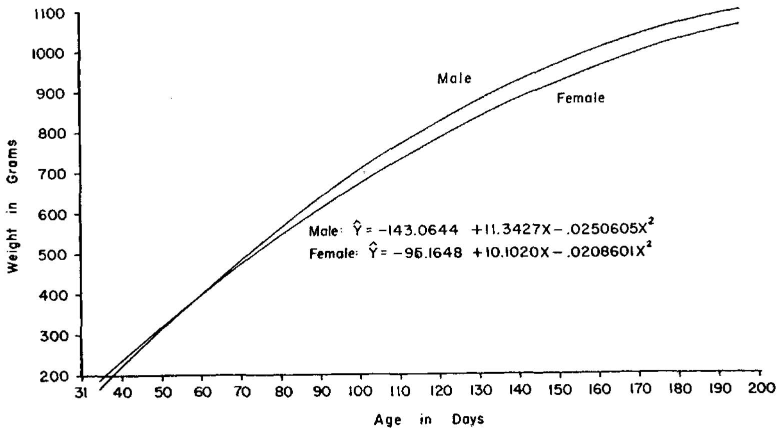


Figure 6
Growth Regression for Male and Female Immature Muskrats from 31 to 199 Days of Age

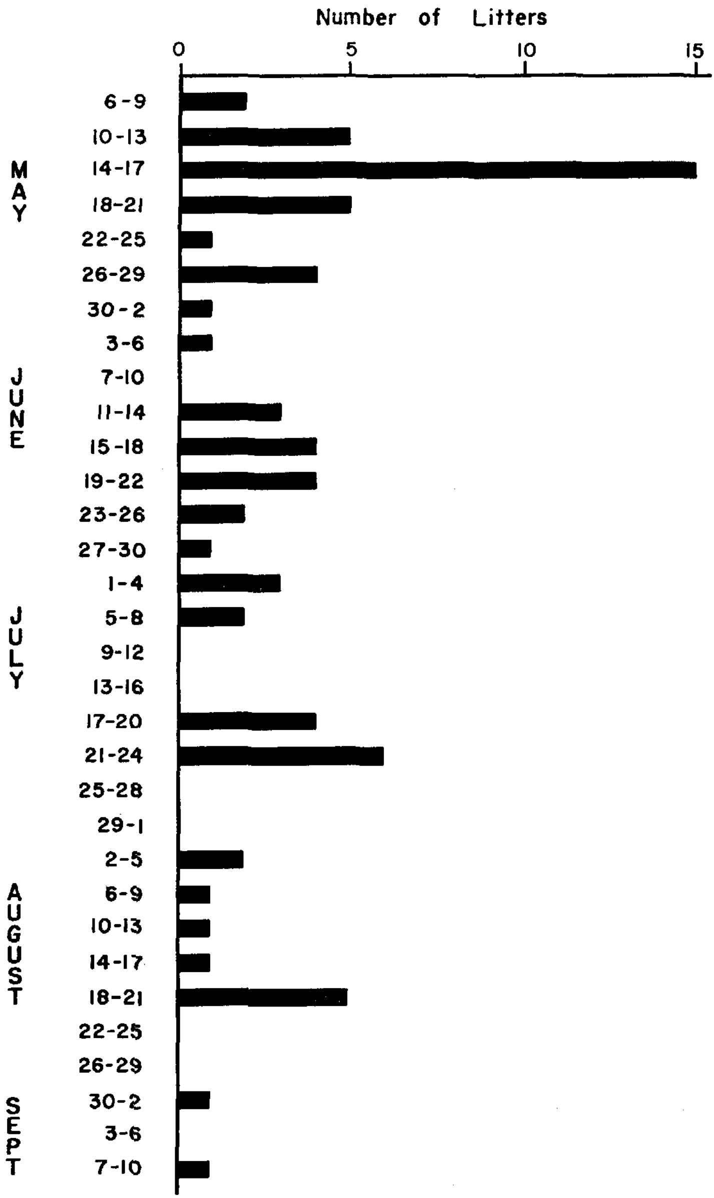
Breeding Season Production Periods

One of the objectives of this study was to develop a method for estimating the birth dates of immature muskrats trapped in the fall so that their periods of litter production could be determined from fall samples. The weight-age regression for immature muskrats suggested that a weight frequency distribution of the fall weights of immature muskrats might be of some value for ascertaining the major periods of litter production that occurred during the preceding breeding season. To test the reliability of this weight-frequency plan, it was necessary to know what the actual production periods had been in Area 50. This information could then be used to compare the actual and the theoretical production curves.

The growth-study data from Area 50 were used to compute these birth periods. Litters had been handled throughout the entire breeding season, and the handling effort had been uniform. Litters older than five days at first handling were aged with tail-length regression criteria (Figure 4). The resulting birth-frequency data plotted by four-day-groups are shown in Figure 7.

As indicated, litters were born from May 6 to September 7 in Area 50. It is unlikely that any litters were born before or after these dates. The oldest litter found during the first house check on May 8 was 2 days old, and no unmarked kits were steel-trapped in November and December that were small enough to have been born

Figure 7
Birth Frequencies of 75 Litters in Area 50
During the 1950 Breeding Season



after September 7. It is of interest that the range in birth dates from this investigation agrees substantially with that found by Errington (1937a) in Iowa. Figure 7 does not show the maximum birth periods recorded for Wisconsin muskrats since birth dates as early as April 28 have been calculated in southern Wisconsin by Beer (1950).

The relative quantity of production occurring during the spring, summer, and fall is of much greater importance than is the actual length of the breeding season. The birth frequencies from this study indicate that the greatest production in Area 50 occurred during the month of May. Gashwiler (1950) in Maine, and Errington *(op. cit.)* in Iowa both report June as the month when litter production reaches a peak. Apparently considerable variation in major production periods may occur either from area to area or from year to year. This variation has considerable economic importance since the average immature pelt size during the trapping season will be directly related to the average period of greatest litter production.

The tendency for the birth dates in Figure 7 to occur as a sequence of peaks about a month apart is apparent. This is similar to what was found in Maine where the data on muskrat birth frequency indicate that litter production occurs as two peaks about a month apart (Gashwiler *(op. cit.)*. The only data which show a single birth peak are those published by Errington *(op. cit.)*. However his production data represent two combined years and are summarized by 15-day birth classes. The lumping of two years data and the selection of 15-day class intervals would tend to smooth any peaks occurring at monthly intervals.

It has been assumed by Gashwiler *(op. cit.)* that the second birth peak indicated the production of second litters. In Area 50 it was possible to investigate the time interval that elapsed between the birth of consecutive litters since five adult females occupied isolated home ranges. These five females gave birth to 11 litters that were born at intervals ranging from 29 to 35 days and averaging 33 days. Errington *(op. cit.)* recorded an average interval of about a month between the births of consecutive litters. Thus these monthly birth peaks of litter production for our data and those of Gashwiler *(op. cit.)* in Maine are apparently the result of an initially synchronized breeding rhythm causing the initial birth peak, and then an average monthly period between litters causing a secondary birth peak.

To compare the actual litter production with the theoretical production estimated by back-dating the fall weights of trapped muskrats, it was necessary to separate fall-trapped immature male from immature female muskrats. Then, using the immature weight regressions (Figure 6), all steel-trapped immature muskrats (marked and unmarked) were back-dated to the nearest semimonthly period. To simplify the back-dating computations only the weights of immature muskrats killed in Area 50 from November 2 to 9 inclusive were used. We assumed that all these muskrats were trapped on November 4. The combined and separate frequency of birth for male and female immatures estimated from fall weights is shown in Figure 8. For easy comparison with the actual number of litters handled during the breeding season, the actual litter-production data from Figure 7 are also grouped by semimonthly periods.

Because of the large amount of weight variation for May-born muskrats killed in November, all muskrats having weights greater than the average May-born muskrat would be considered to have been born before May since an average weight-growth curve was used for back-dating. Figure 8 indicates that eight per cent of the males and 11 per cent of the females had weights greater than the average 187-day-old muskrat. It was known from this study that no litters were born before May 1; consequently this age class was arbitrarily combined with the first May period in the combined male and female histogram.

The distortion of the July, August, and September portion of the frequency distribution of back-dated weights in Figure 8 is correspondingly less, since the growth of muskrats born during these months is still quite rapid (Figure 6). The one female muskrat represented in the late September class in Figure 8 was a toe-clipped muskrat born in the first part of September but with a weight below the normal for that early September age group.

The birth frequency distribution for the handled litters was only a sample of the actual litter production. Also, the steel-trapped muskrats were only a sample of the entire fall population in Area 50. A bias in estimating birth dates from fall weights is introduced by differential survival rates for muskrats born during different months. An accurate evaluation of their relative survival is impossible, since only 62 marked kits were recovered with 219 unmarked immature muskrats. The movement into Area 50 of marked and probably some unmarked immature muskrats from areas of unknown production periods also may bias the data. Therefore we made no statistical comparison of the two methods for determining production. The best

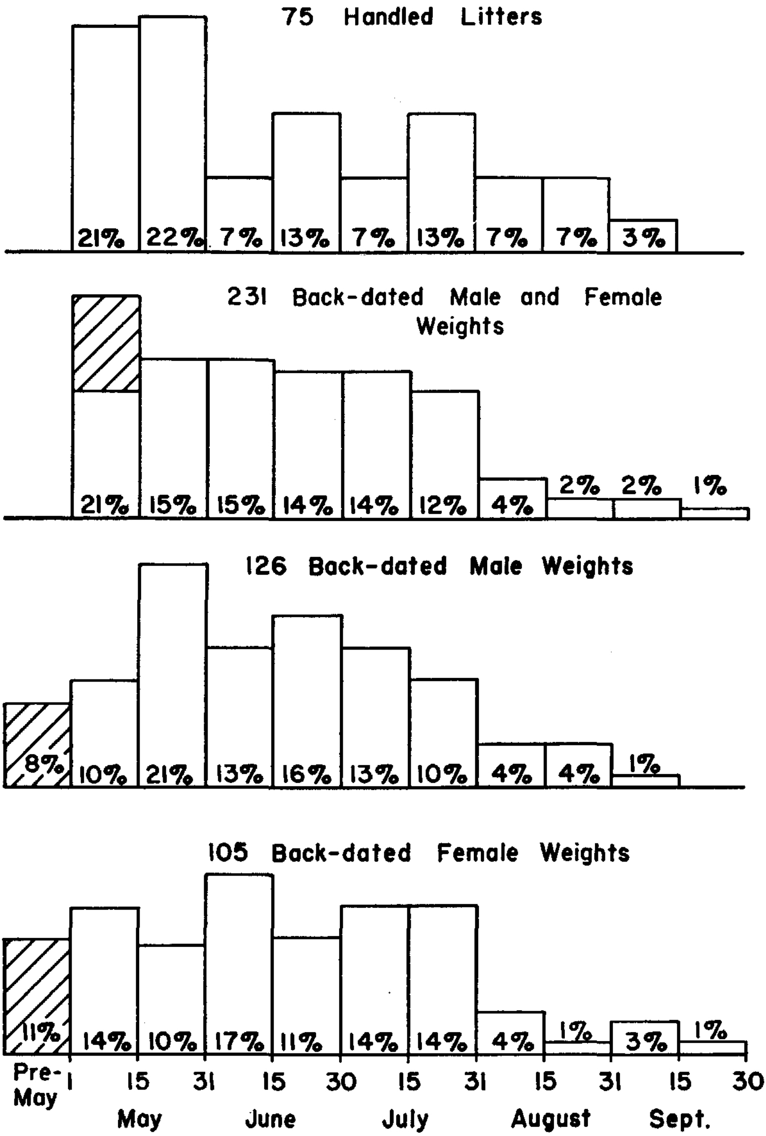


Figure 8
Litter Production Derived from Handling Litters and from Back-dating Weights of Muskrats Trapped in November, 1950.

test of this back-dating method based on the weight of fall-trapped samples will come from long usage under many field conditions where the actual litter production has been estimated through litter-handling methods.

Certainly if litter-production periods vary as much as one month either from area to area or from year to year as the literature would indicate, this weight-frequency method should easily detect these gross production differences. For some ecological studies, all that may be required is the relative amount of production that occurs during July, August, and September for comparisons with different population densities and other related production factors. If kit predation is suspected of being detrimental to muskrat populations, a comparison of the ages of immature muskrats trapped in fall with the estimated summer litter production may point out low survival rates of certain age classes. For these general purposes, the weight-frequency method for estimating production periods may prove to be quite useful.

Kit and Litter Mortality

The recoveries of marked kits in steel traps made possible a study of the mechanics of muskrat kit mortality. Out of a total of 348 tagged kits, only 62 (18 per cent) were recovered. An evaluation of this low recovery rate for the various components of the juvenile population requires a knowledge of the trapping pressure in Area 50. Two independent estimates of trapping pressure were made.

If the number of breeding females for a marsh is known and the fall age ratio is taken, the total population can be computed. The number of breeding females in Area 50 was determined by plotting the location of each handled litter on a map of Area 50. Then, by knowing the approximate home range of an adult female and the approximate birth interval between litters, we estimated the number of breeding females present in Area 50, assuming that the females did not move to new home ranges during the period of litter production. The total number of breeding females calculated with this method was 51. One adult female steel-trapped in November and autopsied showed no evidence of breeding. This one was added to the 51 breeders to make a total of 52.

The trapping-season ratio of young to adult females in Area 50 was 6.15 to one, based on pelt-aging. The total number of young present in Area 50 just prior to the fall trapping season was therefore 6.15 X 52, or 320 immatures. The ratio of adult females to adult males in the trapping take was 43 to 38. This implies an estimated 46 adult males actually on the study area. Adding all these component groups, the total juvenile and adult population prior to the steel-trapping season was 418. Three hundred and eighty-two muskrats were trapped; therefore the trapping pressure was 91 per cent. No correction was made for adult female mortality from summer to fall because 43 adult females (83 per cent of 52) were trapped in November.

Live-trapping prior to the steel-trapping season made it possible to use a Lincoln Index to determine the total muskrat population. Of 38 live-trapped and tagged muskrats 27 were recovered during the trapping season (November 1 to December 5). The computed trapping pressure was therefore 71 per cent. With a total muskrat take of 382, the trapping pressure varied from 47 to 97 per cent at the 95 per cent level of confidence using the method of Adams (1951).

The remainder of the population was not exterminated as planned, so that it was impossible to check the accuracy of these two estimates of trapping pressure. However it is probable that the actual pressure was about 90 per cent since the trapper in Area 50 was experienced and trapped until the daily catch was very low.

If roughly 90 per cent of all the muskrats were trapped, then the low percentage of recovery (18 per cent) for kits cannot be explained on the basis of low trapping pressure. Heavy mortality must have occurred to these marked kits. Any clue to this heavy loss is of importance to muskrat management and research.

Some insight into the reason for this high mortality is gained by comparing the rate of recoveries for litters handled only once with those litters that were rehandled. This comparison can be made since Areas 50 and 52 were intensively searched for all litters at roughly ten-day intervals. For this analysis no litters older than 15 days when first handled were used for comparison. This is necessary because at ten-day handling intervals litters older than 25 days are quite easy to miss.

The recovery rates for these two groups are compared in Table 5. The data are broken down into recoveries by litters and recoveries for kits from these same litters. It is clear that those litters handled only once appear to have suffered heavier mortality than those litters that were rehandled. The difference between the handled and rehandled groups for litters and kits is highly significant. The litter-recovery data in Table 5 are not biased since the average litter size, the average number of recoveries for litters having recoveries, and the monthly periods in which the two groups were born are similar.

Table 5

Recovery Rates for Litters and Kits Handled Once and More Than Once

	Trapping Area	Rehandled		Handled Once	
		Total Number	*Number Recovered*	*Total Number*	*Number Recovered*
LITTERS	50	30	20	34	8
	52	8	5	6	1
Total		38	25	40	9
% Recovered			66		22
KITS	50	176	40	156	14
	52	54	9	23	1
Total		230	49	179	15
% Recovered			21		8

This table indicates that, in general, the reason why many of the litters in Areas 50 and 52 were never rehandled was not due to their escaping the handler, but rather that many litters died before they could be rehandled. Since the mean age when all the litters were first handled was 6 days, while the mean age for rehandled litters at last handling was 24 days, the data in effect constitute an age-specific mortality series. In Table 6 the Area 50 data from Table 5 are arranged to show this litter mortality between six and 24 days, and between 24 days and the fall steel-trapping season. The 38 litters alive at 24 days of age in Table 6 are derived by adding the 30 rehandled litters (average age 24 days) to the eight litters which showed recoveries during the trapping season from the litter group handled once in Table 5. These eight litters are included since they must have been alive at 24 days. The addition of these eight litters constitutes in actuality a partial correction for inability to handle litters known to be alive. This correction is influenced by mortality after weaning and is therefore merely an estimate. Since kit recoveries tend to be concentrated within individual litters (Mathiak 1949a), it is not possible to correct the litter recovery data for 100 per cent trapping pressure. Thus the litter mortality rate of 41 per cent from six to 24 days, and the mortality rate of 26 per cent from 24 days to the trapping season are estimates of the actual mortality that occurred during these respective time intervals.

Table 6

Mortality Rates for Muskrat Litters and Kits from Area 50

		Number Alive At				
		Age 6 Days	*Age 11-24 Days*	*Trapping Season*	*Survival Rate*	*Mortality Rate*
LITTERS:	Actual Number of Litters	64	---	28	44%	56%
			38	28	74%	26%
	Number of Litters Based on 100	100	59	44	44%	56%
			100	74	74%	26%
	Mortality Rate between Periods	41%	26%			
KITS:	Actual Number of Kits	332	---	54	16%	84%
			190	54	28%	72%
	Number of Litters Based on 100	100	57	16	16%	84%
			100	28	28%	72%
	Mortality Rate between Periods	43%	72%			

In the second portion of Table 6 age-specific mortality rates are shown for individual kits from these same litters. The data for kit mortality in Area 50 were also derived from Table 5. Since it was not possible to ascertain whether all the kits in a litter at first handling were alive at subsequent rehandlings, it was necessary to calculate the minimum mean age when the *rehandled* litters were known not to have suffered any intra-litter mortality. This calculated minimum age was 11 days. Therefore the kit mortality data are less time-specific than the litter data, due primarily to the impossibility of capturing the whole litter when they become older. As indicated in Table 6, 43 per cent of the kits were lost between 6 and 11–24 days of age. Between 11–24 days and the trapping season, 72 per cent of the kit loss occurred. The kit recovery data were not corrected to 100 per cent trapping pressure since the litter data were not so corrected.

Although the time periods in Table 6 when litter and kit mortality occurred are not strictly comparable, it would appear in general that most of the nursing kits that died must have died as entire litter groups since approximately 41 per cent of the litters and 43 per cent of the kits died in early life. In general the mortality appears to be somewhat at random following weaning, affecting a higher percentage of individual kits than litters.

These data then tend to indicate that the nursing-litter loss is due to a mortality agent that affects the entire litter. Raccoon and mink predation was light in Area 50 and not severe enough to cause the wholesale loss of entire litters. However, litter movement as the result of handling did kill at least one complete litter in Area 50.

This occurred when the litter was moved by the adult female from inside a muskrat house to an open nest nearby following its handling. Heavy rains drowned the litter the night after being moved. Almost 50 per cent of the surviving litters were known to have been moved by the adult female (Figure 2). Therefore it is apparent that repeated litter disturbance may have been an important factor in the high mortality rate found for nursing litters in this study. However, mortality for litters handled only once with a minimum of house disturbance may be different from that experienced in this intensive study.

The muskrat mortality after 24 days of age may have been partially due to exposure caused by the destruction of houses by high water in July. Continual house opening also resulted in the abandonment of some lodges. Errington (1939) has shown that muskrats are not adept at building houses before the age of four months. Exposure to rain may result in direct mortality to muskrats 45 to 60 days old (Errington 1937b). We found a total of seven dead muskrat kits in Area 50 from 27 to 37 days old, and averaging 33 days of age, during the entire breeding season. This may be compared with only eight dead nursing kits found during the same time interval. Whether the post-weaning period was especially critical for muskrats in Area 50 is unknown. The scanty evidence from this field study would suggest that possibility.

Litter Handling Efficiency

Some estimate of the number of litters that escape handling is indicated in Table 5 by the 22 per cent for Areas 50 and 52 that could not be rehandled but actually were alive. However, some additional mortality must have occurred to these litters from the time they were weaned to the trapping season. Also some of these litters may not have been steel-trapped. Thus the 22 per cent that escaped handling is a minimum estimate of the number of litters less than 25 days old that can escape handling in an area of medium-cover density.

SUMMARY

Muskrat kit growth, production, and mortality were studied on a 69-acre portion of Horicon Marsh located in Dodge county near Horicon, Wisconsin. The information on kit growth was then used by the Wisconsin Pittman–Robertson Fur Research Project (15–R) to accurately age litters for determining seasonal and annual variations in litter production on all of Horicon Marsh. The application of all such information as has been described here has important applications in managing marshes for optimum muskrat production and in setting optimum trapping seasons.

The toe-clipping system used on muskrat kits during this study proved to be a useful method for identifying rehandled kits and immatures killed in fall. This technique makes it possible to study the mortality and movements of nestling kits too small to ear tag. Following handling, about half of the nursing litters were moved by the adults to new lodges, generally within 50 feet of the original lodge. About two-thirds of the 56 litter-handled kits showing recoveries had not moved more than 300 feet when they were steel-trapped in fall. Six of the fifteen marked litters moving more than 300 feet appeared to move more or less as groups to their new location.

Criteria for aging kits up to five days old were based mainly on the condition of the umbilicus, body weight, and tail length. Growth regressions were calculated from 382 kit handlings (1–30 days old) and 556 immature muskrats (31–199 days old). Immature male muskrats killed in fall are generally heavier than female muskrats of the same numerical age.

The litter-production data for the study area during the 1950 breeding season indicated that May was the month of highest production with a secondary peak occurring about one month later in June, and that the last litters were born in September. When 231 immature muskrats killed in November were aged by using their weight as a criterion, the computed birth dates for these muskrats agreed quite well with the known litter production periods for the study area.

Estimates were made of the age at which litters died by opening all muskrats houses every ten days and attempting to rehandle marked litters. In general, muskrat mortality between 6 and 24 days of age affected entire litters, while after 24 days mortality occurred at random. The high mortality of nursing litters may have been caused by intensive litter handling.

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