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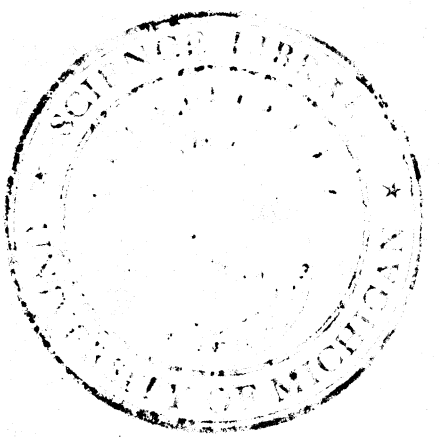

A STUDY OF MUSKRAT MORTALITY IN A TYPICAL BUTTON BUSH SWAMP

by Henri D. Crawley

A thesis submitted in partial requirement for the degree of Master of Science from the University of Michigan.

June 5, 1947

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. Warren W. Chase, Professor of Wildlife Management, University of Michigan, for guidance in carrying on this work; to Dr. Earl C. O'Roke, for helpful hints; to Dr. William H. Burt, for kind permission to use his swamp for study and experiments; to Robert L. Patterson for observations of highway mortality; to Knute Norstog, my collaborator, who worked on muskrat productivity; and to the many farmers in Section 14 who allowed access to their land and helped prevent poaching on the study area.

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INTRODUCTION

Much study has previously been done by others on muskrat mortality. This was done, however, on areas that normally support large muskrat populations. As it is known that predators tend to congregate where the food supply is large, the data obtained on large populations may not be accurate for small areas such as the one studied.

Farmers and trappers need information as to what may be expected in the way of muskrat mortality. Management methods, with sound information, should be promulaged to assist them in increasing populations where possible. Those factors which are the greatest hinderance to increases should be learned. This combined with information as to returns from artificial measures, such as level ditching, will give a firm foundation for successful muskrat management.

Purpose: This study was undertaken with two views in mind; a summary of the volumnous literature on muskrat mortality backed up by personal research and, secondly, it is hoped this work will lay the foundation for some future graduate student to study this type area by altering the physical environment. This can be done through the use of level ditches that would not drain the area but would make more water surface available. This would provide a clearer view as to the yields to be expected from this

practice. It would also demonstrate the possibilities of increasing the yield on a buttonbush swamp.

Importance of Muskrats in the United States: The muskrat has been in the literature for many years especially so in the last twenty-five years. This possibly is due to it's wide distribution and social habits making it a fairly easy animal to study superficially. However, the increased demand for fur with the decrease in muskrats (43) has had a great influence on stimulating methods for increasing the harvest.

The pelt values fluctuate greatly but the volume is so enormous that they have an important place in our economy. Henderson and Craig (31) report the muskrat as being "the most important fur animal in North America". Annual catches in the United States vary between 13,000,000 and 14,000,000 pelts.

Importance in Michigan: Muskrats exceed any other fur animal in Michigan. A 14 year total of 8,824,864, with a yearly average of 630,347, pelts valued at approximately $945,520 has been recorded for 1928 to 1942 (5). These figures show that the place held by muskrats is important and should be maintained and increased where possible.

The importance of muskrats cannot always be set down in dollars. It has a definite place in its ecological benefits to waterfowl habitats (41). It is very necessary

for best waterfowl management areas, where it provides open water areas and its houses serve as foundations for nests.

DESCRIPTION OF AREAS

Climate: The climate here is characterized by fairly cold winters and mild summers. Annual mean precipitation is 31.31 inches which includes melting snow. This is fairly evenly distributed throughout the year with average snowfall of 37 inches. Evaporation and wind movement is low, with moderately high humidity. The land receives approximately 50% of the possible sunshine. Annual mean temperature is 47.7 degrees Fahrenheit with the frost free period averaging 164 days, being ample for the crops grown except sometimes in the lower and wetter places (51).

Soils and Surrounding Agriculture: The soils of surrounding farms are predominantly Miami silt loam which has a low but fairly durable organic content. By local standards it is graded as medium to high in productiveness. The general topography is rolling. Natural drainage is sufficient in the more rolling areas but elsewhere excessive quantities of water may be held in the spring. This is due to the impervious character of the underlying clay.

The surrounding agriculture is of three types: (1) general, which includes grain and hay, produced for dairy and livestock; (2) general combined with special cash crops;

and (3) the production of special cash crops such as poultry, truck, and fruit.

Study Area: The area used for study comprises approximately 9 acres of buttonbush swamp and marsh land. It is located at the southwest corner of southeast one-fourth Section 14, Lodi Township, Washtenaw County, Michigan. A country black top road adjoins it on the south with woods to the north and west. On the east border are cultivated fields used currently for winter wheat. The area belongs to Dr. William H. Burt, curator of mammals, University Museum, who maintains it as a wild life study area exclusively.

The soil of the study area is considered to be Carlisle muck. This is characterized by dark brown to black surface material, coarse granular structure and loamy in texture. It is nearly neutral or slightly alkaline being comparatively rich in lime and phosphorus and poor in potash.

It is a typical buttonbush swamp in having elm, ash, and soft maple intermingled. Approximately three-quarters of the area has woody vegetation covering it while the other is composed mostly of Carex.

Work area looking south. Winter 1947

By far the greatest number of houses are on the perimeter of the swamp. Only one is in the Carex and, one on the border of Carex and buttonbush. The rest of the houses are about equally distributed on the north, east, and south portions. Dens are also found here except on the east side which is a cultivated field.

Water tends to be sufficient during the spring, early summer, and early winter. The remainder of the year the area dries up, making it necessary for the muskrats to dig five to six inches to reach water. During wet times the water varies from a few inches to nearly four feet in places, though these are few. Average depth is approximately two feet.

There was an attempt to drain the area prior to the present ownership. Two main ditches were made which are now grown over with vegetation and practically filled in. This drainage attempt resulted in the west portion being cleared for agriculture. The area was still seasonally too wet for farming purposes and hence reverted to marsh land. (See Map P 21).

There are large aggregate amounts of this type area in Michigan and adjoining states. They are for the most part uncultivated and often worthless for other purposes except for wildlife that prefer this environment.

Check Area: A similar area was used in conjunction with this work to check on the number of muskrats being

harvested, as well as any other mortality. This area was located in the same agricultural and soil region being only one mile away on the Shanahan farm, Section 15, Lodi Township. The main difference between the areas was that trapping was permitted on the check area. The check area had more open water with less woody vegetation adjoining and slightly smaller in size than the study area.

POPULATION INCREASE

Breeding Season: The muskrat is loosely monogamous in its breeding. The season naturally varies with the section of the country it inhabits. Baumgartner (6) reports the breeding season begins about the first of April in the Saginaw Bay region of Michigan and that young are found about a month later. In Wisconsin, Apel (1) reports mating and breeding takes place in March. This agrees with the breeding time in Minnesota (46). The gestation period varies between 21 and 30 days and breeding may continue to August. It is reported in Russia (14) that there are two breeding seasons, May and July-August.

Number of Litters Per Year: Here is the greatest variable, in the opinions expressed, regarding the biotic potential of the muskrat. Estimates range from approximately two per season for Northwest Iowa (20) up to five litters in Europe (44). In Wisconsin (1) three litters are believed to take place with the young females of the

season bringing forth young that year. Errington, upon gonad examination, says that the young females of the season do not produce in the current year (20).

For Michigan, it is reasonable to assume there are two to three litters per year. In the event of any early spring, it is possible the females of the season may bring forth a litter during late summer or fall. This does not necessarily mean that those young produced would be old enough to live through the winter so it is dubious as to whether they should be considered in estimating population.

Number of Young Per Litter: It is probable that approximately six young per litter is an average figure for Michigan. In Russia (14) there seems to be an average of four to six young born per litter, with the rest of Europe (2) averaging six to eight. In Wisconsin (1) four to eight young are born, while in Northwest Iowa (20) 6.5 is thought an accurate average. However, McCann (46) in Minnesota found a female with twenty-three embryonic scars, two females with twenty-one scars, and one with nineteen scars. From these figures it would seem a female could produce nineteen or more young per year. This would closely approach the averages given, per litter, if there were considered three litters per year.

Sex Ratios: The sex ratio varies from the time the young are born until late winter. Lueth (42) reports for Illinois a sex ratio of 1.73 males per female for sub adults

and 1.15 males per females for all ages. The Michigan ratio is very similar with 51.81% males reported upon examination of 8,107 muskrats (6). In Wisconsin the ratio was 69% male or 1.2 males per female (7). This same proportion holds true for Maryland except for kits where Dozier (18) reported 46% male to 54% female. In Iowa, Errington (21) reported for number born in the nest 58.1% male; young less than two weeks 54.5% male and 45.6% female. Utah (45) is recorded as 60.5% male with 39.5% female. In Minnesota (46-32) they have approximately 1.2 males per female for fall and spring. Summer showed a reverse ratio of 1.2 females per male.

In the study carried on here, a slightly predominant male population was found in the fall. The ratio was approximately 1.17 male to one female (see Tagging results) while the spring population was not sufficient to warrant sex ratio conclusions there were two males to one female. (See Spring Trapping P. 18).

STUDY METHODS

Study of Literature: This problem was logically begun by a study of the available literature on muskrats. One half of each day during the summer of 1946 was spent in the various libraries on the University of Michigan Campus. This time was spent locating, indexing, and abstracting the literature written about muskrats. A few

of the references were not available in the University libraries and contacts with the authors were fruitless. However, a reference to all of the pertinent information is included in this thesis. A bibliography is included to enable any future research worker on muskrats more time to develop other important aspects of this problem.

Much has been written on muskrat mortality, particularly muskrat predators. However, many predators are listed as such with no conclusive proof that they do prey on muskrats. There is too much generalization regarding predators without sufficient data. This is definitely true regarding hawks and owls. Merely the fact that hawks and owls might occasionally attack a muskrat does not mean they can be considered serious predators.

The literature did yield, however, valuable information regarding mortality. It greatly helped to clarify the picture in regard to predation and formed the basis for many of the present opinions. It likewise brought up many factors, such as fluctuating water levels, which formerly were given little thought or consideration.

The literature, gave the impression that predators, contrary to many beliefs, are a relatively minor factor in muskrat population. It is true that locally predators may completely depopulate an area. But the largest factors are the intolerance of all muskrats and unfavorable weather or physical conditions resulting in fluctu-

ating water.

Traps and Trapping: The traps used were homemade, using hardware cloth wire with one-half inch mesh. They were constructed three feet long and eight to ten inches square, this variation due to the availability of wire used. Initially the traps were built with both ends open. The gates opening inward were supported by a cross bar balanced on a pointed metal rod used as the trigger. This rod had a piece of stout galvanized metal, nearly as broad as the trap, soldered onto it one inch from the base. This insured that a muskrat passing through would move the trigger, thus allowing the gates to fall. The gates were constructed out of metal grill which had two inch intervals. Each strand was bent through the wire on top of the trap. The locking device was made with a single strand of rod attached to the trap on the inside top near the edge, about at the position of the lower edge of the gate when open. From here it passed down to the gate, across in back of it to the center, then outside through two strands and back in behind the gate, then attached to the far top side of the trap. When the trap was entered the lock would fall at the same time as the gate fell.

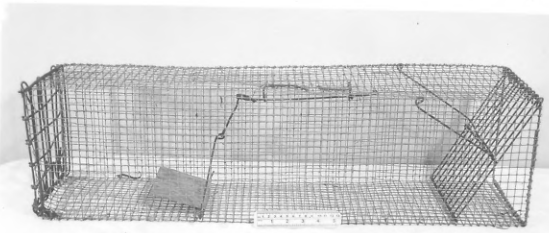


Illustration of Trap Used

A piece of rod was secured horizontally across the gate to prevent the lock from falling too far down. This lock was very effective in preventing the gate from being opened from either side before first lifting the locking device. A confined animal to escape would have to lift the lock and at the same time lift the gate, as the lock was between the gate and the top of trap. This lock was satisfactory throughout the trapping operations.

This trap was satisfactory except for length. The gates swinging down from the inside were released before the muskrat had completely entered. This allowed the animal to back out as the gate rested on his hind parts. One gate was then secured and a conventional treadle type trigger was used to release the other gate. This added length was sufficient to allow a muskrat complete entry.

Trapping was begun on the 26th September 1946. As nothing had been caught be the 28th of September the traps were remodeled as previously mentioned. After this a muskrat was caught on the first of October. Again there was a barren period and it was the 10th of October before an idea was formed that the traps still were not satisfactory. On this day a rabbit sprang the trap and ate the bait then escaped through the gate. The gate was then covered with tin to prevent escape through it.

After this the number of catches increased. The first bait was an apple but this proved a very ineffective lure. An apple which had intentionally been left in

the runway was found trampled in the muck. The bait was then changed to carrots which proved highly successful until completion on 22nd November.

During the early part of the trapping operations the water was low, and the muskrats did not readily enter the traps. One instance was noted where a runaway was dug around the trap rather than enter. The front of the trap was frequently sealed over with muck and debris without the trap being sprung. Rain began on the 12th of October. After this, the muskrats were more or less regularly caught, becoming regular around the 20th of October when there was standing water.

Various Methods of Tagging: In banding animals for identification Cook (15) lists the following requirements:

1. It should not injure the pelt of the fur bearer.
2. It should not increase the mortality rate.
3. It should make permanent identification possible.
4. It should be humane.
5. The identification should attract the attention of a trapper.
6. Identification should be quickly and easily applied.
7. Material should be inexpensive,

and further it is thought by this author that it should give definite instructions as to the disposition of tag.

Errington (25) used an aluminum tag 24mm long, 5mm wide, placed through the skin of the back. He and others found a high mortality rate from this method particularly

among older muskrats. When used on young, two to four weeks old, it was highly effective under Iowa conditions (26).

Cook (16) used a method whereby a metal ring was placed through the Anchilles tendon. This later was used by Takos, (52) in preference to both Errington's back tagging method and to the placement of rings on the legs.

Twining (53) used a variation of Errington's method. A flexible steel needle was threaded through the loose skin of the back and secured with plastic buttons. The needle was then bent in an arc so the buttons laid flat against the back.

Method of Tagging Used: As the methods used up to this time did not seem to meet the desired requirements, fingerling tags 2mm by 7mm were used in the ears. These were easily applied and permanent. Later recapture did not show any signs of infection or sluffing of the skin. There was seldom evidence of pain as regular attaching pliers were used. There was only a slight puncture made where the sharp points of the tag pierced the ear. Evidence thefollowing spring was satisfactory regarding the permance of the tags. Aldous (4) used this method with good results in January 1943 to 1944.

Attaching pliers and ear tags.

It is suggested that for study of an animal where the tracks or feet will possible be used toe clipping be done in conjunction with ear tagging. Several instances occurred in which the tracks or feet of killed or migrating muskrats were available. These possibly could have been used to identify the individual muskrats if toe clipping had been performed. During spring trapping in this study, toe clipping was employed in conjunction with the ear tags.

Results: During the fall the total population of 14 muskrats were caught and tagged. These were handled a total of 38 times. The majority of the houses were on the periferae of the swamp, consequently the majority of catches were in these vicinities. However, traps were set on the interior but with poor results.

The following table shows the muskrat tag numbers and positions of original capture, as well as recapture locations. (See Map P 21). E or W, N or S, designates directions away from map position numbers of distances less than 25 feet. Two numbers separated by a plus sign designates catches approximately between these positions.

Muskrat No.	Original Capture Position	Recapture Position
101 ♂	5	
102 ♂	10	E 13
105 ♂	11	11 - 11 - 13
171 ♂	4	2 - NW 4

Muskrat No.	Original Capture Position	Recapture Position
117 ♀	2	7 4
104 ♂	24	23 - 24
108 ♀	11 13	
115 ♀	7	7 4 - 7 4 7 4
133 ♀	7 4	
166 ♂	2	2-N1-E5-7 4-6-7 4 7 4 - 2 - 7 4
132 ♀	7 4	1 - S2 - 1 - E 6
110 ♀	7 4	
120 ♂	6	
140 ♂	2	

The greatest distance of a recapture from the previous capture position was 225 feet. This occurred only once, with the majority of distances being 175 feet or less.

The following table shows the distances travelled by the muskrats between captures.

Muskrat No.	Linear Distance Moved Between Captures
102 ♂	75 feet
105 ♂	25 feet
171 ♂	75 feet
117 ♀	175 feet
104 ♂	0
115 ♀	0
166 ♂	0 - 100 - 25 - 175 - 150-175-0-175-175
132 ♀	225 - 175 - 100 - 100

Winter Observations: Fall trapping was completed on 22 November, 1946 and it was December 30th before conditions were suitable for accurate observations. During the winter there was an abundance of snow but seldom was there suitable tracking conditions. Often the snows were accompanied by high winds which covered the tracks before they could be examined.

The area was visited and each house examined on 25 days throughout the winter. When conditions were conducive to good observations these days were consecutive, otherwise the days varied depending upon the academic studies which were being carried on at that time. Examination began on December 30, 1946 and continued to March 15, 1947. At this time the ice was too thin to walk over.

Normally, winter is the critical time for adult muskrats for then it seems most of the predation occurs. With the young, predation is more apt to occur when they first leave the nest. At this time they are more vulnerable to predation, such as hawks, than are the adults. During this study all the known predation took place after periods of extreme cold weather. Either those species which act as buffers for muskrats were scarce or the muskrats were easier to catch and kill.

Mink is the most important predator of the muskrat. Particular efforts should be made to trap them during the season. Some authorities have advanced the theory that

predators would be of benefit to the muskrats since they would eleminate the weak and diseased. There were no indications on this area that mink sought those houses which might contain such muskrats. Entry was made into the first house approached which offered the least resistance to digging. Elimination of the unfit would be taken care of by less serious predators or more probably by other muskrats. (See Intraspecific strife P 34).

The animals on the area seldom entered the interior of the swamp during the winter. The exceptions to this were pheasant, rabbit, and fox. The fox entered the interior of the swamp less frequently than pheasants or rabbits. Mink, weasel and house cat tracks were mainly confined to the edge of the swamp but occasionally were found in the marsh.

This zone of activity coincides with the approximate location of the muskrat houses. It seems therefor that this type of habitat presents a more favorable environment for the species concerned. It should be possible to increase the muskrat population by providing clearings, throughout the swamp. These areas would also be the logical place to trap for muskrat predators.

The data gathered during the winter tends to show that predation is a factor of lesser importance in muskrat populations. During the winter and spring 8 dead muskrats were found. Deaths, in which only flesh and bones were found, occurred 3 times from unknown causes. Highway kills accounted for 2 muskrats. Mink definitely took 3 and

possibly 4 of the muskrats.

This small amount of predation was further evident on the check area. Over the winter this area probably had fewer muskrats than the work area. The pre-trapping estimated population was 27, based on 1.5 muskrats per house with 18 houses present. During trapping 18 muskrats and 3 mink were taken from this area. The area was intensively trapped but a few muskrats were left. This was evidenced by most of the houses being kept in repair over winter. Mink tracks were found around this area after the trapping season but only one instance was found where mink had entered a house. Nothing is known as to the success of this entry because the property owner preferred that the house not be opened for examination.

It was of interest to note that the check area, though smaller in size than the work area, had a greater total muskrat population. This probably was due to the greater amount of open water since other conditions were quite similar. This would again indicate the advisability of providing openings in buttonbush swamps for higher muskrat populations.

The specific results observed during the study period will be included under Mortality Factors and Results. (See P 28).

Spring Tagging: The same traps that were used for the fall trapping were used successfully in the spring trapping. Toe clipping was used in combination with the ear tags and

with excellent results. The toes were clipped beginning with the outside right hind toe and clipped inward towards the inner side of the foot. The clipping did not seem to injure the animal seriously as very little reaction accompanied the amputation. Healing was rapid with no sign of infection evident. Previous to toe clipping, handling of each recapture was necessary to ascertain the ear tag number, but with toe clipping identification was easily made upon looking at the feet.

Results: During spring trapping it was found there had been a 100 percent turn over of population since fall. None of the previously tagged muskrats were found during the 25 spring trapping days.

The total population in the spring was 3 muskrats. These three muskrats were caught a total of 22 times. Two of these three were male with one female.

During this trapping period several instances occurred in which muskrats were taken 500 feet from the previous trapped position. Catches of the same individual were made on consecutive nights in which the muskrat had moved from one side of the area to the other. Never did this occur during the fall. This movement compared with the maximum fall movement of 225 feet shows a great variation during the different seasons.

Spring migration could account for the influx and efflux of muskrats from this area (See Migration P 39). Assuming that the fall population did not suffer any further

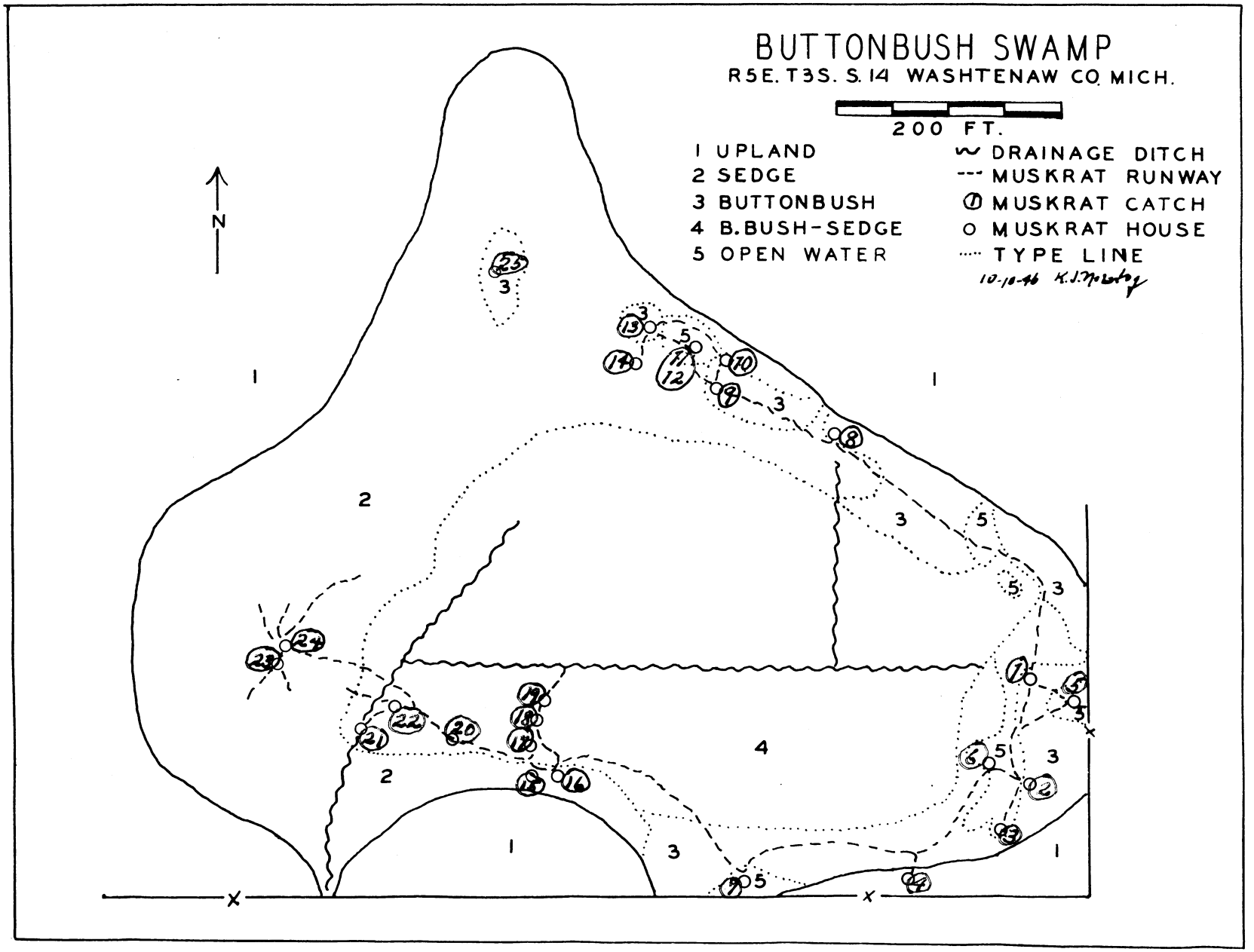
mortality than is recorded here, (See Mortality P28) the efflux of muskrats from the area was approximately twice that of the influx. It is probable, however, that further mortality did occur which would make the movements about equal. With only this population of three the original fall population could easily be reached by average sizes and numbers of litters. Altering the environment by clearings or ditches would have a tendency to hold at least a portion of the wintering population.

The following table shows the spring catches, recaptures, and positions, (See Map P 21) for position locations.

Muskrat No.	Original Capture Position	Recapture Position
124 ♂ Clipped 1st toe	25	25-11-7-11-10-4-19-4-7
172 ♂ Clipped 2nd toe	11	11-13-3-3-3-7-3-7-7
112 ♀ Clipped 3rd toe	11	3

The following table shows the distances between capture positions.

Muskrat No.	Linear Distance Moved Between Captures
124 ♂	0-75-500-500-0-400-225-225-175
172 ♂	0-50-500-0-0-225-225-225-0
112 ♀	500


BUTTONBUSH SWAMP
R5E. T3S. S.14 WASHTENAW CO. MICH.
200 FT.
1 UPLAND
2 SEDGE
3 BUTTONBUSH
4 B. BUSH-SEDGE
5 OPEN WATER
DRAINAGE DITCH
MUSKRAT RUNWAY
MUSKRAT CATCH
MUSKRAT HOUSE
TYPE LINE
10-10-46 K.J. Morley
N
X
X

MORTALITY FACTORS AND RESULTS

Juvenile Mortality: Young muskrats are vulnerable to practically any predator or the elements. The lack of care by the mother increases this vulnerability. The mother may, if frightened from the lodge, leave so fast that suckling young are pulled in after her and frequently drown. After being pulled from the nest, she may or may not pick them up. This is true also for rising water levels where the young may be left to drown in the nest, or completely ignored if they are fortunate enough to be placed on surrounding debris. The mother often will move the young from a flooding nest and leave them in any convenient place exposed or concealed. She then goes about her own business oblivious to crying young (23). Under these conditions the young are particularly vulnerable to predators and other animals such as hawks and owls (8) which do not normally prey on them.

In Manitoba there was one instance where 25 jackfish (Northern Pike) were caught and 11 young muskrats were extracted from their stomachs (3). Here, it was the smaller fish weighing two and one-half pounds that were the worst offenders. In another example in Canada 500 jackfish were examined and 0.6 contained remains of young muskrats (13).

Bowdish (10) relates an instance of the Great Blue Heron as capturing a young muskrat. In a personal talk with a trapper this author was told of instances in which this bird was seen to pierce young muskrat through the middle as the young swam past.

Although not troubled by snakes in this part of the country, Svihla (48) reported in Louisianna an instance in which a four foot water moccasin killed and ate two muskrats' kits. Alligator and Barred Owl pellets also showed signs of muskrats, probably young ones, having been eaten. Not only are the juveniles subject to many larger animals but Errington (24) has shown that in the fungus skin disease of muskrat only those less than two months old are visibly affected. Furthermore, before two weeks old, infection is fatal to those showing gross manifestations. Except for the disease just mentioned, it has been shown that the post weaning season is the most critical time for young. The young are then subject to attack almost anywhere in relation to their natal localities, and at almost any age. (25)

It has been shown (8) that low water levels may seriously affect the number of young. Under these conditions the parents fail to or retard breeding, thus lowering the population expectation for that season. Unfavorable conditions of any long duration bring on this.

Disease: Muskrats in this country, contrary to some popular beliefs, are subject to several diseases. Although reported in Russia (14) as seemingly free from disease, muskrats may on closer study be seen to be subject to the many variable diseases recorded here.

Much popular thought is that if muskrats do have disease why worry about it since it cannot be cured in the

wild. While the latter is true the disease may have significant results in that some of them are transmissible to man. Diseases of wild animals other than muskrats often play an indirect role in muskrat population. Decimating diseases of "buffer" species, or those animals which absorb part of another animal's predation, are important since they would tend to cause an increase in predation on muskrats.

Although in this study no instances were recorded where death could be directly attributed to disease, there is very little doubt that the muskrats were subject to diseases and parasites to a greater or lesser degree. The meager remains of one muskrat was found before the onset of winter. Death might have been due to disease. If this were so, it did not seemingly affect the other muskrats in the area.

Tularemia: Of the diseases affecting muskrats probably the general public knows Tularemia best. This infection is caused by Bacterium tularence. It is primarily a fatal disease of wild rodents but highly infectious to man. Several methods of transmission are known among which are: the bite of infected blood sucking flies or ticks; contamination of the hands or conjunctival sac with portions of the internal organs or body fluids of infeted rodents, flies, and ticks. (3). Nearly all laboratory workers who have worked with the disease have become infected. Infection occurred regardless of the use of all the modern known

medical methods of prevention. The incubation period is approximately three days and the human death rate about 4.5%. No methods are known for the prevention of spread among wild animals and no cure or preventive serum has been perfected for man.

Coccidiosis: This disease is found in muskrats as well as many other animals. Becker (11) thinks there are several species of Eimeria affecting muskrats simultaneously. This disease occurs most commonly among young animals sometimes taking whole litters. In the laboratory infected muskrats cease to grow, become emanciated, lose their appetite three to four days before death and in most cases show severe diarrhea.

Ringworm Infection: Dozier (19) reports a ringworm infection, apparently due to Trichophyton spp. as causing a high mortality rate in those muskrats which are infected. Also "lumpy jaw" due to Streptothrix actinonmycosesbovis or a closely related homminis type was recorded by the same author as having a high mortality rate. The infected animals suffer from large abscesses under the jaw and pus from these contain typical rosettes.

Fungus Skin Disease: Errington (24) recorded a fungus skin disease in muskrats in which only those less than two months old were visibly affected. In general, however, the incidence and severity of infection arose as the breeding season progressed. In the same record is a hint as to why disease may not be so severe to a total population in musk-

rats as in other forms of wildlife. He observed that losses of young from both disease and predation was offset by a prolonged breeding season and in the production of extra litters.

Predation: The problem of predation is a big one and subject to much controversy especially in the hunting and trapping circles. There is and will continue to be predation. However, it is conceivable that a certain number of predators are beneficial since they will prey on the undesirable, e.g., mice, etc., as well as on those animals desired. Often too, the predator may yield returns from pelts greater than those of the prey. This is particularly true for mink.

Predators do not normally confine their food to one species of animal. They, like most other animals take what food is most readily available. In the case of mink predation upon muskrats, the mink probably prey on muskrats only when other sources of food are more scarce or more difficult to obtain.

Where the environment is adequate for the muskrat population present, predation will normally be low if the predators are held down to the point where other food items will supply their needs. Particularly is this so when the predators are mammals.

If other prey food is low in comparison to the number of predators the attacks are more apt to turn toward muskrats. This was shown by the present study in which most of the

predation occurred during and immediately following severe winter weather when other foods were probably harder to get than were the muskrats.

To counteract this effect, it would be advisable to begin the trapping season by taking the known predators. In this way a return from predator pelts could be obtained, and at the same time lessen the predation on muskrats later in the winter. The further the season is advanced the more prime will be the fur. In the event some of the predators are not trapped off inroads may be made into muskrat population which would otherwise yield a return to the owner.

Since on an area of the type studied trapping can be completed in a relatively few days, it is better to refrain from trapping the muskrats until later. If predator trapping is delayed too long and severe weather comes after the muskrat population has been already decreased by trapping, the prey will be those animals which would have been the foundation stock for the succeeding year.

Whether predation will be considered extreme will depend upon the total population of muskrats present. If the population is high, the predators may be of more value than the muskrats eaten. However, if the population is low the results of predation would be considered worse as the breeding stock is being taken.

Poole (47) commenting after 15 years observation on a game refuge says: "In that time I have seen much that

leaves me to believe predation is a much less serious factor in the abundance of wildlife on such an area than some would lead us to think, and that whatever changes in population have occurred have been due more to radical changes in environment."

Mink: Without question the mink is the greatest predator on muskrats. During this study only two instances occurred where predation or attempted predation could conclusively be said to have occurred on muskrats. On the night of February 8th a house was entered by a small mink and two muskrats were killed. One was partially eaten in the house and the second was dragged approximately 400 feet to where a drainage tile passed under the road. Here was an opening in the ice which was the last trace that could be found. Whether the mink took the muskrat in the hole or across the road could not be discerned as a high wind with drifting snow had obliviated the tracks.

The identity of neither muskrat could be found. The partially eaten one left in the house had all the meat eaten off the head. An ear tag could not be found among the remains. The muskrat that was taken away had both hind legs eaten off and these were left in the muskrat house.

Upon opening the house for clues it was seen to have two compartments. The first compartment was about 5 inches higher than the second. A tunnel lead from the second to a plunge hold about 18 inches away. Both compartments were

relatively roomy being 5 inches high, 24 inches in diameter and roughly circular. The rooms were clean and had no fecal matter present but the tunnel leading from the lower had evidently been utilized as a latrine. It was interesting to note that the mink had torn open the house at the position where the wall was thinnest making a minimum of digging necessary.

The second instance of predation occurred on the night of 10th February when a mink dug into a house. This house was entered from the top after an attempt had been made about half way up. Evidently when the mink got inside a muskrat got by and left the house through the hold which the mink had made for entry.

Judging from the tracks it must have been frightened as it ran all over the east side of the swamp, attempting to dig through the ice at every little knoll. These tracks were lost in the center part of the swamp where dense stands of Carex made it impossible to track. It was preferred not to disturb the house at this time since the escaped muskrat might return so the house was left until the following day. Examination the next day showed that the entry hole had been sealed up and frozen. It was impossible to tell whether the mink had any success out of this venture. There were no indications that it had carried a muskrat carcass away.

Prior to an ice storm which occurred the 30th of January conditions for tracking were extremely poor.

During this time house No. 14 was broken into and from the size of the hold a mink had entered. Evidently, it was successful as the hole remained opened for the remainder of the winter.

Mink and muskrat have been found occupying the same complex tunnel system (22). This tends to explain why Errington's report (27) that drouth, intraspecific strife and wandering in strange places were especially important in making muskrats vulnerable to predation. Kinds and numbers of wild predators with few apparent exceptions had little bearing upon net mortality. Predation merely functioned as a substitute for other mortality factors.

Winter food habits of mink naturally vary with the supply of available food, ease with which it is caught as well as its own preference. Hamilton (35) found in New York, out of 100 carcasses examined, only 14.12 frequency indices of muskrat remains. This was the highest of all mammal remains found, exclusive of mice. On work done regarding the food of the mink during the summer the same author (33) found muskrat remains in mink scats in 49.33% of occurrence and 37.95% by bulk.

Sealander (49) upon examination of 102 stomachs and 101 intestines of mink in Michigan reported that mammals formed 50% of winter food with muskrats being the most important prey item. This agrees with most authorities which place the mink as the greatest predator on muskrats. Some believe that one mink may destroy over 100 muskrats

a year (54). If this is true, mink would be a problem in the management of a marsh for muskrat production, particularly if there was a small population as is usual on a small area.

Fox: Although the fox is mentioned as a predator on muskrats most of the evidence shows that this predation is rather slight. This probably never acts strongly enough to greatly change the total population on a marsh. A six year study of red fox food based upon scat examination indicated that muskrat remains were evidenced only two times, giving .4% of total food taken (17). This closely approaches the findings of Errington (28) in which no muskrats were found in red fox stomachs and only one in the stomachs of grey fox.

That fox do prey on muskrats is brought out by one investigation in which 54 remains of muskrat were found upon examination of five dens (34). Heit (37) also list muskrats as being 37 in occurrence and 38.9% frequency in 95 scats of red fox examined.

Fox tracks were commonly seen on both the study area and check area but never did they indicate that the fox was looking for more than a mouse or rabbit. One instance occurred on the study area where a little snow was dug out by a fox from on top of a house.

Raccoon: Very little has been found to show that raccoon is anything more than an occasional captor of muskrats. Hamilton (33) found 7.99% occurrence and 4.07% by bulk contained muskrat in 163 scats examined. This

merely would indicate that racoons will prey on muskrats if given the opportunity. As to whether there is a difference on the basis of muskrat size is not indicated.

Great Blue Heron: This bird is a frequenter of marshy areas and undoubtedly has opportunity to capture muskrats, especially young. Predation would be most evident on this area during winter. Since this bird is not found here during that time there would be no results from this source. It is thought an area such as the one studied would not be particularly attractive to the Great Blue Heron as there is not enough running water and the supply is too unstable to support attractive foods.

As previously mentioned in regard to juvenile mortality the author was told by a trapper that he had witnessed a Great Blue Heron kill muskrats. Whether the muskrats were eaten did not come out in the conversation but there is no reason to believe they were not. This trapper further stated that his father had commonly seen this bird pierce adult muskrats while the latter was swimming past.

Snakes: It is seriously doubted whether in this section of the country there is any predation due to snakes. It is conceivable that there might be some, particularly in the young. No evidence was found to bear this out but in Louisianna water moccasin have been known to kill and eat kits. (See Juvenile Mortality P 22).

Turtles: Johnson (40) offers the only evidence found in the literature in which turtles had preyed on muskrats.

He relates, upon testimony given him, that a quite small snapping turtle seized a full grown muskrat by a hind leg and dragged it into the water, until it was supposed to have drown. Again though the literature is scarce in regard to this, it would seem logical that turtles do occasionally prey on muskrats. If they prey to any extent probably only the young are taken.

Bobcat: Hamilton (36) found, upon examination of 140 bobcat stomachs, five which yielded muskrat remains. However since all of the bobcats were taken during muskrat trapping season, there was a possibility the cats had come upon trapped muskrats.

Hawks and Owls: Little conclusive data are available upon predation due from hawks or owls. These birds are frequently mentioned as being predators but no evidence is offered to back this up. Bellrose (8) relates one instance where a marsh hawk made sallies at exposed muskrats during a flood. Twining (53) considered the following as predators: Sharp-shinned Hawk, Marsh Hawk, Coopers Hawk, Redtailled Hawk, Duck Hawk, Swainsons Hawks, Bald Eagle, Burrowing Owl, and Barn Owl. In addition, Johnson (40) lists Great Horned Owl, and Bent (12) lists this owl also but without data. Probably most of the hawks and owls would be predators if given the opportunity, especially on young muskrats.

Fish: The possibility that fish are natural predators on muskrats has received very little study. This possibly is due to the fishes habitats which would necessarily limit

direct observations. Northern pike are referred to as being muskrat predators in Canada but there mainly in relation to young. (Refer: Juvenile Mortality P 22).

On the size area studied, and many similar areas throughout the mid-west, fish would hardly be considered serious. The unstable water supply would usually prevent their presence and if not their presence at least limit them in size. Most swamps would become uninhabitable frequently enough, due to unstable waters, to kill off the fish.

Intraspecific Strife: This is a difficult aspect to discuss separately in muskrat mortality. It ties in so closely with the different reasons for its occurance that separation into definite catagories is impossible.

Territorial intolerance and intraspecific strife are synonmous. They are the results of variable degrees of unfavorable conditions for the muskrat population. This intolerance may vary from mortal combat to mild displays of ill temper between individuals. All age classes, sexes, and sizes, of muskrats are susceptable. The young may be killed by older individuals. Older ones may fight, killing or driving the less hardy out of the area. This friction is shown to a greater or less degree regardless of the environmental conditions but seems to be greatest when unfavorable factors are existant.

This intolerance is especially important in being a predisposing factor to predation. When a muskrat has been

vanquished in a fight and is forced to leave its home territory, it is at a decided disadvantage. Since most animals fight better and with more success in familar surroundings, the wandering muskrat is often hard pressed to find a suitable home before the onset of winter.

While wandering in this hunt for a suitable home, the muskrat is subject not only to the fighting sedentary muskrat population but to the predators as well. The exile being unfamilar with the area in which it finds itself is easy prey, since that area is usually in the territory of the predator which is familar with the environment. It is thought this intolerance is an even greater factor in muskrat populations than predation since it automatically limits the population within the level of the habitable environment (27).

Aside from the driving out of the less hardy muskrats, intraspecific strife still plays an important role. The fights that occur mar the pelts resulting in a decreased market value. These fights cause wounds which may so hinder the muskrat in its movements that it is easy prey. Wounds provide entrance places for disease which may further reduce the population.

Often the wandering muskrats are subject to highway mortality. While this is not serious considering the total population, it is serious where the population is low. (See Highway Mortality P 37).

Starvation: The lack of food may be a great contributing

factor to lessening of the muskrat population. This is due not so much to the actual dying from starvation as to the increased intraspecific strife which accompanies low food supplies. As the food supply dwindles the fighting increases.

A low food supply has additional ill effects. Adult muskrat may produce smaller and fewer litters if there is a shortage of food. If conditions are too severe breeding may be stopped altogether.

The muskrat under necessity utilizes a wide variety of food. Even in areas where its main food items are lacking it often fares satisfactorily. During extreme conditions it is known to eat dead and decayed wood as well as numerous other items not usually thought of as food.

Food is an extremely important item especially during the winter. Since the muskrat cannot make long travels during this time in search of food, it is important that food be located in the immediate vicinity. This dependence upon a close food source is brought out by Errington (22). He reported that muskrats prefer for a winter home an area of more food and less water rather than less food and more water.

Starvation is most likely to occur in localities where the water supply is so erratic that winter food plants are killed. This is an extremely important factor to consider on many buttonbush swamps. On many areas with unstable waters, and hence unstable food, it might adversely influence

the population. Where the majority of the swamp is buttonbush with little or no marsh land near, there is very likely a deficient food supply. Another factor affecting food is availability. In those areas of deep freezing water the depth should be 2 to 3 feet thus allowing sufficient depth for muskrat movement beneath the ice. Freezing of water in an area may not however be detrimental providing the muskrats are able to find food in the soft mud underneath the ice.

It is thought there were no deaths on this area due to starvation. Since the marsh land was adjacent to the swamp a food source was present. Upon spring thawing the vegetation did not seem unduly utilized. The food was available as runways had been made in the mud.

In areas where buttonbush is predominant its thick growth tends to kill out other vegetation. Thinning of the buttonbush or creation of large openings would allow desirable vegetation to become established. This would likewise provide a larger and more suitable environment for muskrats. (See Winter Observations P16).

Highway Mortality: If a highway is adjacent to a swamp the problem of muskrat kill from this source is important to the owner. In these local areas mortality from the highway might be serious. This would particularly be true if the food source were on the opposite side of the highway. Usually, however, the most serious results occur during the spring migration. (See Migration P 37). Some of the migrating muskrats needed to replenish a depleted

area, might be eliminated by automobiles.

Haugen (38) found in Michigan that at two periods of the year highway mortality noticeably increased. April and again in August-September were the most severe periods from highway deaths. This was thought due to the onset of the breeding season and resulting spring migration. The fall rise in mortality was probably due to intrapecific strife (See Intraspecific strife P 34) or a decrease of suitable habitat. The calculated mortality rate based on these figures would be 1.49 individuals per 1000 miles for April and 1.34 for September. This was based on Conservation Officers reports. The total reports comprised over one million miles of highway.

Errington (20) found this movement to take place in Northwest Iowa from about mid-March to the first of June. He contributes the cause to accentuated intraspecific strife.

In Wisconsin, Shorger (50) reported many muskrats as being killed by automobiles. This was an unusual migration where the path was through the center of town.

During this study two muskrats were killed by automobiles. One, an untagged female, was found on March 5, 1947. The second, a tagged male, was found on March 9, 1947. The latter was within 150 feet from the original fall tagging position. There were no deaths from automobiles found on the check area though this was less than one-eight miles from a

county road.

Migration: There are two periods of migration by muskrats. The larger, brought on by the approach of the breeding season, occurs in the spring. This movement radiates out from the better protected and more favorable habitats to those areas on which there is a small population, due either to natural emergencies or excessive trapping. Formerly used homes are taken over by the newcomers but selection of breeding territories are rather hap-hazard in areas not recently occupied. Errington (29) found this distribution to be equalized in the more attractive environment for some miles away from the wintering area. This period of movement is very important since it repopulates depleted habitats.

The second movement occuring in the fall, is smaller and of little consequence in repopulating vacant habitats. Migration atthis period is probably due to variable degrees of intraspecific strife resulting from the greatly increased population. As this is the post breeding season, movements from an area at this time are a direct loss to the land owner since there will be fewer muskrats available for trapping.

In southern Michigan, these movements seem to be in April and in late August or early September (38). However, during this study a muskrat was trailed, on January 10, 1947, from the study area to a small stream one fourth mile away. Two other instances of migration occurred on the study area. These,which resulted in a highway kill of both individuals, were found. (See Highway Mortality P).

At the completion of spring trapping on the study area it was found the population consisted of all untagged muskrats. The residue of the fall population which could not be accounted for was six individuals. It is thought these migrated from the area, being replaced by half this number of migrants. Migration could partially account for a more or less set population size for areas of the type studied. This turn-over in population was the most important information gathered as a result of muskrat tagging. Further studies along these lines are needed before definite conclusion can be reached however.

Generally it is not desirable to attempt to control migration. If the area is satisfactory and has been trapped during the fall season there should be very little migration from the area. The area would then adequately support the spring population present. If, however, over-trapping or natural emergencies were present during the winter then migration would tend to repopulate the depleted area.

Floods: Floods are incidental to exposure and intra-specific strife and merely brings these conditions on or accentuates those present. Errington (23) found that most mortality was due to exposure rather than an actual rise in water levels.

Excessively high waters are a predisposing cause of predation when the muskrat houses are destroyed or the individuals are driven from their home territories. Attempts are made by the muskrats to repair their houses with the oncome of flood waters (9). This work is con-

tinued until the house perishes or the muskrats must give up due to fatigue. During floods the mother may allow the young to drown but more often will leave them exposed where they are readily susceptable to predation.

Hawks particularly, are a great source of danger during floods. They are dangerous not only to young but to those adults too tired from swimming to put up any substantial resistance.

Intraspecific strife is greatly increased during periods of extreme high water. The muskrats fight to prevent any encroachment on their shelter. Mortality among young may be extremely high. If they have a place of shelter it is apt to be taken over by an adult which disposes of the former possessor. Fighting is greatest among the most exposed muskrats and varies directly with exposure.

Flooding, except in severe local situations, is of much less importance to muskrat populations than fluctuating water levels. High waters are usually more or less local and of short duration. On the type area studied, floods are very seldom of any consequence. Most of the existing emergencies are due to a lack of water rather than too much.

Fluctuating Water Levels: Fluctuating water levels affect not only the muskrat population but adversely affects the environment. This increases the existing

pressure on the individuals. Studies made by Bellrose and Brown (9) revealed a direct and indirect effect upon the current and potential population. Indirectly, the animals were affected by composition of vegetation. This in turn was affected by the seasonal changes in water levels. In the studies just referred to, the areas were classified as to their water content into stable, semi-stable, and fluctuating. Six times as many houses per unit area were recorded in those areas with stable waters as in those with semi-stable. Twice as many houses were found in semi-stable areas as in those classed as fluctuating.

The same effect of water levels was found in Wisconsin by Hamerstrom and Blake (39). Here unstable water levels accounted for a great lack of muskrats in the spring after large fall populations were present.

Unstable waters are one of the biggest factors affecting muskrats in buttonbush swamps. Usually water is present but in late summer muskrats must dig into the muck to reach it. The litter size may be curtailed if this lack of standing water occurs prior to completion of breeding. This lack of muskrats represents a direct loss to the owner. Fall migration cannot be expected to increase the population to that sustainable by the area after fall rains.

The most satisfactory management method to correct this instability of standing water would be to provide ditches 3 to 4 feet deep, and of the same width, in which water could accumulate. This would provide the muskrats with

water and at the same time banks would be available for burrows.

Ditches may be made by blasting, drag line or slip. Usually the former is cheaper. This is done only by a man experienced with dynamite. The charges are set in line in the muck. The distance between charges vary depending on the ground texture. Detonated is by concussion after the first is set off manually. Drag lines are very satisfactory but usually more costly. The interval between ditches in all cases should be approximately 50 feet. This will allow suitable area for burrows and growth of food resource.

SUMMARY

1. Muskrats are a good source of potential income. Owners of buttonbush swamps should consider using these areas for added revenue.
2. The study and check areas used for this study were similar. Both were located in general farming regions.
3. Breeding seasons vary but usually start about the first of April and are normally continued to August.
4. There are many variable opinions as to the number of litters produced each year. Two to three litters a year is thought an accurate figure for Michigan.
5. Environmental influences may affect the number of young per litter. Averages vary for different sections of the country but approximately six per

SUMMARY (Cont'd)

litter are produced in Michigan.

6. There is a slightly predominate male muskrat population.

7. Carrots proved superior to apples as a muskrat bait. Muskrats are hestitant to enter traps when there is a low water supply.

8. Many tagging methods have been used. The use of fingerling tags in the muskrat ears proved satisfactory. Fall tagging showed a maximum muskrat movement of 225 feet and spring tagging a common movement of 500 feet. Toe clipping used in combination with ear tags was highly satisfactory in the spring.

9. Muskrats are susceptible to several diseases, some of which are transmissable to man.

10. Many animals are considered as muskrat predators but little proof is available. Discernable predators occurred during this study only after periods of severe weather. Mink was the only animal found during this study that conclusively can be said to have preyed on muskrats.

11. Intraspecific strife or muskrat intolerance is an important factor in determining populations. It is brought on by adverse condition of any kind.

12. Death due directly to starvation is probably slight. The most serious result of starvation is increased

SUMMARY (Cont'd)

territorial intolerance.

13. Highway mortality is serious if the highway is located close to areas of low populations.

14. There are two periods of the year in which migration increases, spring and fall. The spring migration serves to repopulate underpopulated suitable environments.

15. Floods are locally serious to muskrats. This is due to increased intraspecific strife and exposure which predisposes the individuals to predation.

16. Varying water levels adversely affect muskrats by altering the environment. Unstable and fluctuating waters are not conducive to the production of muskrats.

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