# Chapter 10

# Central Iowa Streams and Outlying Waters: Introduction and Story City Block

CENTRAL IOWA MUSKRAT HABITATS here treated were selected for longterm study on the basis of their representativeness as places frequented by primarily stream-dwelling populations. The regularly observed habitats included the small and medium-sized rivers and creeks, pasture brooks, tile flows, ditch and oxbow pools, and field ponds that together comprised the muskrat habitat – whatever the quality – to be found more or less typically in the equivalent of two townships of farm land in the central part of the state. All lie in the extensive Skunk River drainage and may be chiefly grouped in two blocks. One block lies south, southwest, and west of Story City (Figure 10.1); the other, north and northwest of Ames and southwest, west, and northwest of Gilbert (Figure 10.2). Descriptions of the individual areas may be found in Appendix D.

Studies of muskrat populations of central Iowa streams and outlying waters were all but confined to private property, and I am grateful for the cooperation received from farmers and trappers. In this connection, I should particularly express appreciation for the help given me on so many occasions by Magnus Olson of near Story City and by the late Cleo Turner of near Gilbert. Others to whom I owe special thanks include the following trappers who saved valuable specimen material for me: Clarence Adams, O. Boyd, Ralph Brown, Noble Christianson, Ernest Clouser, F. C. Corneliussen, Harley Doolittle, Merlin Doolittle, Wesley Doolittle, Edwin Egenes, Herbert Egenes, John Egenes, Theodore Hermanson, Torkell Hill, Walter Hill, Leslie Hoffman, Willard Johnson, Simon Kemmerer, J. M. Kerr, Curnie Larson, Arthur Matheason, George Matheason, Guy Mathews, Andrew Mathison, Irvin Mathison, Victor Mathison, Frank



Fig. 10.1. Map of Keigley's Branch drainage and neighboring Skunk River, mostly south of Story City, Iowa.

Mattingly, Forrest Millikin, Homer Olson, George Roberts, LaVerne Russell, J. B. Stahlman, Earl Sturtz, Edward Sturtz, James Thorson, Richard Turner, Robert Turner, and Ole Wald. Iowa State Conservation officers Warren Wilson and Eugene Hlavka collected specimen material at times when such was particularly needed.

While marshes may have either high or low water levels at rather unexpected times, with occasional pronounced differences even in the same neighborhood, the status of central Iowa stream habitats for muskrats often reflects more immediate weather conditions.

The weather data summarized in Appendix E pertain to Ames and vicinity. The averages and extremes presented in Table 5 (also in Appendix E) were largely furnished by Robert Elford, State Climatologist, Des Moines, and comprise an 82-year background against which the weather vicissitudes for the study years may well be considered. The detailed Iowa State University and U.S. Weather Bureau data

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Fig. 10.2. Map of Squaw Creek drainage, including Onion Creek, west and northwe of Ames, Iowa.

SEC. 36

were obtained through the cooperation of Doctors Gerald L. Barger and Robert H. Shaw.

The area case histories follow.

SEC. 35

#### SKUNK RIVER (STORY CITY BLOCK)

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SEC. 33

The mile-and-a-half stretch of Skunk River southeast of Story City was put under observation in 1939, rather late in our study program. It then had 9 muskrat territories or about 20 adults in early summer, including one territory in an oxbow less than 100 yards west of the main stream. By early October, the surface water was reduced to pools, some isolated, some in connected strings. The total fall population was estimated, pool by pool, at about 65. Low water notwithstanding, the muskrats wintered under the ice in good numbers, especially along and near a dredge cut bordered by a much-raided corn field.

Fifteen territories in 1940 (including one in the same oxbow

occupied the preceding year) probably meant around 35 adult muskrats during the early breeding season. Dry weather in midsummer and fall lowered the stream level but never stopped the flow, and excellent pools always remained. A sample of 240 carcasses of muskrats trapped during the 1940–41 fur season from upstream and downstream, as well as from within the observational stretch of Skunk River, consisted of 14 adult males, 18 adult females, 109 young males, and 99 young females. Application of these ratios to a base of 15 adult females for the observational stretch would give a grand total of about 200. I would say that more than half of these animals were massed along about 250 yards of stream bordering a corn field.

Placental scars in the uteri of the 18 adult females of the trapped sample averaged 15.3 per female for the breeding season of 1940, mostly reflecting early-season breeding and a little more than 2 litters of young per female. No "kits" were listed in the post-mortem notes on the 208 young of the year, and only one of the breeding females had a set of placental scars suggesting a late – probably late July – litter.

Working conditions on the observational stretch were unfavorable early in the summer of 1941, and no wholly satisfactory data on breeding densities were obtained. The figure arrived at was of 11 territories, representing about 23 adults. Water levels for May were rather low, but the heavy rains of June and part of July kept up the flow until fall. Of 82 trapped carcasses examined for the fur season of 1941– 42, 6 were adult males; 5, adult females; 38, young males; 31, young females; and 2, young of undetermined sex. Based on the above figures, the pre-trapping fall population figured out at about 165.

One of the specimens of adult females had conceived two litters in 1941; 2, three litters each; and 2, four litters each. Only one of the 16 sets of 1941 placental scars was of a fairly late litter, assigned to late July.

The muskrats surviving the trapping appeared to winter well, and, on March 12, 1942, signs were generally heavy in favorable places. There were 9 territories, representing about 20 adults, being maintained by early summer. The sample of trapped carcasses from the Skunk River, itself, was not sufficiently large to afford valid sex and age ratios for the 1942–43 trapping season. If we apply the ratios from 52 carcasses taken in the vicinity of Story City – 4 adult males, 4 adult females, 24 young males, and 20 young females – we would get a fall population figuring out at about 115 for the mile-and-a-half stretch of Skunk River.

The 1943 breeding-season check showed 14 territories (including 2 in oxbows), or around 30 adults. Except in the vicinity of the dredge cut having adjacent corn fields, the 1943 territories were almost restricted to heavy stands of scrub willows, yet the evidence was beginning to suggest that more was behind the patchy distribution of the muskrats than inequalities in food resources. In a spring of generally saturated breeding densities over the central Iowa countryside, with seven territories crowded into the middle third of the observational stretch, the south third had a single territory. As for the preceding trapping season, the sample of trapped carcasses obtained from Skunk River, 1943–44, was insufficient to afford suitable sex and age ratios; and the ratios from specimens from the entire Story City block had to be used for a basis for calculations. Of 202 carcasses, 12 were of adult males; 19, adult females; 102, young males; 66, young females; and 3, young of undetermined sex. If we assume negligible spring to fall losses of adult females and apply the Story City ratios to the 14 Skunk River territories, we would get a 1943 fall population of about 140 for the observational stretch.

Eight territories, or about 20 adult muskrats, were recorded for the 1944 breeding season, including 3 territories in the suspicionarousing lower third of the observational stretch. Of 71 carcasses of muskrats trapped along the mile and a half of stream during the 1944–45 fur season, 3 were adult males; 5, adult females; 42, young males; and 21, young females. Assuming no spring to fall loss of adult females, we would, applying the above ratios to eight territories, arrive at a total of about 115 as the fall population. However, there were some unusual variables in the local population equation.

Summer floods had been highly destructive to young muskrats born in the first half of the 1944 breeding season, but the effects of this on muskrat production had been partly offset by prolonged, late breeding. Each of the five adult females had conceived three litters, and, of the 15 litters, seven were assigned to July and August. No exact figures are at hand concerning the incidence of "kits" in the 63 specimens of young animals handled during the trapping season, but the last lot of 12 examined consisted entirely of young judged to have been born in July or later, and probably a good half of the 63 specimens actually belonged in this category.

The hemorrhagic disease was known to have wiped out most of a concentration of muskrats along a long-raided corn field. At this place, the equivalents of 3 pairs and their season's young, probably together with some animals from downstream, or a total of about 60, had been living along a stretch of less than 200 yards; yet the trapper caught only 7 there and found 1 dead on land, which he saved for examination. The dead one proved to be a typical victim of hemorrhagic disease. Earlier, the same trapper had found a freshly dead one downstream, opened the body cavity, noted the spotted liver, and buried the animal. Two of the last 12 animals caught (examined on November 25) were diseased. Not many muskrats survived on the observational stretch even to enter the winter of 1944–45, and, considering the hemorrhagic infection in the corn field burrow systems, still fewer may be judged to have wintered.

The spring, 1945, breeding census gave six territories or a total of about 15 adults. Considerable upstream and downstream adjustment was noted in late summer and early fall. Observant trappers reported conspicuous mortality upstream; this was attributed to disease, and, in one case, several dead muskrats were lodged together in stream debris in early November. Whatever happened, there were unusually few muskrats living along the mile-and-a-half stretch by the opening of the 1945–46 trapping season. The 24 muskrats caught by a trapper surely represented almost the whole population: 2 adult males, 4 adult females, 13 young males, and 5 young females. Of the 4 adult females, one had conceived 12 young in two early litters in 1945; two, 17 young each in three early to midsummer litters; and the fourth, numerous young (the placental scars were uncountable because of decay of the specimen) in probably four litters, including a litter assigned to August. Two of the 18 young in the trapped sample were of "kit" sizes.

The spring, 1946, breeding census gave eight territories, or about 18 adults. The 1946 territories were rather uniformly distributed, which meant more muskrats in the usually more sparsely populated central and south parts and fewer at the north end. By early September, there was evidence of much readjustment. For the muskrats, some dry weather in late summer resulted in only a harmless lowering of water levels. Still, the animals displayed conspicuous restlessness and, for no patent reasons, engaged in a tremendous amount of not only upstream and downstream but also cross-country movement involving both sexes and all mobile ages. Trapped carcasses examined for the 1946–47 fur season totaled 39 (4 adult males, 1 adult female, 11 young males, 18 young females, and five young of undetermined sex), and about 14 other muskrats were known to have been trapped but not obtained for examination. The pre-trapping fall population probably had been about 65.

A careful breeding census gave only four territories, or about nine adults, for 1947. Three territories were fairly close together in the most attractive part of the north end, and the other was far downstream. Floods in June were probably very destructive of early-born young. In mid-July, I doubted that there were more than 6 or 8 young muskrats along the observational stretch other than at the north end. At the north end, there may have been the equivalent of about three full litters, including one late-born litter. This would add up to perhaps 35 animals in all.

Then came weeks of rainless, hot weather. By late August, considerable readjustment of the Skunk River muskrats was in progress, without any important cross-country movements. By late September, the stream flow had ceased, except for seepage between pools. After more readjustments in the fall, probably about three-fourths of the muskrats were restricted to a series of residual pools. Because of the legal closing of the 1947–48 trapping season on muskrats, no carcasses were obtained for examination. A final, generous estimate would be of about 30 muskrats remaining at freeze-up, or possibly nearer 25.

The observational stretch had eight territories in late spring, 1948. Five of the eight territories were concentrated in the north third of the stretch; one was near the middle; and the other two were well down toward the south end but over a quarter of a mile apart. The old dredge-cut was widened during the summer, and the old river channel was partly filled in with dirt; the muskrats nevertheless adjusted well to these drastic changes, and, by mid-September, signs were heavy in the neighborhood of three original territorial sites. At this time, drought had almost stopped the flow over the stream bed at the north end. Farther south, the flow had stopped, but several favorable pools still had many muskrat signs. Most of these signs were localized about the breeding territories, but certain other places were also occupied — some having by far the most muskrats in many years. I estimated, from comparisons with signs of other years, that there were well over 150 muskrats living along the mile and a half of stream in September. Two months later, possibly about a sixth remained.

Almost-critical if not critical drought – from the muskrats' position – continued past the middle of November in 1948. I do not know of anyone taking muskrats from the observational area during the December trapping. Wintering muskrats came out of some of the frozen-over pools to forage on bank vegetation or to raid convenient corn fields. There was also evidence of winter-wandering up and down the partly dry stream bed.

An early May, 1949, breeding census gave twelve territories, of which six were concentrated in the upper third of the stretch and the other six were rather uniformly distributed throughout the mile below. The flow of water over the stream bed was slight by mid-September, with pools being well-defined. Pool-by-pool population estimates totaled about 135, of which about 85 frequented the upper three-quarters of a mile. The muskrats were much more scattered through the lower three-quarters. Trapping conditions were favorable along Skunk River during a short open season in December, and 95 of the 130 trapped carcasses examined from the vicinity of Story City were from Skunk River, though not all from the observational area. The 95 from Skunk River consisted of 7 adult males, 4 adult females, 44 young males, and 40 young females, but the entire 130-carcass sample from the Story City block was probably the more representative: 10 adult males, 9 adult females, 57 young males, and 54 young females. Allowing for a spring-to-fall loss of the equivalent of 3 pairs suggested by late-summer data, the pre-trapping fall population of the Skunk River area should have been virtually the equivalent of the Story City trapped sample, or about 130.

Of the 9 adult females in the Story City sample, one had conceived a single early litter in 1949; 3, two litters each; 2, three litters each; and 3, four litters each. Three of the total of 25 litters were assigned to August, which is in close agreement with the 12 "kits" recorded among the 111 young of the year.

There was evidence of substantial local adjustments upstream and downstream in September, and it is certain that the late fall occupants of the observational stretch were not exclusively animals breeding and reared in the area. Apart from these adjustments, the scarcity or lack of animals about some very attractive pools at the south end of the Skunk River stretch suggested effects of the hemorrhagic disease. My failure to find any dead during three visits made during the period of decline may be partly explainable in terms of the large number of raccoons and foxes that hunted and scavenged about the drying stream bed. In December, one of the trappers did bring me a typical hemorrhagic victim from upstream.

Because of greater fluctuations in water levels, the Skunk River area was the most difficult to study in the Story City block in 1950. As of early July, it had 10 recognized breeding territories, of which three were situated close together (along about 250 yards near the middle), and the other 7 were well separated from each other. The lower threequarters of a mile had only two territories, still maintained by mid-August, but with few muskrats. The 1950 breeding season appeared to have been productive in the upper three-quarters of a mile, and the respective family groups stayed at their territorial sites. Weather conditions during the 1950–51 trapping season were sufficiently unfavorable to prevent any effective harvest of muskrats in the observational area, and probably upwards of 100 muskrats wintered there.

But, in 1951, the observational area had, early in the breeding season, a population of only about ten adults. Three territories (including one in a shallow oxbow that was abandoned in the course of late-summer adjustments) were in the upper half mile, but the lower mile was almost muskrat-vacant by late July. Then, very peculiarly, five territories were established in the lower mile, of which four were showing tracks of six-to-eight-weeks young by September 6. There were also signs of some drifting of muskrats into the mile-and-a-half stretch from downstream. Adjustments continued into the fall, with two of the original territorial sites in the upper half mile remaining well-used. Ten fall-trapped specimens from the above two territorial sites were two adult males, two adult females, four young males, and two young females. The two adult females had their young early the last of three litters of one female was assigned to mid-June and the last of four litters of the other was assigned to July – which agreed with the track sign. No really accurate basis exists for determining the late fall population, but my estimate would be a little over thirty for the entire stretch.

Nine territories were present in 1952, including one in an oxbow. Six of the territories were close together in the upper third of the observational stretch, and the equivalents of 4 of these were remaining functional by late fall, when they had a population figuring out at about 60 animals. An estimated 15 more remained in the lower part, which would bring the total population up to about 75. Nine carcasses of muskrats trapped in the lower part were examined in late fall, 1952, and 3 of these showed lesions of the hemorrhagic disease, thus suggesting clearly the agency of the partial depopulation earlier observed.

Four territories were maintained in the late spring of 1953, of

which three were localized along about 500 yards of the food-rich upper end of the observational area. The lower half mile was devoid of muskrat signs of any recent age: a circumstance believed due to disease. By late September, about 85 muskrats were estimated to be present on the whole Skunk River area, including about 50 at the sites of the massed territories of the breeding season. Skunk River, having more water than the smaller streams, drew considerable numbers of muskrats during the drought-accelerated adjustments of late summer and fall, but so much of Skunk River was food-poor, and the better places were so full of intolerant residents, that it offered no really good attractions to home-seeking newcomers. Downstream, the half mile that seemed dominated by the hemorrhagic disease had almost no sign of living muskrats even at times of the most general movements.

May and June floods and high water at other times forced postponement of the 1954 breeding census until early July, when 5 territories were recorded, all in the northern third of the observational stretch. These were still the places having the muskrats by late September. The midfall population was estimated at about 60; by late fall, at about 85, after an upstream movement had been in progress for a few weeks.

In the spring of 1955, the area had seven territories, including one with a solitary animal. This was the only muskrat known to be living along the lower half mile, which had been showing evidence of becoming essentially uninhabitable for muskrats because of the hemorrhagic disease. Four of the productive territories were in the channel of the upper third of the area, and nearby were two territories in oxbow pools. The oxbow territories were abandoned in July as their water went down, but the flow continued in the channel of Skunk River until mid-August, and the deeper pools retained sufficient water for muskrats until freeze-up. The attractive food resources were sufficiently localized, however, so that the places still holding muskrats by late September were chiefly those having well-worn trails from pools to corn fields.

Contemporaneously with drought-eviction of muskrats from central Iowa stream habitats, substantial numbers appeared on the observational stretch of Skunk River in the fall of 1955. The population figure arrived at before freeze-up was about 125, and the greatest concentration was in a place having no better food resources than thickets of scrub willows. With the onset of freezing weather, the status of the massed newcomers became precarious; they did much foraging in miscellaneous dry and woody vegetation on shore and preyed upon drought-handicapped fishes. Six of eleven mink scats for late October and early November contained muskrat remains (all, I think, of separate muskrats), and evidence of a seventh victim was seen. There was also evidence of some outside activity, if not wandering, after freezeup. Probably few muskrats survived the winter on the observational stretch except in a beaver dam pond next to a corn field.

The 66 specimens of central Iowa muskrats examined in the fall of 1955 are probably as representative of the Skunk River stretch as of any one area: 9 adult males, 12 adult females, 31 young males, and 14 young females. The adult females had conceived a mean of 3.25 litters. A mean of 3.75 young per adult female in the sample, compared with a mean of 22.8 young conceived, would seem to reflect the severity of the drought as much as any known factor. Only one (2.2 per cent) of the young in the sample was judged to have been born in August or later, whereas six (15.4 per cent) of 39 litters represented by placental scars were assigned to this late in the breeding season.

Only four maintained territories (including one occupied by a lone animal) were present on the mile-and-a-half observational stretch, as of late May, 1956. Movements of unsettled animals were still in progress at that time, and one probable transient was known to have been preyed upon by a red-tailed hawk.

By the first of July, a territory next to an old and dangerous disease focus had been lost, and the remaining three territories were restricted to beaver pools. All three were productive of young and were well maintained throughout the summer. By late September, the muskrat population of the observational area was still all but confined to the three territorial sites; by late October, the signs indicated a remaining muskrat population estimated at no more than about 20.

Unfavorable working conditions on Skunk River prevented an accurate determination of breeding territories in the spring and early summer of 1957, but there certainly were few in the observational area. However, in midsummer and early fall this area proved to be virtually the only one of the regularly observed central Iowa stream areas that had muskrats, and most of these were congregated both upstream and downstream from a newly constructed beaver dam. Here, there were possibly 100 muskrats at one time along less than a mile of stream, with the lower half mile of the long-observed stretch still almost muskrat-vacant. By early October, the muskrats were no longer congregated about the new beaver dam, and, at freeze-up, possibly 20 muskrats remained in the area, to winter without any detected trouble.

#### **KEIGLEY'S BRANCH**

The Section 26 stretch of Keigley's Branch shown in Figure 10.1 was the only one on which observations were made in 1934, and the downstream stretches of sections 35 and 36 were not put under regular observation until 1939. Meanwhile, more or less attention was paid to the northeast corner of Section 27 and the middle of Section 22

between 1935 and 1939, but no especially significant data were obtained; the muskrats of these stretches merely responded to drought exposure and availability of choice foods in typical ways.

Section 26 had five probable territories or about 12 adult muskrats in the spring of 1934; and, on an inspection trip of October 11, I estimated, pool by pool, a population close to 35. The 1935 census gave 5 territories or about 12 adults for spring and about 55 muskrats as a midfall estimate. Four territories were accounted for in 1936; by mid-September, the signs of partly grown young could still be seen, despite drought conditions, and a late fall population was estimated at between 15 and 20. Some outside activity of muskrats was noted during the winter of 1936–37, but the signs to be seen early in March suggested that nearly as many may have survived as entered the winter — and despite the possibility of undetected mortality from mink predation under the ice.

On May 11, 1937, three territories were localized along about a quarter mile of stream in lower Section 26, but signs of unsettled animals were abundant over the rest of the stream in this section. Except for the occupants of a fourth territory established later, the animals of the upstream part ultimately departed. By mid-September, the stream had stopped flowing, and much evidence of adjustment was seen. One territorial site had been completely abandoned by then, and a new muskrat headquarters appeared a half mile upstream, where an inviting pool in food-rich surroundings persisted. The first half of October was a period of much traveling along the stream bed, but this represented activities of obvious residents, busy carrying food and repairing nearly dry burrows. By mid-October, the water levels were improving, and the stream was soon filled up to about its usual mid-summer level. My pool-by-pool estimate of the late fall population was about 17.

The muskrats entering the winter of 1937–38 seemed to survive until spring, but, with the softening and break-up of the ice in late February and early March, they may have been unusually vulnerable to predation as they foraged along the banks. A mink scat deposited about the first of March consisted of muskrat remains, what I now interpret as remains of a second mink victim dated back to late February, and a horned owl pellet datable to about the first week of March consisted of the forequarters of a third muskrat. All of this mortality occurred somewhat prior to the recognized spring dispersal.

In the spring of 1938, five territories were established in Section 26, three near the west boundary of the section and two near the south, thus leaving nearly a half mile of stream unoccupied by muskrats. By fall, after a summer of favorable weather conditions, it could be seen that a substantial muskrat population was present, including a few that had moved into a wet gravel pit in the southeast corner of the section. By November 1, the muskrats had abandoned the gravel pit, and additional reorientation had occurred. One of six mink scats deposited in early November contained muskrat remains. Thirty-five

carcasses of muskrats taken by trappers during the fur season in November were 2 adult males, 3 adult females, 17 young males, and 13 young females. These ratios applied to five territory-maintaining females of late spring would give a total fall population of about 60. The population of perhaps 20 surviving the trapping seemed to be mostly comfortable and secure, and only one was noted to be coming out on the ice or snow during the winter of 1938–39.

Section 26 had six territories in 1939. The dry weather of late summer did not bring about any known crisis for the muskrats before September, but, by then, evidences of a pronounced adjustment were to be seen. Except for one place in the east half of the section, nearly all of the muskrats of the observational stretch were massed within a quarter mile of the west edge in the deeper pools there available to them. Within the first two weeks of September, the creek dried up until only residual pools contained surface water, and much movement of muskrats between pools occurred. Flattened bodies of two subadults were seen, September 18, on a paved highway to the west. By early October, the remaining population was all but confined to the vicinity of a single pool. Mink-eaten remains of possibly two muskrats lay on the creek bottom in a trail between two pools.

Beginning on October 7, 1939, flowing water gradually covered the creek bed. This partial relief from the drought promoted extensive readjustments, muskrats appearing in parts of the east half of the section that earlier had been devoid of the species. By about the first of November, the population had stabilized, most of the muskrats then being localized in five places – of which four were sites of 1939 breeding territories. The pool in which the muskrats concentrated at the height of the drought was one of two places showing the most signs at freeze-up. My pool-by-pool estimate was about twenty. One of four mink scats deposited in late October and November contained muskrat remains. In late December, muskrats were gnawing through the ice of two pools to forage outside. One winter-active individual improvised a system of snowdrift tunnels and chambers on top of the bank, and its mummified body, partly eaten by a mink, was found when the drift melted in the spring.

It was also during 1939 that regular observations were begun on another stretch of Keigley's Branch, this stretch being downstream from long-observed Section 26 and running through the northeast corner of Section 35 and most of Section 36. Of two 1939 territorial sites in the newly observed stretch, one was still occupied by late October, and the estimated four or five muskrats seemed passably well situated for wintering.

Section 26 had five territories in 1940, and Section 36 had another. Of 53 carcasses of muskrats trapped during the 1940–41 fur season, 4 were of adult males; 4, adult females; 18, young males; and 27, young females. These ratios applied to the six territories of the breeding season would give a fall total of about 80 muskrats for the two miles of creek. The four adult females in the trapped sample had a mean of 14.8 placental scars for 1940, representing about two earlyseason litters each. These early-born young had been quite self-sufficient at the time of floods coming in late July and August. The twomile stretch was in flood again in mid-February, 1941, but this is not thought to have seriously endangered the muskrats surviving the trapping, for signs were plentiful in early March in expected places.

Section 26 had five territories in 1941, and Section 36 had two. All territories were clearly established with reference either to especially attractive food resources or to old sets of burrows. The summer brought great variation in stream flow, droughts and floods alternating. One territory was situated right in the midst of a horned owl territory, but no muskrat remains were found in 71 of the owl pellets deposited mostly during a period of considerable land activity of the resident muskrats. By late August, the stream in Section 26 showed well-distributed, locally heavy signs (in the horned owl territory as well as elsewhere), though only the central stretch in Section 36 continued to be well-used by the muskrats. Little further change was noted until the stream was again in full flood, on October 7 and November 1. Trapping conditions were difficult during the 1941-42 fur season, and only 20 carcasses were examined: an adult male, an adult female (with 19 placental scars for 1941), 9 young males, 7 young females, and 2 young of undetermined sex.

The 1941–42 Keigley's Branch specimens comprised such a poor sample that it should be preferable to combine the data from these with the data from specimens taken from elsewhere in the neighborhood. The combined sample totaled 46 specimens: 2 adult males, 4 adult females, and 40 young of the year. These sex and age ratios applied to a base of 7 breeding territories would give a pre-trapping fall population of about 60 for Section 26 and about 25 for Section 36. These would seem plausible figures, for it was very apparent by late January, 1942, that unusual numbers of muskrats were wintering in Section 26. Conspicuous signs could be seen under ice shelves, in places where the stream was ice-free, and about upper parts of burrows. No muskrat remains were found in 10 early-winter pellets of a horned owl that roosted near one of the burrows showing the most activity.

Despite exceptionally heavy wintering densities, the Keigley's Branch muskrats seemed disinclined to begin large-scale cross-country movements in the spring of 1942. As late as March 24, the heaviest sign was still to be seen along stretches known to have wintered muskrats. Members of closely observed populations took their own time about leaving familiar quarters, engaged in much preliminary commuting, and behaved as if easily satisfied when establishing living quarters in new places. The spring dispersal took place without the stimulus of floods and was manifested chiefly by increasing local activity.

Section 26 had five breeding territories in 1942, all well situated with respect to food. In Section 36, none of 3 territories had especially

attractive food resources. Only 18 trapped carcasses were examined from observed stretches of Keigley's Branch during the fur season of 1942–43: 2 adult males, 3 adult females, 8 young males, and 5 young females. In view of the smallness of this sample, it should be preferable to consider the entire series of 52 carcasses examined from the vicinity of Story City: 4 adult males, 4 adult females, 24 young males, and 20 young females, and, of the 44 young, 11 were "kits." One lot of 13 muskrat specimens included 7 "kits," some of which looked as if they had been born in September. Of the 4 adult females, one had conceived 3 litters, including a late litter; and 2 females had conceived 4 litters each, including 3 late litters. The Story City sex and age ratios applied to the 8 territory-holding females gives a late-fall population of about 65 for Section 26 and about 40 for sections 35 and 36.

Repeated floodings during June and July, 1942, drowned a large proportion of the season's young. Biologically, the losses of so many helpless young were in part offset by prolonged late breeding and high survival rates of the late-born young. Tracks of very late litters could be seen almost anywhere along the two-mile stretch in the fall. Some trappers quit trapping for the stated reason that, even in mid-December, they were catching "nothing but young ones," i.e., the lowvalue "kits." The floods also changed the configuration of the observational stretch by cutting off oxbows, filling in old pools and gouging out new ones, washing away fallen trees and drift debris of former years. At the height of floods, the adult muskrats responded by improvising nests under hanging banks and extending burrows upward under the sod. Undoubtedly some movement took place in and out of the two-mile stretch, though there seemed to have been little movement on the part of territory-holding adults.

Field observations late in the winter of 1942–43 indicated that an abundance of muskrats remained alive along the stream in both sections 26 and 36. In the spring of 1943, the Keigley's Branch channel in Section 26 had eight territories, plus another in an adjacent gravelpit pool; Section 35 had one territor; and Section 36, although relatively unfavorable habitat, had seven territories. These seventeen territories along a two-mile stretch were remarkably evenly spaced, presumably as one result of a near-saturation density of muskrats. Extremely little evidence of late summer and early fall movement was detected.

Of 62 carcasses of muskrats taken during the 1943–44 fur season, 4 were adult males; 7, adult females; 36, young males; 12, young females; and 3, young of undetermined sex. The ratios from the trapped sample applied to the number of territory-holding females (assuming no losses or departure of adult females between spring and fall) gives a pre-trapping population of about 80 for Section 26 and about 70 more for sections 35 and 36.

The 1943 season's breeding showed considerable irregularity. Two of the 7 adult females had conceived early litters only, another had conceived only late litters (assigned to July and August), and another had conceived two small litters (averaging five young each) having birth dates assigned to June and July. The over-all record for the breeding season for the 7 adult females: one had conceived a single (early) litter; 3, two litters each; and 3, three litters each. The rather low mean of 7.3 young reared of 18.6 young conceived per breeding female may have reflected crowding as much as anything, with several agencies of mortality operating to reduce the population surplus. Only one of the 51 young of the year examined was a "kit." A single mink scat found on November 21 consisted of muskrat remains. The creek had numerous minks, foxes, dogs, and horned owls hunting it, but strong local populations of predators were not peculiar to this high-density year of muskrats.

Many muskrats escaped the trapping, 1943–44, to winter – so many that external signs suggesting food shortages could often be seen as the winter progressed; and, with the spring dispersal of 1944, the population was sharply reduced. Only six territories were maintained in 1944 in Section 26 and one in Section 36.

The 41 muskrats taken during the 1944–45 fur season from the two-mile observational stretch of stream represented nearly the entire population: 6 adult males, 7 adult females, 15 young males, and 13 young females. Of the adult females, 4 had conceived two early litters each; one, two midseason litters; 2, four litters each, including late July or August young for both females.

As in 1942, floods were very destructive of young muskrats in 1944, though resident adults sat out the high waters and remained in their home ranges without apparent difficulty. The ratio of only four young per adult female in the fall-trapped population for a mean of 17.7 young conceived suggested heavy losses after, as well as during, the period of flooding. The evidence was that the hemorrhagic disease may have been a principal agency of loss, especially about the time when the trapping was coming to a close. One of the very last animals to be taken showed disease lesions, as did two of the last taken from an outlying muskrat habitat connected with Keigley's Branch.

Despite the combination of unknown disease losses and practically annihilative trapping of the previous fall and winter, the twomile stretch of stream had six breeding territories in the spring of 1945. A total of 112 fall-trapped muskrat carcasses was examined from Keigley's Branch for 1945 (9 adult males, 7 adult females, 48 young males, and 47 young females), but most of these muskrats were trapped outside the two-mile observational stretch. The 38 animals (3 adult males, one adult female, and 34 young of the year) trapped from sections 26 and 36 probably represented a good two-thirds of the population present at the time, for only in one place did many muskrats escape the trapping. The fall population of sections 26 and 36 would seem to have been about 65, with perhaps 60 of these in Section 26.

Disease and summer and fall movements surely affected the muskrat populations of sections 26 and 36 in 1945. Something of the magnitude of the movements is indicated by the finding of three traffic victims in a seven-week period of August and September within a mile of the stream; and a substantial cross-country movement continued into October. This movement is not to be explained in terms of unsuitable habitat for the muskrats, and it took place several weeks in advance of the time when muskrats were known to have started dying from the hemorrhagic disease. Diseased specimens included one of 35 muskrats caught in Section 26, two of 50 caught downstream from Section 36, and one found dead upstream from Section 26.

In reviewing the population changes of the muskrats of Keigley's Branch in 1945, I would judge that a relatively small proportion of the late summer and fall movements away from sites of breeding territories or original home ranges took place as gradual upstream or downstream adjustments. There seemed to be almost a tendency for resident animals either to stay or to break completely away from the familiar surroundings to wander — though such a statement might be an oversimplification.

The adult females caught by trappers were probably true residents of the places in which they were trapped. The specimen of an adult female from Section 26 had conceived 29 young in 4 litters in 1945, of which the latest litter was assigned to August. Of 2 adult females trapped upstream, one had conceived a single midsummer litter of 5 young, and the other had conceived 18 young in 3 early to midsummer litters. Of 4 adult females from downstream, 2 had conceived 2 early litters each, totaling 16 and 17 young; one, 15 young in 2 midsummer litters; and one, 23 young in 3 early-summer to midsummer litters.

A mid-April, 1946, breeding census gave six territories in Section 26, another territory in Section 35, and two more in Section 36. In sections 35 and 36, the territories were widely separated. Those of Section 26 were distributed as two rather closely adjacent territories in the south part and as four territories almost crowded into the west part, with nearly a half mile of unoccupied stream between the two groups of territories. By August, there was evidence of only two functional territories and perhaps a half-dozen muskrats elsewhere in Section 26; the Section 35 territory had a few muskrats remaining; and only one territorial site in Section 36 had many muskrats. The total midsummer population of all ages occupying the two-mile stretch was estimated at about sixty, with about thirty-five being in Section 26.

In September, a great influx of animals, apparently coming from downstream, filled the choicer Section 26 stretch about up to capacity. My estimate for an early October muskrat population was about 75 for Section 26 and about 40 for sections 35 and 36 combined. A trapper's catch of 101, examined from Keigley's Branch during the 1946–47 fur season, was not taken exclusively from the observational stretch but was considered about the equivalent of the population resident there, as of early November.

Sex and age ratios for the above sample were 7 adult males, 5 adult females, 47 young males, and 42 young females. There were no young

of "kit" size among the 89 young of the year. Of the 4 adult females that were in fit condition for examination, one had conceived 2 early litters; one, 2 midsummer litters; one, 3 early to midsummer litters; and one, 4 litters.

Three of the 101 trapped carcasses had gross lesions of the hemorrhagic disease. One of the animals – an adult female – seemed about ready to die when trapped. I would say that an epizootic was about to get started at the time that the trapping reduced the local population.

As of early May, 1947, Keigley's Branch in Section 26 had seven territories, fairly evenly spaced; Section 35, one territory; and Section 36, four territories, of which all were evenly spaced throughout the upper half of the section at the same time that the lower half was muskrat-vacant. Rechecks of breeding territories in late July showed that Section 26 had one less territory than in early May and that the six functional territories were divided into groups of three each by a long stretch of unoccupied stream. The three territories lying farthest upstream had retained their May sites, but two in the mid-stretch of Section 26 had disappeared, and the downstream part ultimately had three instead of an originally well-separated two. Downstream, in sections 35 and 36, only three territories persisted by late July.

June floods, which left windrows of drift a good foot above the banks in the flatter parts of the valley, effectually eliminated the muskrat litters of helpless sizes born over a period of six to seven weeks in the middle of the 1947 breeding season. There is no reason to suspect, however, from careful consideration of the local situations, that the May-to-July territorial changes were related to the floods. The territories that were abandoned were no more hazardous for the floodedout adults than the majority of territories that were tenaciously retained, and the lost territories included one of the most favorably situated with respect to flood refuges.

Track signs during the hot, dry weather of late July, 1947, indicated the active presence only of adults and of the larger sizes of young that had been born in mid-May or earlier. Later, the tracks of weaned July-born young appeared, and these, in the absence of tracks of intermediate sizes, contrasted with the tracks of the very large young. Heat and drought continued into the fall, but the ground had been so saturated early in the summer that a trickling flow persisted for weeks over the stream bed. The flow ceased only for a couple of weeks from the middle of September to the end of the month, though nothing approximating a fair water level was restored until November. But the floods of 1947 gave individual pools in the bed much more filling in than scouring out and left them less attractive and habitable for muskrats during the drought of 1947 than they had been during the actually more acute droughts of 1934, 1936, 1937, and 1939. Nevertheless, it was noted in early September, 1947, and thereafter up to the restoration of normal water levels in late fall, that muskrats were not engaging in the general cross-country movements that had been so conspicuous the previous fall. Such movements outside of established territories or home ranges as did occur and could be traced in late summer and fall, 1947, consisted typically of minor adjustments upstream or downstream along the exposed creek bed between pools; they were followed by orderly establishment of new living quarters at variable but almost always rather short distances (i.e., within radii of a few hundred yards) from old quarters.

As of October 9, 1947, muskrat signs along the two-mile observational stretch of Keigley's Branch were fair to excellent in or about all sites of territories that had been functional from midsummer on. About the last of September, numerous muskrats moved into one of the gravel-pit pools near the stream, but these animals clearly had their origin in one of the stream territories. The best late-fall estimates from signs gave something like 60 muskrats in the Section 26 stretch (including the gravel pit) and about 40 more for the corner of Section 35 and the upper half of Section 36. With legal protection from trapping during the 1947–48 fur season, an obviously substantial population wintered, especially in the gravel pit and in the deeper pools of the stream bed that were near corn fields.

Section 26 had ten territories as of mid-May, 1948, Section 35 had one, and Section 36 had six. By September 9, the stretch of creek was dry except for pools, most of which were in the west half of Section 26. At this time, signs of only a single muskrat – that one a transient – could be seen along the bed in the southeast quarter of Section 26 and in sections 35 and 36. A gravel pit had a good sign although the water was low, and a dog had been digging out the upper parts of the muskrat burrows.

In the west half of Section 26, the muskrats were concentrated in two sets of burrows. A tremendous number of trail signs revealed the adjustments that had taken place between newly abandoned old burrows and the last two sets to be occupied. Rotten remains of a suspected disease victim lay in the pool having the most living muskrats, but no further mortality was detected here. By mid-October, the entire muskrat population of the two-mile observational stretch was concentrated in two sets of burrows near the west edge of Section 26. One of these two burrows was that of the pool having the dead muskrat of early September, but the other set had been recently excavated a short distance upstream by what was judged to have been a group of animals moving into the observational stretch from upstream. This place, with a series of pools and a corn field nearby, would have been inviting to newcomers except for the presence of the established residents. The occupants of these two sets of burrows (which were about 40 yards apart) did stay by themselves as social units, practically no current tracks crossing the mud bottom separating their respective home ranges. Both groups raided the corn field but via separate routes. These muskrats were trapped out illegally before the fur season opened on December 1, but, on the basis of signs, I estimated the pre-trapping concentration at about 40.

The spring dispersal of 1949 put the equivalent of five pairs of muskrats in the previously depopulated stretch of Keigley's Branch in Section 26, one pair in Section 35, and another pair in upper Section 36. No muskrats remained past midsummer except at the sites of three territories near the west side of Section 26. By early September, the signs indicated that the muskrats in residence at the latter places had maintained relatively independent living quarters as late as the middle of August, although, at that time, all three groups had massed along about 100 yards of stream. Next, the remaining animals had all congregated in a puddle beside a big root-tangle of a fallen tree that was adjacent to a corn field; they had plugged and plastered the roottangle with mud to make a lodgelike habitation out of it and they had raided the corn field for weeks after the surface water disappeared from the puddle. My guess was that upwards of 20 muskrats were here at one time, but that no more than 10 remained when a slight flow of water returned to the stream in November. This population remnant had ear corn stored under the root-tangle and wintered satisfactorily.

In 1950, four territories were established and maintained from late April through July, within a 500-yard radius of the root-tangle, and clearly by animals that had wintered there. Downstream from these territories, a mile and a half of stream had no muskrats in early spring, but, as of the last week of April, four territories were established (or in process of establishment) in the lower mile. The upper one of the four lower territories – in Section 35 and the lower edge of Section 26 – showed considerable readjustment over a stretch of about 300 yards between April 20 and June 20; and, after weeks of vacancy in May, June, and July, the original territorial site was taken over by other animals for a *new* territory.

The really astounding territorial adjustments occurred in Section 36. This stretch had but three territories by late April, then enough muskrats moved upstream into the lower mile of the area to raise the total of established territories to nine, the greatest breeding-season concentration of muskrats observed in that section in the course of the Iowa investigations. "Reading of sign" indicated that essentially no upstream movement of newcomers occurred past the middle of the two-mile observational stretch until late summer. From May into August, the nine breeding territories of Section 36 were centered 80 to 225 yards apart, at mean distances of less than 150 yards. The occupants of each of the more downstream territories seemed content to crowd rather close to their upstream neighbors but without attempting to pass them and continue moving into less crowded habitats. Furthermore, the general food supply of Section 36 was inferior even for a generally food-poor type of habitat; of two corn fields planted within convenient muskrat-reach of the water, only one was raided and that by few muskrats; and the other muskrats fed upon what watersedge vegetation was growing in a partly open, partly wooded cattle pasture. But such fare seemed ample until late summer.

By early August, eight of the nine territories of Section 36 were still functional, but some changes were occurring. A territory at the extreme lower end had by then been abandoned; its former occupants apparently moved downstream. The occupants of the three territories lying next above were massed into a 100-yard stretch, above which was a muskrat-vacant stretch of almost a quarter of a mile. The next quarter mile above that contained the members of all of the other five territories in Section 36. This behavior could not be attributed to dry weather, for Keigley's Branch still had a good flow, and all pools were almost as deep as they had been in June. At the time of the late-summer adjustments of Section 36, the muskrats of Section 26 were still living at or in the vicinities of the old territorial sites.

Most of the muskrats of Section 26 left the observational stretch in 1950 without any detected preliminary massing. This egress involved occupants of pools where the continuity of water over the stream bed was unbroken as well as where the bed was exposed except for isolated shrinking pools. It was characterized by relative suddenness, datable to late August.

By mid-September, the territorial sites of Section 36 were abandoned, with the exception of two, of which one still harbored a family group of late-born, newly-weaned young. Fresh trails of two transients could be distinguished – of a small "kit" (having an estimated age of about 70 days) heading upstream and of a probable subadult heading downstream. In Section 35, perhaps a dozen animals moved into a previously unoccupied, food-poor pool. In Section 26, the muskrat population consisted of an estimated half dozen in one pool, about two more in another, and about eight in a third.

By late fall, 1950, all of the muskrats had left the two-mile stretch except for a few that wintered precariously in a nearly waterless habitat next to a corn field, at the 1949–50 wintering site under the roottangle in the west part of Section 26. At least two muskrats got through the winter of 1950–51, despite attentions of minks working about the exposed burrow entrances.

Section 26 had nine territories in late June, 1951, while Section 36 had two. Of the nine in Section 26, four were massed along less than a quarter mile of stream, and most of the active young of the whole twomile observational stretch were localized here. Of the other seven territories of the two miles — which were far more widely spaced with reference to each other — only three had active young and obviously not nearly so many per territory as the signs indicated for the four territories massed upstream. These differences were considered a manifestation of the less efficient mating to be expected in the more isolated territories.

By the second week of August, it could be seen that six territories in Section 26 were still functional, as were two in Section 36, though two of the Section 26 territories had relatively light signs. At this time, nothing more than the most localized up-and-down-stream movements were taking place. By early November, after weeks of adjustments, signs could be seen of what were judged to be single animals or small groups scattered rather widely along the stream in Section 26. I estimated that no more than 20 muskrats then remained in the channel of the two-mile stretch, plus possibly a half dozen more living in a gravel pit in lower Section 26. The observational stretch was nearly depopulated by the beginning of the trapping season, November 20, and only a very few muskrats, if any at all, successfully wintered there, 1951–52.

Section 26 had seven territories in 1952, of which only one was located in the formerly favored sites near the west edge. In addition, a breeding pair became established in a small, wet gravel pit away from the pit that commonly had the muskrats during the preceding years. Section 35 had a territory, and Section 36 had four, all in the upper half mile. Postbreeding adjustments were very extensive, but most of the Keigley's Branch animals appeared to remain within the two-mile stretch or its vicinity. Sex and age ratios for 303 carcasses trapped from the vicinity of Story City during the 1952–53 fur season were 17 adult males, 21 adult females, 143 young males, and 122 young females. Application of these ratios to the 13 original territories of the two-mile stretch would give a fall population of about 190, a figure that is probably close to the truth.

One of the most interesting situations was studied at the small gravel-pit pool. This pool had a surface area of 27 square yards but was watered by an artesian flow and was partly covered and fairly well surrounded by cattails. About mid-July, muskrats moved in from a larger but food-poor pool lying 70 yards distant. On August 4, I watched a very tame family group consisting of two adults and a minimum of eight young of two sizes (about a month and two months old), which were living on grassy and weedy growths and had hardly started cutting the cattails. By August 28, the muskrats had cleared about two-thirds of the cattails. By September 11, it could be seen that some animals judged to have come from the gravel pits were established along neighboring Keigley's Branch to the west; the little cattail pool was almost denuded but still had many muskrats. About a month later, the whole gravel-pit territory was nearly, if not wholly, abandoned.

One of thirty-eight trapped carcasses known to have come from Keigley's Branch had lesions of the hemorrhagic disease, but more evidence of disease was found in two neighboring stream habitats than on Keigley's Branch itself.

Section 26 and Section 36 each had 6 territories in 1953. By midsummer, an estimated residuum of about 35 muskrats was massed along about 125 yards of still-wet bottom lying adjacent to a corn field near the west edge of Section 26. By mid-September, these muskrats were concentrated at the sole habitable pool near the corn field. By late October, perhaps half of the muskrats had abandoned the pool. Of those remaining, several muskrats survived the winter of 1953–54.

The above survivors, together with some migrants coming upstream from Skunk River, established seven territories in the two-mile stretch in the spring of 1954: three each in sections 26 and 36 and one in Section 35. The creek was flooded twice in June, with probably deadly consequences to young muskrats of helpless sizes. By mid-July, the two-mile stretch had only two functional territories (both with young), and it had only one territory left by late September. This one place that continued to be occupied was also the only one that had had muskrats by late fall of the previous year. Few if any muskrats were known to have survived the winter of 1954–55 on the Keigley's Branch observational area.

Twelve territories were established in April and early May, 1955: six well separated in Section 26, three in the corner of Section 35, and three in the upper half of Section 36. By the first of August, when the surface flow was stopping in a few places, ten of the territories showed varying degrees of productivity. By mid-August, the two-mile stretch was well on the way toward abandonment, except for a territory having a late litter. By September 2, only a single resident animal seemed to be left. The exact routes of departure could not be traced satisfactorily; one downstream trail was dated to the first week of August and another to September 2.

Signs of rather pronounced movements were to be seen by mid-April, 1956. Three productive territories and two lone-animal territories were established along the two-mile observational stretch by early June. Two family groups and a lone animal remained by the end of June. The most productive group (having three litters, with births assignable to late March, late April, and late May) did considerable adjusting along less than a quarter mile of stream, from late June through August. By mid-September, this group had gone. The members of the second family group (having two litters, assignable to early April and early May) left the upper part of the area in late June, took over the abandoned territory of another upstream family group (which had in turn moved about a half mile farther upstream), and spent the latter part of the summer moving back and forth out of and into the observational area. By mid-September, only a single muskrat seemed to remain here.

One of the lone-animal territories provided an exceptional case history. Because of its isolation along a stretch of creek having had no known muskrats passing through over a period of 13 months, the local sign may with some confidence be considered that of a single individual. On September 2, 1955, a medium-sized muskrat had come down the then exposed stream bed and built a retreat under a roottangle. It had stayed until freeze-up, wintered on stored ear corn, and continued to stay on through most of the summer of 1956. It was by then a full-grown animal having a characteristic living routine. In mid-August, 1956, it shifted its main living quarters to another roottangle (which was more conveniently situated in relation to raidable corn and soybeans) about 125 yards downstream, but it was still visiting the old retreat at the last of the month. It then disappeared from the observational area, after having spent a year in a very circumscribed radius of activity.

As of the middle of May, 1957, the two miles had five territories, or about eight adults; as of late summer, an apparently lone animal. Whatever may have been the reason for this decline, it could not have been due to lack of water. The two-mile stretch again had muskrats by October, perhaps about 25, on which no further data were obtained.

## DRAINAGE DITCH WEST OF STORY CITY

The three-mile observational stretch had five territories in the drought year of 1936 - all localized in the northeast corner of Section 22 along a half mile of ditch bordered by corn fields and kept wet by an artesian flow. The ditch muskrats were still concentrated there in late October, at which time a careful estimate of about 60 was made. Fall rains that broke the summer's drought for the muskrats of naturally flowing streams of central Iowa did little to improve the situation for the ditch-dwellers, for the dry ground took up so much of the moisture as to leave nothing to flow from the tile openings in the upper miles of the ditch. Hence, the muskrats here entered the winter of 1936-37 with no more water than they had had all summer, or with barely enough to cover their burrow entrances. They did respond to the scantiness of the water in some effective ways, as by deepening channels in the ditch bottom, digging labyrinths of tunnels in the banks and under the bed of the ditch, and storing great quantities of ear corn in the burrow chambers.

Remains of six dead muskrats were found during the winter, of which three were judged to have been mink victims, though there is a suspicious connection between the main site of mortality and mink-feeding upon muskrats and a disease focus studied in later years. Two minks were known to frequent the ditch, including a big one surprised, February 16, while feeding on a muskrat in a snowdrift tunnel right next to the place where the disease focus was later found. Three of seven mink scats contained muskrat remains. Two of the three muskrats killed or fed upon by minks had been either wanderers or ill-situated individuals, while the third — the one the mink was eating when surprised on February 16 — was at least fat. A fat adult female was found dead, February 12, under a melted snowdrift, and it had what was recorded as a ruptured, suppurated stomach.

Water from the artesian flow and from snow melting during thaws laid down increasingly thick overlayers of ice in January and February, 1937. Muskrats came out in places during mild weather of midwinter and again in late winter. One muskrat broke out of a drift to travel on the surface of the ice and snow for three consecutive days, February 7 to 9, but it failed to find a place where it could get back under the ice on February 10, when its passage hole had drifted full of snow. The animal gnawed at the ice in many places in the vicinity and finally moved down the ditch to leave the area.

The ditch in Section 22 was the site of an extremely detailed investigation of muskrat food habits and damage to corn fields in 1937 (Errington, 1938). Section 22 had four territories, and the south part of Section 15, across the road to the north, had another territory. The animals responded to the drought of late summer and fall in their usual ways, by deepening channels, enlarging or repairing bank retreats, and by filling their chambers with ear corn. No muskrat remains were found in 10 mink scats from early fall, despite much foraging on land by the muskrats.

Two territories did not produce young in 1937. Of 39 carcasses of muskrats taken by trappers from the observed stretch of ditch in November, 3 were adult males, 2 were adult females, 20 were young males, and 14 were young females. By the opening of the trapping season, the population had been largely concentrated in two sets of burrows, of which the more extensive set yielded about 20 without being completely trapped out. With the aid of the specimen data, the pre-trapping population was calculated at about 60, including about 20 in lower Section 15.

The animals surviving the trapping wintered fairly well. Most of them revealed their presence to outside view only by plugging holes left by intruding minks, though one individual came out frequently in mild weather. As the ice melted in late winter and spring, 1938, signs of living muskrats could be seen in expected places.

There were three 1938 territories in the Section 22 stretch, plus another at the south part of Section 15. Crop rotations left decidedly less corn conveniently available to the ditch muskrats in 1938, and the local population reoriented itself with respect to the two corn fields remaining. In late fall, a big dog engaged in extensive digging out of burrows — mostly near the site of the suspected disease focus of 1936. In November, 35 muskrats were known to have been legally trapped from the observational stretch of ditch, of which 25 were examined. They were an adult female, 13 young males, and 11 young females (including 4 of "kit" sizes). A dog (presumably the one that did the digging) robbed traps of 3 other muskrats. The pre-trapping fall population was calculated at about 80.

Of seven breeding territories listed for 1939, three were at widely separated sites in the upper two miles, one was in lower Section 15, and the other three were in the artesian-watered stretch in Section 22 that usually had concentrations of muskrats. Drought, in combination with less convenient access to corn fields, localized the remaining population by October. Only one of the three upstream territories had muskrats in late fall, and this one possibly had a half dozen. The little surface water remaining was solidly frozen by early winter, but the muskrats revealed their continued presence by plugs. Concentrations of muskrats were by no means restricted to the vicinity of corn fields, for good wild food plants (such as sedges and composites with edible roots) grew abundantly along some of the ditch banks. By mid-December, the greater part of the population lived at a single set of burrows — incidentally, not adjacent to a corn field — and the signs here indicated about twenty animals. The total population of the three-mile stretch entering the winter of 1939–40 was estimated at about forty-five. The only outside activity studied in detail during the winter was on the part of a wanderer that explored several places on December 22 and finally went on through, heading downstream. In the spring, the body of a dead muskrat from the winter was found partly eaten by a mink.

The mile of ditch in northeast Section 22 and lower Section 15 had five territories in 1940, and the two miles of ditch upstream had three widely separated ones. The ditch muskrats were not fortunately situated with respect to corn fields in 1940: no corn was planted adjacent to any part of the observational stretch that had old burrow systems, and the two main corn fields near the observational stretch were out of the radii of activity of settled muskrats. One of the 1939 burrow systems in Section 10 was evidently taken over by muskrats in 1940 because of the old ear corn stored within. The usual foods of the ditch muskrats in 1940 were legumes and composites and planted oats. Oat fields were raided much as the muskrats usually raided corn fields, though on a lesser scale. Water levels in the ditch remained fairly constant during the alternating wet and dry periods in 1940. In late summer and early fall, muskrats moved upstream from the more populous lower mile of the stretch to dig new burrows in many places that had not been occupied for years.

Fifty-five trapped carcasses were examined during the 1940–41 fur season. They were 7 adult males, 4 adult females, 30 young males, and 14 young females. Three of the young were of "kit" sizes, classed as August-born. Of the 4 adult females, one had conceived a single litter in 1940; 2, two litters each; and 1, three litters. One of the two-litter females had given birth to a rather late litter. From the above ratios, and assuming neither spring to fall losses of adult females nor substantial movement in or out of the area, the total fall population of the three miles of ditch may be calculated at about 100, of which roughly half remained localized in the lower mile.

Downstream from the three-mile stretch of ditch and in the northeast quarter of Section 26 is the series of artesian-fed artificial ponds known as Lake Comar, owned by F. C. Corneliussen. The ponds themselves were never kept under regular observation as part of the research program, but a two-thirds mile of creek into which the artesian overflow drained was added to the study area in 1940. This two-thirds mile of creek ran through the southwest corner of Section 25 and was a continuation of the Story City drainage ditch, though not dredged except at its upper and lower extremes. It was pastured along its length (except for a short, brush-grown stretch parallel to a road), but corn fields always were within easy reach of the water in places.

In 1940, the two-thirds mile of creek had a single territory, this in the roadside brush. There was, however, a movement of muskrats out of the stretch, culminating in early September, at the height of local drought conditions. By late fall, after the water came back, the remaining population was estimated at about 10 - mostly large-sized animals. No muskrat remains were found in 16 mink scats from September, 1940.

Muskrats were scarce along the three-mile stretch of ditch in the spring and early summer of 1941. There were four territories, all in exceptionally favorable situations, as the few muskrats present took their pick of available sites. Two of the territories were depopulated by late summer drought, and another had only a single muskrat after a heavy rain put puddles back in the ditch bottom. Muskrats spreading upstream from the two functional territories in late September and early October rehabilitated an old burrow system lying a mile or more away. Here a trapper took 25 in December, but I did not learn of the catch in time to examine the carcasses.

The total of 49 specimens examined from the ditch during the 1941–42 fur season (including some caught below the three-mile observational stretch) was probably close to the equivalent of the population of the three-mile stretch. They were 3 adult males, 4 adult females, 23 young males, 16 young females, and 3 young of undetermined sex. Three of the 4 adult females provided data from placental scars: one had not conceived during the 1941 breeding season, whereas the other 2 had conceived 13 and 29 young in two and in at least three litters, respectively.

The extent of the population adjustments taking place along the ditch after a return of flowing water is indicated by data from the two-thirds mile of undredged creek below Lake Comar. This stretch of creek had no breeding muskrats in the spring of 1941 and was dry in mid-August. But, with the onset of fall rains, a surprisingly large number of muskrats moved in, to start the winter near the edge of a corn field. At this place, the newcomers dug a fine set of burrows in once-vacant habitat, from which I examined 19 carcasses trapped in early December: 1 adult male, 3 adult females, 2 young males, 8 young females, and 5 young of undetermined sex.

The ditch had four territories in northeast Section 22 and lower Section 15 in 1942, and six were established in the upper two miles, making a total of ten for the entire observational stretch. Four of the upper territories were at sites not previously used for breeding territories, but they actually had their origin in burrows dug in the course of the population adjustments of late summer and early fall of 1941 and then were stocked with 1941 ear corn. By mid-September, the south mile had heavy signs in one place, representing probably about 30 muskrats. Three of what had been four well-used territories showed many old but few current signs – fading trails into corn fields – and these three territories in a foodrich and attractive place were contiguous. Although this antedated our real experience with the hemorrhagic disease, the evidence looked to me like that of an epizootic, nearly depopulating about a mile of ditch.

Elsewhere, in the upper two miles, a trapper reported catching between 55 and 60 (which I had no opportunity to examine) in December, 1942, and an allowance may be made for perhaps 10 escaping the traps. This would give a total of about 100 for the pretrapping population of the three-mile stretch.

Downstream from the ditch, the two-thirds mile of creek in Section 25 had three territories in 1942. One was at the old site near the brush-bordered road, and the others were in burrows that had been dug in the late summer and early fall of 1941 and then stocked with ear corn. About twenty-five muskrats entered the winter.

In 1943, the three miles of ditch had 11 territories or about 25 adults, which was not, comparatively considered, quite the breeding population that one might have expected from the overpopulated status of Keigley's Branch and environs. The territorial site of 1936-42 in lower Section 15, suspected of being at or near the focus of infection of the hemorrhagic disease, had no breeding muskrats living near it in 1943. As during previous springs, settling muskrats showed an evident partiality for vacant burrow systems that already had been stocked with ear corn. Forty-three carcasses examined from the three miles during the 1943-44 fur season were 2 adult males, 4 adult females, 19 young males, and 18 young females. No apparent scarcity of muskrats was noted in the fall in any of the territorial sites of the breeding season, so negligible mortality of adult females between spring and fall (as from disease) may be assumed. These ratios applied to the 11 territories would give a fall population of about 115. Of the 4 adult females examined, 2 had conceived two midsummer litters each, and 2 had conceived three early-season litters each.

The two-thirds mile of creek in Section 25 had three territories in 1943. By mid-September, the heavy signs were localized at the edge of a corn field, but there were some muskrats elsewhere along the stretch. Thirty-three carcasses trapped from or near the two-thirds mile are considered practically the equivalent of the fall population of muskrats resident there: an adult male, 3 adult females, 17 young males, and 12 young females. One of the adult females had not conceived young in 1943, and the other 2 had each conceived 26 young in three midseason litters.

The three miles of ditch had 8 territories in 1944, and there were 3 along the two-thirds mile downstream. The ditch did not flood during the wet summer, and, though the small creek flooded, it still reared early-born young. Forty-one trapped specimens from or near the two-thirds mile of creek were about the equivalent of the total population living there by late fall: 2 adult males, an adult female (with 29 placental scars of four ages, the latest of about August), 25 young males, and 13 young females. No trapped carcasses were obtained from the 3 miles of ditch during the fur season of 1944–45, but the over-all sex and age ratios for 192 carcasses from the vicinity of Story City were 14 adult males, 15 adult females, 105 young males, 57 young females, and one unsexed young of the year. Application of these ratios to the 8 ditch territories without correction for possible losses of adult females between spring and fall would give a total of about 100 muskrats as the late fall population for the 3 miles of ditch.

The ditch had nine territories, and the two-thirds mile of creek had one in 1945. Fourteen of an estimated twenty muskrats in the two-thirds mile were caught in November: an adult male, an adult female (with fourteen placental scars of two early-season ages), six young males, and six young females. The ditch had been the site of both extensive late summer and fall movements and severe illegal trapping before season. Samples totaling three adult males, two adult females, twenty-one young males, and twelve young females from or near the observational stretch of ditch were probably representative for the ditch populations, but these ratios can not be applied without correction to the original number of territories. There is reason to consider that the reduction through late summer and fall egress may have been about 40 per cent, which would have left a population of about a hundred remaining along the ditch by the beginning of the human exploitation.

Of the 2 adult females legally trapped from the ditch, one had conceived 16 young in two early litters and the other 14 in three early to midsummer litters. Of 158 young of the year examined from the Story City block, 15 were classed as "kits," or August-born, and all but 2 of these "kits" came from the ditch.

The ditch had 10 territories, and the two-thirds mile of creek had one in 1946. By late August, 8 ditch territories and the creek territory were still functional. The site of the creek territory yielded an adult female, 7 young males, and 4 young females during the 1946–47 trapping, but, insofar as the female had conceived only a single litter of 6 young in 1946, many of the trapped young had to be animals born and reared elsewhere. Of 84 trapped from the ditch, 5 were adult males, 6 were adult females, 39 were young males, and 34 were young females. These ratios should be fairly applicable to the eight functional territories recorded for late August, which would give a pre-trapping ditch population of about 115. Although six of the sixteen litters conceived by the 6 adult females from the ditch were July or August litters, only one of the 73 young of the year was of "kit" size.

Central Iowa trapping conditions for muskrats in November, 1946, were ordinarily favorable, but trappers were disappointed in their catches from the Story City block – though probably less disappointed

with their catches from the ditch. Even so, the muskrats of the ditch certainly shared to some extent in the mortality and unrest manifested by the muskrats of other central Iowa stream areas. A trapper brought in for me a victim of hemorrhagic disease that he found on the ditch bank, and the ditch was right in the midst of a general area in which hundreds of muskrats engaged in upstream and downstream adjustments and footloose cross-country movements in late summer and fall. Undoubtedly, many muskrats just moved out of given habitats, to be eliminated by enemies, exposure, accident, and strife.

The three miles of ditch had nine territories in early May, 1947, and there was another in the two-thirds mile of small creek. The creek territory was abandoned in June or early July, but the ditch – which neither flooded during the June rains nor dried up during the following drought – had a carefully estimated population of about 120 by November. No legal trapping of muskrats was permitted during the 1947–48 fur season in central Iowa. I doubt if more than about 100 entered the winter along the ditch, however, for one territorial site – situated next to a bridge – was completely depopulated, evidently through illegal trapping.

The ditch had 11 territories in 1948, and the two-thirds mile of creek had 3. The creek retained its flow throughout the drought, but only one territorial site had a wintering group, which was estimated at between 20 and 25. In view of the unfavorable status of musk-rats, generally, in the Story City area, the trapper controlling the two-thirds mile of creek gave this group complete protection as breeding stock.

The three miles of ditch became drought-exposed except for the half mile watered by an artesian flow. About 90 animals had concentrated along the wet half mile by late fall, with about 30 still remaining along the dried-out stretch. Fourteen trapped carcasses, mostly from the dried-out part of the ditch, consisted of an adult male, 3 adult females, 8 young males, and 2 young females. Of the adult females, one had conceived two early litters in 1948 and the other 2 had each conceived three early to midsummer litters. No specimens were obtained from the half mile of ditch having the heavy concentration, for this stretch again had been virtually depopulated through illegal trapping before season.

During the drought of 1948, there was much moving away from established quarters in the Story City block but remarkably little evidence of cross-country movement. Upstream and downstream adjustments occurred on an increasing scale from late summer until the acute stages of drought were relieved by a rain on November 19, but these adjustments had an orderliness not witnessed in the course of the extensive and obscurely motivated footloose movements of 1946. In 1948, a large proportion of the total movements seemed to result from bands of muskrats (presumably of family or otherwise closely associated groups) moving deliberately and remaining together as social units while exploring for new living quarters after their old quarters became untenable. There seemed to be a greater tendency, also, in 1948, for animals to headquarter in their familiar burrows until these burrows lost all of their surface water.

In 1949, the two-thirds mile of creek furnished a splendid illustration of the role of locally wintering animals in restocking for a new breeding season. The stretch had four territories, including one at the 1948–49 wintering site previously mentioned and the other territories were distributed with some uniformity along the rest of the two-thirds mile. The ditch had nine territories; though no muskrats were known to have wintered, 1948–1949, along the three miles, it cannot be said with certainty that none had; hence, the 1949 breeding population may have consisted of both newcomers and old residents.

Except for the half mile kept wet by the artesian flow, the ditch was practically dry by August, 1949, and stayed dry all fall. As of mid-September, the carefully estimated population was about 50. By early winter, 1949–50, the observational stretch of ditch had no living muskrats left. The loss of perhaps 20 muskrats occupying the burrow sets near a road may be charged, as in some other years, to illegal trapping before season. Other than that, the reduction was due mainly to a combination of drought exposure and disease, and the crisis resulting therefrom was studied in particular detail throughout the fall of 1949.

No muskrat remains were found in 19 mink scats deposited in the first three weeks of September along the wetter half mile, nor in 56 scats of earlier deposition. One of 13 scats deposited in late September did contain muskrat remains. The victim was a young of about six weeks of age from a dried out burrow system at or near which 5 other occupants died in the space of days.

The latter burrow system had had something over a half dozen residents in mid-September. On September 23, remains of six dead were found outside or just visible within the burrow entrances: (1) an adult male was clearly a victim of hemorrhagic disease, though it had been carried about eighty yards down the ditch and urinated upon by a red fox, (2) a subadult female without recognized disease lesions, killed outside the burrow and left there by the fox, (3) an intact six-weeks young that had crawled into a hole to die of disease, (4) the previously mentioned six-weeks young that had been eaten upon by the mink, (5) a third young of about six weeks, dying several days earlier than the others, to decay in otherwise intact form (with no broken or disarranged bones) outside the burrow, and (6) a subadult male dead about two days from hemorrhagic disease.

At least two and probably up to a half dozen of the ditch muskrats hung on to a dry burrow system most tenaciously. They had beaten trails to a corn field and left ear corn all about what was the last freshly plugged burrow entrance to be seen on September 21. Remains of a freshly eviscerated small muskrat – probably a subadult – lay on the mud. A fox or a raccoon had dug out one of the main chambers probably in late August, and the soft mud on the bottom revealed the continued interest of these two species. By October 5, the last muskrats here had either died or abandoned the burrow system.

At the upstream end of the half mile made wet by the artesian flow, the concentrated muskrats got along well until early November, though by mid-October water remained only in the channels of the burrow entrances. On November 10, a freshly dead victim was found lying on the bank, out of reach of a drove of hogs that was systematically rooting out the most accessible parts of the burrow system. On November 22, a good covering of ice showed no bubbles of living muskrats beneath, and the evidence indicated that the entire group had died of hemorrhagic disease, chiefly deep in the burrow system or in the mud where the hogs picked them up. (This place was in the vicinity of the suspicious mink and dog activities of 1936–38.)

It may be mentioned that wet mud surfaces upstream from the muskrat concentration of 1949 showed that at least one animal had come from the drought-exposed part of the ditch to join the group in late fall. The ditch bottom extending downstream had wet mud along the edges that was highly suitable for the taking of tracks, and the part flowed over by the artesian water had a diatomaceous film on which muskrat tracks were conspicuous for a distance of 30 yards downstream from the last part of the burrow system showing signs of living animals during the dying. Downstream from there, not a track of a muskrat was seen after early fall on either mud margin or diatomaceous film for a distance of about 600 yards.

The occupied burrows near the extreme downstream end of the three miles of ditch – the site of so much illegal trapping near the highway – may have recruited a few muskrats from downstream in October, for the increased signs to be seen there in late fall could well have reflected more animals than had been present in September. Less than a half mile downstream (off the regularly observed stretch) was another concentration, a "fur pocket" from which a trapper took 26 without trapping it closely. The sex and age ratios of the sample were 2 adult males, 3 adult females, 10 young males, and 11 young females, including one of "kit" size. Of the 3 adult females, one had conceived an early small litter (5) in 1949, and the others had conceived three litters each of early to midsummer ages.

Starting about a half mile farther downstream from the above "fur pocket," the two-thirds mile of creek had an estimated population of about eight muskrats left in the four territorial sites by late September. The flow was then good, but earlier the stream had been dry or practically so. No trapping was done here during the 1949–50 fur season, but nine muskrats taken nearby were an adult male, two adult females, three young males, and three young females. The two adult females had each conceived four litters during the 1949 breeding season, and the time of birth of one of these litters was assigned to August. The "kit" in the catch from the upstream "fur pocket" was probably the offspring of one of the four-litter females. The two four-litter females had conceived a total of 74 young in their eight litters, which would imply that these particular females must have had superior living conditions.

The 1949 drought crisis in the Story City block was characterized by a minimum of cross-country movement. I saw no traffic victims at the height of the drought. Neither had any of the resident trappers and farmers with whom I talked. Some stream-bed exploration occurred in places, but other places favorable for taking track signs did not have a track laid down for weeks, even when conditions were critical for local animals.

By late April, 1950, five territories were established along the three miles of regularly observed ditch, and soon thereafter another territory was established. These newcomers to a depopulated stretch almost certainly came from the moderately trapped "fur pocket" lying between the observational stretch of ditch and the two-thirds mile of creek below. Few if any muskrats moved through the two-thirds mile during the spring dispersal.

Minor adjustments occurred along the reoccupied three miles of ditch during the summer of 1950. The territory nearest what had been one of the disease foci of the previous year seemed to have only a single muskrat in it by early August. Later, after rehabilitating the burrows of the old focus, this animal also disappeared. Five territories – all situated along a wet ditch adjacent to raidable fields of corn and soybeans – were patently successful in rearing and holding young.

Another group of muskrats settled in the lower part of the threemile stretch, the animals moving in from a food-poor territorial site immediately downstream. The obvious new attraction was a corn field. The first of the newcomers to be noted was a "kit," which left its tracks at the lower edge of the three-mile stretch about the first of July. In the course of July, the muskrats from downstream took over the whole lower end.

The surface water disappeared from about half of the length of the three-mile stretch of ditch during the fall of 1950. By mid-November, the ditch-dwellers had withdrawn from two of the five productive territories of the summer and from the place at the lower end that had been occupied by the immigrant group in July. Following these withdrawals, the ditch population congregated about the three other territorial sites, there to maintain themselves with very little apparent change in total numbers until the 1950–51 fur trapping.

The two driest of the three occupied territorial sites along the ditch showed considerable surface activity of the muskrats when the

trapping season opened on November 25, and a trapper caught 20 here in land sets. The pre-trapping population for the three miles figured at about 80, of which probably between 50 and 55 survived the trapping – all in the most habitable of the old territorial sites. No wintering mortality, 1950–51, was detected, and the best-situated local population was estimated at about 40. Signs as early as the last days of February indicated that some muskrats were beginning to disperse from this latter group. The farthest movements occurring at this time (during a thaw) could be traced about a quarter of a mile both upstream and downstream. This was the only place along the regularly observed central Iowa streams where evidence of dispersal was seen so early, and it may be judged that certain individuals of a crowded population were desirous of getting away.

The two-thirds mile of creek had a single territory established in the lower part by a muskrat or two appearing late in the spring dispersal of 1950. A young animal judged to have been April-born appeared briefly at the lower end of the two-thirds mile early in July. In early August, a lone animal (probably a subadult) moved into the upper end of the stretch, there to stay through September and part of October. The maintained territory never did have signs of many animals and may have had only one animal in residence during the breeding season. It suddenly became vacant in late September, despite the proximity of a muskrat-raided corn field and a continued flow over the creek bed throughout the driest weather.

The animals surviving the winter of 1950–51 filled the three miles of ditch about up to capacity for the breeding season of 1951. As of late May, the stretch had 12 territories or about 28 adults. No evidence was seen of animals moving into the three-mile stretch from downstream. A single animal was known to have died from undetermined cause in late April or early May.

Ten territories were plainly functional by late July, but, by mid-November, the muskrats of the three miles were almost restricted to three places, all in the vicinities of corn fields. The lower 30 yards had the heaviest concentration in its recorded history, or probably between 60 and 80, of which perhaps 40 were illegally trapped before the opening of the 1951–52 fur season. On the basis of sex and age ratios of 111 legally trapped muskrats (4 adult males, 12 adult females, 48 young males, and 47 young females), the late fall population figured at about 165.

The occurrence of 12 adult females in the trapped carcasses agrees well with the known distribution of territories, including 2 nonproductive ones. (Two of the adult females had not conceived young in 1951.) There was only one "kit"-sized or August-born young among the 95 specimens of young of the year, although 5 of the 10 adult females that bred in 1951 had placental scars assigned to August. Of the 10 breeding females, 4 had conceived three litters each during the 1951 season, and 6 had conceived four litters each. If the 111 specimens be regarded as a representative sample for the stretch, a total of 95 young reared of 313 conceived would still reflect poorer reproductive efficiency than is thought to have been the case. It does then look as if a substantial number of young, plus most of the adult males, could have moved downstream out of the area – this despite the adherence of the adult females to their home ranges and the unusually high population of muskrats maintained until the trapping. Two of the young in the trapped sample had lesions of hemorrhagic disease.

The two-thirds mile of creek had, during the breeding season of 1951, an interesting population of four territory-holding lone individuals, all establishing themselves since spring and all being unproductive of young. However, the creek drew a heavy ingress of muskrats in the fall. By late fall, the lower part of the two-thirds mile, which was well-lined by corn fields, was literally filled with muskrats. Of 69 trapped during the 1951–52 fur season from or near the two-thirds mile and downstream, three were adult males, three were adult females, 38 were young males, and 25 were young females. The three adult females in the sample had finished their breeding by late July or earlier, though two of the 38 young of the year were of "kit" sizes, judged to have been born in August. One of the adult females had conceived three litters each.

The 1951 data for the Story City area as a whole may here be summarized to put the ditch and two-thirds mile of creek in perspective. Twenty-six territories were recorded from the regularly observed areas in late spring and early summer. The over-all sex and age ratios shown by a total of 193 fall-trapped carcasses were 9 adult males, 17 adult females, 90 young males, and 77 young females. If insignificant mortality of adult females (which is consistent with the known facts) be assumed and if these ratios be applied to the 26 territories, the fall population should have been about 300. When we consider that only the drainage ditch had even a fairly self-contained population in 1951, and that the Keigley's Branch and Skunk River stretches were sites of such pronounced changes, the transitory importance of the little creek extending downstream from the ditch becomes all the more marked. A place that usually harbored few if any muskrats and lacked a breeding population in 1951 thus seemed to serve in this one fall as a principal catchall for adjusting muskrats living in its vicinity. The Camp Comar fish ponds also drew in the largest number of adjusting muskrats within the memory of their owner, F. C. Corneliussen.

In 1952, the ditch had ten territories, and the two-thirds mile of creek had three. The ditch had the more nearly self-contained population, much as during the previous year. Sex and age ratios of 17 adult males, 21 adult females, 143 young males, and 122 young females obtained chiefly from the Story City block may be applied to

the ten ditch territories, which would give a fall population of about 145 for the three miles. The two-thirds mile of small creek should have had something less than 50, a substantial population though not representing as much massing as during the previous fall. The impoundments of Lake Comar, lying to the north of the creek though connected with it by flowing water, appeared to be the main site of local massing, with up to 100 muskrats present by late fall.

Of the 21 adult females examined from the Story City block during the 1952–53 fur season, one had not conceived in 1952; 2 had conceived a single (June and July) litter each; 4, two litters each; 9, three litters each; and 5, four litters each. The sample of 122 young females of the year included 3 precocious breeders, each having had an August-born litter. Of the 57 litters conceived by full adults, the times of birth of 4 were assigned to April, 12 to May, 15 to June, 17 to July, and 9 to August. Of the sample of 265 young of the year, 25 or 9.4 per cent were classed as "kits," or August-born, compared with 20.0 per cent of the total number of litters born to the females of the sample at a comparable time of year.

The status of the hemorrhagic disease in the Story City block was hard to appraise, but there were 6 diseased among 181 trapped muskrats examined largely from the drainage ditch. Of 10 diseased animals from the entire Story City block that had been sufficiently active to have been caught in traps, 5 were "kits," and 3 of the 5 large diseased animals had lesions of patent severity. The ditch had two disease foci at which victims were found -2 dead at one place and 6 dead at the other.

The ditch had 9 territories in early summer of 1953, and the twothirds mile of creek had three. By late September, careful estimates gave a total of about 100 muskrats present along the ditch. However, most of the ditch bottom was dry, and all but about a dozen of the animals were concentrated in the few still-wet places situated in the vicinity of conveniently raidable corn fields. One of the drought-exposed ditch territories was the site of dying from disease in late September, and, by late October, it was doubtful if more than 30 to 40 muskrats remained, these being almost confined to the halfmile watered by the artesian flow. Six dead of hemorrhagic disease were found at one shrinking pool in October and early November, but about as many more were known to have survived until the fur trapping started. Along the two-thirds mile of creek, about 15 were localized near a corn field from September to November.

Only about 20 muskrats appeared to have survived the winter of 1953–54 in the Story City block, and these survivors were mostly residents of the ditch. Peculiarly, the above site of mortality from hemorrhagic disease of at least six muskrats was also the place where most of the muskrats successfully wintered. The burrows here had been well stocked with ear corn.

The three miles of ditch had only two territories, as of early May,

1954, and the two-thirds mile of creek had one territory. By midsummer, the ditch had one functional territory, and the two-thirds mile of creek had no muskrats at all. These areas were virtually devoid of muskrats during the winter of 1954–55.

As of late May and June, 1955, the ditch had seven functional territories, established by newcomers from downstream, and an eighth territory seemed to have been lost through disease. Downstream, the two-thirds mile of creek had a probable lone-animal territory, which was abandoned by early July. Evidences of upstream and downstream adjustments were noted along the ditch as early as mid-July, and, by late August, the muskrats were showing highly variable local behavior.

A group occupying one of the more productive territories had a corn field conveniently close by. This group maintained dry burrow systems from late August through September, packing trails from burrows to the corn field, and plugging burrow entrances with miscellaneous dry vegetation. In late August, another group rather sud-denly appeared some 500 yards from the nearest 1955 territory, at a not-quite-dry territorial site of previous years. It rehabilitated the old burrow system, stayed about a week, and then disappeared. Nearly a half mile from the nearest breeding territory a fair-sized pool, which had had no early-summer muskrat signs, suddenly did have muskrats in late July. The newcomers soon left, however, and the pool remained muskrat-vacant and about 600 yards from muskrat-occupied retreats until about the first of September. By September 13, the pool had heavy signs of muskrats - recently dug burrows, a heavy trail to a corn field 40 yards away, corn in trails and floating in the water - and these corn-feeding animals, too, behaved as if intending to stay. This group was about a mile and three-quarters from the nearest place then occupied by muskrats. A 150-yard stretch that had the most muskrats during the breeding season (equivalents of two pairs and young) was sufficiently food-poor to be abandoned in late summer, though it was watered by the artesian flow; but a similarly wet stretch 200 yards upstream had raidable corn fields on both sides, and here the majority of the muskrats still alive along the three miles of ditch were concentrated by September. The signs here indicated a well-situated population estimated at 25 to 30, which would mean a total of perhaps between 40 and 50 still being present along the three miles.

Most of the muskrats abandoned the ditch before freeze-up. There was some fall mortality (possibly due to disease) at one dried-out burrow system. In the latter case, remains of a dead muskrat were dug out of the burrow by a large striped skunk. A few muskrats wintered, 1955–56, at a corn-stocked burrow at the head pool of the three-mile observational stretch; an unknown but probably small number, near the lower end.

There were, as of early May, 1956, four maintained territories

along the three miles, and a single, very temporary, territory in the downstream stretch of two-thirds of a mile. Of these, only two of the ditch territories (including a lone-animal territory) were at or near the burrows where animals had survived the previous winter. The origins of the other animals that established territories were not traced.

By late June, the three miles of ditch were, except for puddles, drought-exposed. Three of the four territories were in process of abandonment, but some muskrats were then beginning to move in from downstream. Only two of the territories appeared to be productive of any young at all. The young of one of the territories just seemed to disappear, but an old animal established itself, alone, at a pool next to a corn field about 500 yards distant. The old one remained through September.

One territory was truly maintained throughout the breeding and postbreeding months. It was at the head pool of the ditch, where some muskrats had wintered on stored ear corn. Evidence was found of four litters having been born here in 1956 – in April, May, June, and July. The surface water became foul but did not quite disappear at the height of the drought, and the family foraged both in ditch vegetation and in an adjacent corn field.

# OUTLYING WATERS OF STORY CITY BLOCK Indian Creek Area

The mile-and-a-half observational stretch of brook near the headwaters of Indian Creek had fewer muskrats in 1938 than had a pool formed by water from a broken tile in a corn field about 100 yards to the side of the brook. The trapping catch from the brook itself for the 1938–39 fur season was four or five muskrats, compared with a catch of about 20 from the corn field pool. The landholder dug out the burrows of the pool in connection with repairing the tile in the spring of 1939, and I examined them carefully. The pool itself was about four feet deep and eight feet across, and, in the banks, the muskrats had an extensive set of burrows stocked with ear corn. At least two bushels of corn had been stored in the visible chambers.

The 1939 breeding census for the Indian Creek brook gave four territories. By mid-June, much of the brook was dry, and adjustments by resident muskrats were in progress. By early July, even after some rains, muskrats were living in plugged culverts and nearly exposed burrow systems. A five-weeks young was found dead with no recognized evidence of pathology. By early September, the whole watercourse had long been dry except for a spring-fed pool. Muskrats were living in the weeds about the latter pool and also in a road culvert kept slightly moist by seepage water. Another young, likewise of five weeks, was found freshly dead in early September; it was thought to have died of heat or thirst. By early October, muskrats were still alive (though leaving many fewer signs) in the same two places of the observational stretch that had been occupied a month before. The road culvert was almost filled with mixed vegetation and ear corn and kept tightly plugged with mud wet from traces of seepage water that continued to appear. By November, the culvert looked dry, with about a bushel of ear corn stored in it and plugged with corn, mud, and debris. I think that the local muskrats suffered a total loss during the winter.

The mile and a half of brook had the equivalent of a single pair in late June, 1940 - at least two adult-sized muskrats lived in the same road culvert that had been used in 1939. This was one of the few places retaining surface water in the area. By early July, the culvert was dry, and only a single muskrat seemed to be left. By early September, the brook flow had been resumed, but only the one muskrat was still around. No evidence of successful breeding was seen.

By the spring of 1941, the culvert showed long disuse, but two territories were established, by early May, along the brook itself. One pair was evicted and its territory ruined by road grading during the summer. By August 19, the brook was dry except in a few places; one territory was still well-used, and what appeared to be a single individual was again living in the road culvert. Five fall-trapped muskrats from the area were all young of the year, and my estimate of the pre-trapping population was eight to ten animals.

In 1942, the brook had two territories. One muskrat pair lived and produced young in or near the road culvert, despite the grading of the road and the installation of a new culvert during the summer – the muskrats adjusted to the disturbance and readily accepted the new culvert in place of the old. Trappers took 24 muskrats from the mile-and-a-half observational stretch by New Year's, 1943, of which eight were from the culvert.

No further studies were conducted on the area.

#### Headwaters, Keigley's Branch

In late September, 1940, a survey of the headwaters of Keigley's Branch was undertaken, about fifteen miles of dwindling creek being inspected upstream from the regularly observed stretch in Section 26, northwest into Hamilton County. Above the Section 22 stretch, on which observations had been made during earlier years of the central Iowa studies, there were practically no muskrats nor attractive environment for them until one came to a series of gravel-pit pools lying about four miles southeast of Stanhope. The gravel-pit pools drained at high water stages by means of a tile leading to Keigley's Branch, which at that place was only a brook. Some of the pools were deep and with considerable vegetation, including cattails. Muskrat signs of varying ages could be seen about the pools having the most food, and I think that the equivalent of about a pair and their season's young were in residence. Signs in the spring of 1941 indicated that the animals may have wintered there in nearly the numbers present in the fall of 1940.

The Stanhope gravel pits were visited occasionally during later years, and some general observations were made that may here be summarized. During 1941, 1942, and 1945, the pools collectively had single breeding territories and by each fall possibly eight to ten muskrats. The pools never were very productive for the muskrats, which is partly explainable in terms of food limitations. Neither did the pools prove to be gathering places for muskrats engaging in the pronounced upstream and downstream adjustments of the late summers and early falls of 1955 and 1956, when all muskrats then present in both years were behaving like established residents at two territorial sites. In 1957, there was an apparent family group at the pools in early summer, then these animals disappeared, to leave the pools virtually without muskrats for months. Several muskrats established themselves at one of the pools about the middle of October, and at least one very large animal successfully wintered.

One concentration area of muskrats near the headwaters of Keigley's Branch was studied in 1956 and 1957. It was situated five miles west of Randall and six miles upstream from the regularly observed two-mile stretch near Story City.

In the summer and fall of 1956, a half mile of stream was bordered by corn fields and ungrazed herbaceous and grassy vegetation and had some wet spots that had not dried up completely during the driest weeks of the drought. Although it was an exceptionally attractive stream habitat for muskrats, it looked no more favorable to my eyes than some places that had neither attracted nor held muskrats at the peak of their postbreeding adjustments along the central Iowa streams. An estimated 60 to 80 muskrats had congregated in the halfmile stretch by late fall. Of 76 carcasses (mainly trapped muskrats, but including 3 victims of hemorrhagic disease) examined from or from near the area, 7 were adult males, 6 were adult females. 33 were young males, and 30 were young females. Five of the 6 adult females yielded breeding data: 2 had not conceived in 1956, 2 had conceived three litters each, and 1 had conceived four litters. Of the 10 litters represented by placental scars, none had a birth date assignable to August or later, yet 2 of the 63 young of the year were still of "kit" sizes by December.

The above stretch was kept under regular observation during 1957, when it had three territories. In early April, three dead muskrats were found in what appeared to be a focus of the hemorrhagic disease, and this also was the site of a territory that later "went dead." More evidence of mortality was found here during the summer, and the main burrow system of the disease focus remained virtually unoccupied until fall. The other two territories were well maintained and productive.

Crop rotation left the half mile in less attractive condition for

muskrats in 1957 than had been the case in 1956, for the muskrat occupants of 1957 had no convenient access to corn fields – though the dense stands of natural vegetation bordering the creek were of obvious utility to them. The next half mile of creek lying downstream was in more attractive condition, however, and better utilized by muskrats in 1957 than it had been in 1956, so the concentration area of 1957 accordingly consisted of about a mile of stream instead of the half mile of 1956. As of early fall, 1957, the muskrat population of the mile stretch was estimated at between 80 and 100. Despite the existence of one known and another strongly suspected disease focus, no epizootic accompanied the fall and early winter massing of the muskrats.

The early-December trappers' catch from mainly the mile stretch consisted of 7 adult males, 4 adult females, 45 young males, and 33 young females. Two of the adult females in the sample had not conceived in 1957, but the other 2 had conceived four litters each and a total of 66 young for the season. The fact that more young (78) were trapped than had been conceived by the population sample substantiates the field evidence indicating that adults had more of a tendency than young animals to stay in their original home ranges at times of extensive population adjustments. Animals drifting into the upper stretches of the water course contained higher percentages of young than did the parts of populations that tended to remain more at home in or near their scattered territories of the breeding months.

From the mile stretch, itself, muskrats had been noted to work both upstream and downstream during the late summer and fall of 1957. The first sign of a large number of muskrats moving as a group had been noted on August 5, and such movements had still been occurring as late as late October. Patently, the muskrat populations entering the winter on the concentration area had been of very mixed origin.

## Hay Field Ponds South of Story City

The wetness of 1942 made habitable for muskrats a scattering of hay field and other ponds lying between Skunk River and the twothirds mile of creek downstream from the Story City ditch, but they did not seem to draw any muskrats during that year.

The equivalent of four pairs of muskrats established territories in these ponds in the spring of 1943. By late fall, but before the trapping began, some 15 small ponds had one or more muskrat lodges in each one. Considerable local adjustment was by then apparent. One family group moved from a drying pond in a corn field (the site of the summer's breeding territory) to a larger and wetter hay field pond 80 yards distant. About 20 animals were accounted for at the ponds, collectively, as of late fall and early winter, of which 14 were trapped and about a half dozen were estimated to have survived the trapping. Thirteen carcasses examined were of 2 adult males, 1 adult female (having 30 placental scars of 3 early to midsummer litters), 5 young males, and 5 young females. One carcass had lesions of the hemorrhagic disease. The 10 young of the year among the trapped specimens were exceptionally large, doubtless as a result of early birth combined with access to corn, cattails, and other excellent food. As of late January, 1944, the deepest ponds had about a foot and a half of water under the ice prior to a two-inch rain. One animal was noted to forage outside during the winter, and that was an occupant of one of the shallower ponds. In March, when conditions for reading signs were very good, at least two muskrats were living in each of two lodges on separate ponds, and two lone muskrats lived at other ponds.

The hay field ponds had a single breeding territory in 1944, but, presumably because of the lowered water levels of summer and fall, no muskrats were known to have remained until the 1944–45 fur season. With the disappearance of the original breeding adults of 1944, together with any offspring produced in that season, these ponds almost ceased to be occupied by muskrats for the period of our records. They were in good condition from the June rains of 1947 but without muskrats. A few drifters came in during the summer or fall of 1950, and three young (one male and two rather small females) were trapped in late November. There was a productive territory in 1952, but this was abandoned in late summer.

# Gully Near Keigley's Branch

During the years of study of Kiegley's Branch in Section 26, this gully had muskrat residents for the first time in 1943. It then had two places habitable for muskrats: a pool just below a culvert under U.S. highway 69 and a boggy area of about a half acre lying next to a corn field. The bog did have two territories, and the population was considered to have been quite self-contained up to the beginning of the trapping season of 1943-44. At my request, the trapping was done as annihilatively as possible, to give the fullest data on the population group. Two adult males, 2 adult females, 20 young males, and 13 young females were caught. The 33 young may be regarded as essentially "home grown." One of the adult females had 33 placental scars of four ages, and the birth date of the latest litter was assigned to early July; the other adult female had 29 placental scars of three ages, of which the latest litter was assigned to July. Thus, of 62 young conceived, it appeared that around 33 actually had been reared by the two isolated pairs. Not only did the bog have an excellent food supply in its natural cattail growths and the corn of the adjacent field, but the digging of the muskrats in deepening and enlarging their burrows also resulted in partial damming of the water trickling into the gully.

The fall population of 1944 turned out to be similar to that of 1943, but the spring and summer events of 1944 were by far the

more complex. Only one pair occupied the boggy part in spring and early summer of 1944, but there was a lone male at the pool. This latter had been captured uninjured while wandering in the Skunk River bottomlands, toe-clipped, and released on April 20 in a set of old burrows at the pool, and the burrows had been experimentally stocked with ear corn to induce this stranger to stay. Its distinctive tracks had been made out until late June at the site of release, within 100 yards of the naturally established pair of animals. Of 40 muskrats trapped annihilatively (as in 1943) from the bog during the fur season of 1944–45, 3 were adult males (not including the toe-clipped one), 2 were adult females, 24 were young males, 10 were young females, and 1 was a young of undetermined sex.

Where, presumably about midsummer, had the second adult female and the second and third adult males come from? The origin of the second adult female seemed traceable with fair satisfaction from one of two closely adjacent territories near the mouth of the gully. The evidence was that it had moved up the gully in midsummer. One of the adult females had conceived 21 young in three litters and the other, 33 young in four litters during the breeding season of 1944.

The last animal (a very fat young female) trapped in the boggy drain in early January, 1945, had lesions of the hemorrhagic disease suggesting that it was just becoming sick. One of a lot of 10 taken shortly before also had lesions.

The bog was drained naturally by a ditchlike erosion channel cutting through it in the early summer of 1945. The roadside pool, however, had some muskrats in subsequent years.

In May, 1947, a pair reoccupied the pool, but these adults and their offspring were evicted by the late summer drought, and this loss was uncompensated by any known establishment of a group of newcomers elsewhere along the two-mile observational stretch of Keigley's Branch.

In 1948, the pool was silted in, and the erosion channel through the bog cut down to about three feet below the surface. The pool regained its attraction for muskrats during the next few years, though apparently no more muskrats lived in it until the spring of 1955, when it became the site of a probable lone-animal territory.

The above territory continued to be maintained by what seemed to have been the same animal through September, 1955. By mid-October, more than one size of tracks could be made out in the marginal mud. By freeze-up the main burrow entrance had only a small puddle of surface water, and I was not sure that any muskrats remained in residence. Thus it looked all winter until February 20, 1956, when it could be seen that muskrats within the burrow were using ear corn for plugging material. At least two muskrats successfully wintered.

The pool was the site of a maintained territory in the spring of 1956, although one of the occupants had been killed by highway traffic

in early April. Flooding by a freshet in late May terminated the territory, for no further sign of occupancy was seen after the water receded. In 1957, a lone animal maintained a territory at the pool in early summer, then abandoned it. No further muskrat sign was observed here for the duration of the study.

# Drainage Ditch Lying South of Wall Lake

The observed mile and a half of ditch had the equivalent of eight breeding pairs of muskrats in 1940. The ditch became dry except for puddles, but, insofar as most of the muskrats continued to have access to some water and to an abundance of corn, I doubt that the residents suffered any important pre-trapping mortality. By October 19, the signs suggested considerable local massing in the best places, after abandonment of the burrow systems in the food-poor or the long-dry places. Between this date and the opening of the legal trapping season, November 10, illegal trapping so drastically reduced the ditch population that I obtained only 19 carcasses for examination: 4 adult males, 1 adult female, 8 young males, and 6 young females. If this ratio be applied to the breeding density of the summer and if it be assumed that little movement in or out of the observational stretch occurred during the summer and fall (though there was considerable adjustment from pool to pool), the late fall population would figure at about 130. This should not be out of line with the heavy local signs and the actual data from comparable situations analyzed elsewhere.

In the spring of 1941, the equivalent of nine breeding pairs occupied the observational stretch of drainage ditch. Later, the ditch was cleaned out and widened by dredging that cut through the burrow systems and heaped towering spoilbanks. Four of the nine territories were ruined, but five continued to show heavy use after the mud settled. The territories maintained despite the upheaval were all located in stretches of the ditch having burrows of long standing in hard clay soil and extending deep into the banks. The ditch also went largely dry, but it may be doubted that a lethal crisis resulted, as there was by late August about as much sign as might have been expected in the territories that were still functional. The pre-trapping sign suggested a population of perhaps 80, situated mainly along three-quarters of a mile of ditch where the muskrat habitat nearest corn fields best withstood the dredging.

Work on the mile-and-a-half stretch of ditch was discontinued after a breeding census in June, 1942. Only three breeding territories were then distinguished, and few other muskrats were using other places there. The ditch itself was then functioning with maximum efficiency for drainage purposes, with a steady shallow flow over the bottom and with pool-like waters in but three places, of which two were territorial sites.

Roadside ditch pools near the above drainage ditch also yielded data for 1940 and 1941. A breeding pair that established itself in one

of the shallower pools in May, 1940, raised many young, despite adjustments forced by drought and the presence of a big mink. None of 23 early-summer mink scats contained muskrat remains, nor did the prey debris littered in and about numerous mink holes in the road grade. In late June, most of the family group of muskrats took over some old burrows in a deeper pool about 200 yards from the original territorial site, but the latter continued to be frequented by some muskrats up to late August. By mid-December, good muskrat signs could be seen under the ice over the deeper roadside pool, but muskrats did not winter successfully at or near this place.

No territorial foci were recognized in the roadside ditches as late as May 19, 1941, though later field notes indicate that a pregnant female may have been in the process of settling at that time. Just when a male appeared at the roadside ditch is not clear, but there was a male around to father a second litter. By late August, before rains relieved the drought, all the roadside muskrats were living in the deeper pool, which, by then, was dry, too. No evidence was seen of summer mortality, and, by early November, good signs were visible at the above pool. After the trapping season opened on December 1, I was able to obtain data on seven trapped carcasses: an adult female (with nine placental scars representing two litters assigned to June and July) and 6 young of the year. As of December 6, when the trappers took up their traps, I estimated from fresh signs that at least three more muskrats remained alive.

The last entry in my notes concerning the muskrats in the roadside pool is of June 24, 1942, when signs of a territory and recently weaned young could be distinguished. Soon thereafter, the drainage of the roadside ditch was artifically improved and its attractiveness and habitability for muskrats lost.