

Chapter 11

Central Iowa Stream Areas and Outlying Waters; Ames-Gilbert Block

THERE ARE SEVERAL IMPORTANT WATERSHEDS in the area surrounding Ames and Gilbert; each demands careful and individual study.

SKUNK RIVER (AMES-GILBERT BLOCK)

No regular studies were made of the muskrats of a one-mile observational stretch of Skunk River lying east and southeast of Ames until 1934, but some data had been obtained incidental to horned owl studies on neighboring stretches in the spring of 1933. Substantial local predation by the owls then reflected vulnerability of muskrat occupants of two series of oxbow pools (Errington, Hamerstrom, and Hamerstrom, 1940, pp. 841-42). Of 88 owl pellets from late winter and early spring, one contained muskrat remains, but there were remains in 9 of 70 pellets dated from late spring to midsummer. The victims, with one exception, were young animals that evidently had been taken from a particular territorial site at a drying pool. These pools were marginal habitats at best and, as the water receded from the muddy banks, living routines of the muskrats became increasingly hazardous.

The 1934 data indicate nine breeding territories or about 20 adult muskrats along the one-mile stretch. Sufficient water remained over parts of the stream bed to protect the muskrat population from critical drought exposure. A carefully estimated total of about 60 entered the winter of 1934-35, under the legal protection of a closed trapping season. The animals were locally concentrated in their wintering quarters, and one such wintering group suffered some mortality. Of 80 scats of a single mink (a medium-sized one, probably a female), 74 consisted of muskrat remains. All of this material, which represented about three individual muskrats, was taken from a snowdrift latrine

used by the mink from about the middle of January to the middle of February, 1935. This mortality could have reflected either or both population tensions or dislocations caused by two winter floods. A third possibility is of an undetected focus of the hemorrhagic disease at the site of the greatest concentration of the muskrats.

In 1935, the figure arrived at for the stretch was eight territories, representing about 18 adults. By fall, muskrat signs were not only abundant along the main channel, but some muskrats also lived in wet oxbows to the side. The fur trapping was highly competitive and "dirty," with much thieving, and neither reliable information nor specimen material could be obtained from most of the trappers. The best pre-trapping estimate that I could make for 1935 was about 70.

In 1936, the stretch had six territories or about 15 adults, and the pre-trapping fall signs indicated a population of about 60. Again the muskrats were given legal protection from trapping, but this was only partly effective, as the use of water sets for other fur bearers was permitted. One trapper told of seeing about a dozen dead muskrats discarded beside a strategically located trap, and, while I did not see anything like this, I did see dead trapped muskrats.

Unusually satisfactory winter observations were made in mid-December, 1936, at which time under-ice signs were very heavy about certain burrow systems, and the animals appeared to be getting along well. Conditions for observations became more difficult as the winter progressed, but evidence that muskrats were wintering in fair numbers could still be made out in places, until the ice broke up in mid-February.

Nine breeding territories, or about 20 adults, were recorded for the spring and early summer of 1937. By late September, the dry weather had almost stopped the river's flow, but, because of the reduced evaporation in the cool weather of autumn, the slight flow increased and was well maintained through the winter. Prior to the trapping season of 1937-38, very abundant signs could be seen, and my estimate of the fall population was about 100.

Three territories were established in 1938, and there could hardly have been more than about 30 muskrats present by fall. Trappers took few if any muskrats from the stretch during the 1938-39 fur season.

In 1939, five breeding territories were established. The dry Indian summer reduced but did not quite stop the flow over the main stream bed. More important than drought in the upper 200 yards of the mile seemed to be pollution by calcium and magnesium carbonates from the city of Ames water softening plant. Very few muskrats remained in the polluted zone, though downstream the animals did not appear to be affected. My fall estimate for the observational stretch was about 70. Most of the muskrats wintered well under the protection of a closed trapping season.

Six breeding territories were recorded for the early summer of 1940, the last year of intensive studies. Water fluctuations were well

within the toleration limits of the muskrats, and many signs of free-living young could be seen by late June. The fall population was estimated at about 80.

A three-mile observational stretch of Skunk River south of Cambridge was put under observation in 1939. Breeding censuses gave an equivalent of 23 pairs, or probably more than 50 adults. Even when the weather was driest in 1939, the flow never completely stopped, and the deeper pools were always in excellent condition for muskrats and usually within easy raiding distance of corn fields. In September and early October, very heavy signs were localized about favored retreats. The population was then estimated at about 240.

Two separate 1939 breeding territories could be distinguished in a pool lying east of the river. By October 3, about half of the area of the pool had water over it, and lying at the edge of the water was a freshly dead subadult female. From field notes, I would now diagnose this as a victim of the hemorrhagic disease. By November 7, the pool had been dry for some time, though many muskrats still remained; the exposed burrows were plugged with corn, grass, mud, and debris. I doubt that any muskrats survived the winter here, whether because of drought exposure or disease or both.

The three-mile stretch had, by midsummer of 1940, the equivalent of 31 more or less successful breeding pairs. There was evidence of an early-season loss of perhaps five territories, which suggests an initial settled population that may have been about 80 adults. Environmental conditions were favorable — moderately fluctuating water levels and a superb food supply — and by early July the mud margins nearly everywhere along the stretch were tracked up by newly independent young. A family of great horned owls frequented the stream banks, but, of 14 pellets examined that had been deposited from mid-June into July, none contained muskrat remains.

The 59 carcasses examined from the three-mile stretch during the 1940–41 fur season were 4 adult males, 4 adult females, 28 young males, and 23 young females. The population equivalent of 31 pairs recorded as successfully breeding should have been about the number of adults present by fall. The sex and age ratios of the specimens applied to 31 females should give a pre-trapping population of about 450, or an average of 150 per mile.

The year 1940 was notable for a populous colony of brown or barn rats (*Rattus norvegicus*) centered about a crib of ear corn that had been stored near the river bank since 1938. The burrows of the rats riddled 225 yards of the bank nearest the corncrib, and the rat-dominated part of the stream was avoided by the muskrats. However, dominance by the rats may not have had much actual depressive influence on the muskrats, which simply withdrew across the stream to live in the opposite bank. In late summer and fall the concentration of barn rats dispersed away from the river bank. By early October, scarcely any rats remained there, and the muskrats were again using the formerly rat-infested bank of the river.

The 1940-41 trapping toll of muskrats was very moderate along the three-mile stretch, and the trapping ceased before the first of December, leaving about half of the fall population still alive. Trappers reported seeing many muskrats dead from unknown causes during the trapping. I was unable to obtain any specimens of these dead ones for examination. Now I am almost certain that they must have been victims of the hemorrhagic disease and, furthermore, suspect that the disease had had something to do with the loss of territories observed during the summer.

When spring came in 1941, astonishingly little evidence of living muskrats was found along the three miles, and the animals remained decidedly scarce — that is, compared with their 1939 and 1940 abundances — throughout the rest of 1941. I doubt that the breeding population was more than about 30 adults. Fall signs indicated fewer than 100 muskrats. Fifteen trapped specimens examined in December were an adult male, 2 adult females (which had conceived two early litters each), 4 young males, and 8 young females.

After 1941, observations on the muskrats of the Cambridge stretch of Skunk River were made only as they related to special problems.

In 1947, the three miles had only five territories (four of them with young by July) along the entire stretch. In this case, it was believed that some adult as well as young muskrats had been drowned or swept away by extremely high early-summer flood waters, which in places had covered the bottoms up to a mile or more from the channel. But, in addition, there are excellent grounds for suspecting that the fewness of muskrats was due in part to disease.

The three-mile stretch continued to have a flow at the height of the 1949 drought, and I was able to make especially good observations on the process of depopulation through an epizootic of the hemorrhagic disease. Pool-by-pool estimates in mid-October gave a total of about 180. Probably fewer than a dozen of these muskrats lived along the upper half mile of the three-mile stretch, although some favorable-looking pools adjacent to corn fields and some little-used or quite unused burrow systems could be seen there. The main population (an estimated 125) was concentrated along a strip of somewhat less than 1,000 yards extending a short distance into the middle mile; this population filled its habitat to near apparent capacity. Then, for almost the full two miles to the south end of the observational stretch, the total estimate amounted to only about 45, patently a remnant of what had been a much higher population earlier in the fall. Inspection downstream for a half mile south of the boundary of the observational stretch revealed similar evidences of depopulation.

The south two miles of the three-mile stretch were reworked when it became clear that something special was wrong. Of two diseased dead that I found, one was in *rigor mortis* at the edge of a pool and another (a slightly smelly one) had been caught on a branch overhanging a swift, deep riffle, there to hang out of convenient reach of the numerous scavenging raccoons. Decay-tainted air about an open

bank burrow presumably meant another dead one inside. Upstream from this site, a raccoon had just dug out part of a burrow. Still farther upstream about 600 yards, some fresh muskrat signs were visible, but most of the signs were only of recent origin — there were numerous unused holes and burrow systems, including two that had been dug into by raccoons. Downstream from the dead muskrats were several vacant or almost-vacant stretches of 300 yards or more in length, with lone or small groups of living muskrats between them. In three places in particular, most of the signs looked a month or more old, which afforded a minimum basis for judging the time of onset of the lethal epizootic — early to mid-September. Only one trail of an animal behaving like a transient was seen on the mud and sand of the stream bed in three days of field study.

SQUAW CREEK

Preliminary work along Squaw Creek in 1934 and 1935 was restricted to a seven-mile stretch, tracts A–E (Figure 10.2). As actual records of territorial sites were not obtained prior to 1936 for Tract F, the whole nine-mile stretch may be treated as a unit in the earlier years of the study only if prorata interpolations are made for 1934 and 1935 to supply equivalents for the missing data.

The figure thus calculated for 1934 was 30 territories for the nine miles, or a total of about 65 adults. The summer's drought was relieved before most of the muskrat-occupied pools went dry and, so far as I know, the Squaw Creek muskrats suffered little mortality because of the drought. They seemed generally to remain within their familiar home ranges, not engaging in much cross-country movement. Such adjustments as they made in response to partial drought exposure were made in gradual stages up and down the stream bed. The most extensive adjustments occurred in early fall, as animals spread away from crowded pools after the return of flowing water.

Estimates of the 1934 fall population for the nine miles totaled about 250. These muskrats had legal protection during the 1934–35 fur season, but a terrific winter emergency surely killed large numbers. While the creek was in a very high flood stage in late January, 1935, the temperature dropped to 19 below zero Fahrenheit officially (an unofficial reading gave nearly 30 degrees below zero), to leave few places habitable for muskrats. Two individuals living under heaped ice on shore and foraging on land were known to have survived the crisis, but nearly all of a population calculated at between 34 and 45 along a two-mile sample stretch evidently died. Fully two-thirds of the muskrats living along the nine-mile stretch must have been exposed to the flood waters and cold to a similar extent as those of the above sample stretch.

The prorated figure for 1935 was 29 territories or a total of about 65 adults for the nine miles. My best estimate of the population entering the fall was about 240, or somewhat fewer muskrats than in 1934, the much better environmental conditions of 1935 notwithstanding.

Shortage of signs in some of the more attractive places for muskrats aroused suspicions of local disease losses, but evidence of considerable movement up brooks and small creeks was also noted in late summer and early fall.

In 1936, the nine-mile stretch had fifteen territories or about 35 adults, and late-fall estimates totaled about 120 animals. The surface water disappeared in all except the most nearly permanent pools. A rain of over four inches in early September broke the drought, but did not do much more on Squaw Creek than to fill the stream-bed pools and start a slight flow. More rains came in mid-September and later in that month. Unquestionably the Squaw Creek losses had been severe during the summer, and they did not cease with termination of the drought. I saw one partly hairless animal for the first time on September 4 (at an estimated age of between 40 and 50 days), and am sure that it was afflicted by a fungus like the *Trichophyton mentagrophytes* with which I had much experience at Round Lake (Chapter 5 and Errington, 1942b); the presence of such a lethal and contagious skin disease of young muskrats could hardly have meant other than mortality. On September 13, a dead suckling female was found with lesions that were almost certainly those of the then-unrecognized hemorrhagic disease.

A closed trapping season on muskrats seemed to give the species fairly effective protection on Squaw Creek, despite legal water-trapping of minks and raccoons. Only one muskrat was noted habitually to engage in outside activities during the winter of 1936-37, and it appeared to have died in early February.

Twenty-two territories, representing about 50 adults, were recorded in 1937 for the nine miles. The fall drought crisis was accompanied by much population adjustment. By then, the muskrats were sufficiently reduced so that they or their signs did not occur abundantly just anywhere, but along Squaw Creek they were abandoning untenable retreats, trying to establish new quarters under difficult conditions, being caught in exposed places by cold weather, and engaging in a certain amount of desperate wandering. Their increasing vulnerability was reflected by their remains in 5 of 95 mink scats. Each representation was of a different victim (one adult and four young), taken as drought exposure became locally acute. The predation followed a definite pattern, and an observer could virtually predict when the minks would start killing muskrats at a given pool — as the last surface water in the burrow entrances dried up. Because of the severity of the drought, probably no more than 20 muskrats were alive on tracts A-E by the opening of the trapping season on November 10; Tract F, with considerably more water, had about 30.

Fur trapping completed the annihilation of muskrats along a five-mile stretch in tracts B-E; and the total catch here, according to the trapper, was 10. Seven of the 10 (including 2 living in holes in dry ground) were caught from the vicinity of one pool. A lone muskrat

was known to have lived from midfall to late November in dry lodges erected in a corn field, to disappear after the weather turned cold. Farther downstream in Tract A, another lone muskrat came out at intervals all winter to forage on bank vegetation; and one of two animals behaving in a similar way still farther downstream was illegally shot by a hunter in mid-January, 1938.

My estimate was that between five and eight muskrats wintered in 1937-38 on the whole stretch of Squaw Creek represented by tracts A-E, and these were all in Tract A. Upstream in Tract F, neither drought nor trapping on drought-exposed and drought-concentrated remnants had such serious effects, and I think it probable that nearly all of that tract's muskrats entering the winter survived until spring.

The 1938 spring population was about 30 adults, maintaining 13 territories. Animals resettling the depopulated five-mile stretch in tracts B-E invariably established themselves in what had been the last-occupied pools of the preceding summer and fall, despite generally favorable water conditions in the whole area. Considerable evidence was seen of late summer and fall movements within the ordinary cruising radii of the resident muskrats, or up to 200 to 300 yards away from the territorial burrows. Up to the middle of September, several long stretches remained unoccupied by muskrats, but by late October enough muskrats gradually came into the vacancies so that there were no great differences in local populations anywhere along the observed nine miles of stream. The muskrats seemed comfortably situated throughout this time, and no remains of the species were found in 126 mink scats. Some animals (mostly if not all subadults) appeared in outlying waters.

Fur trapping during the 1938-39 season nearly annihilated the muskrats along most of the nine-mile stretch. Forty-seven carcasses or skins representing most of the population of tracts B-D were examined: 4 adult males, 6 adult females, 14 young males, 15 young females, and 8 young of undetermined sex. Muskrats were believed to have survived the trapping at only five places in tracts B-D, probably one or two in each place, from which a pre-trapping figure of about 55 may be estimated for B-D, not counting occupants of outlying waters. This figure, applying to five miles of stream and seven or slightly more than half of the territorial sites, might be assumed to comprise slightly more than half of the fall population of the nine-mile stretch. If the population data obtained from tracts B-D were prorated to tracts A, E, and F, the total would be about 100 for the nine miles. However, in view of a late September drift into tracts A and F, which had few breeding muskrats in spring and summer, the actual fall population was probably higher than the prorated figure or possibly about 130.

The nine-mile stretch had 21 territories, or about 50 adults, in 1939. No extensive crisis appeared to develop along either the channel or the outlying waters during the spring and summer months. None of dozens of horned owl pellets examined in bulk in late April, and

none of 140 mink scats for June and July contained muskrat remains. In August and September, typical adjustments occurred up and down the increasingly exposed stream bed. Beginning about the last of September, conspicuous mortality of muskrats was observed on the highways. Four of 22 early-winter mink scats contained muskrat remains (of two individuals, an adult and a "kit"), compared with no representations of this prey in 22 scats deposited in the Squaw Creek area from September to November.

The muskrats of Tract F were less affected by drought than the muskrats of the downstream tracts. Early-winter estimates for the nine miles totaled about 50, of which about 20 were resident in Tract F. From consideration of the field notes, I would say that the Squaw Creek animals entering the winter of 1939-40 got along henceforth with little mortality, but also without much comfort, under the wintering conditions prevailing. For the duration of a snowless early period, or up to about the middle of January, many occupants of the frozen-over stream pools had no access to vegetation under the ice except for such roots as they could still reach. Their main diet was of animal matter, bullheads and other fishes, as well as frogs, that they preyed upon much as did the minks. They also fed upon the dry grass and other vegetation that they had stored or used as linings in their burrow chambers. In warmer weather, they would come out to forage amid the dry weed stalks and scattered green plants on the banks.

In 1940, the nine miles of stream had 22 territories, plus another in a shallow oxbow close by. Territorial adjustments continued into late May and early June. It is probably significant that the best evidence of late territorial adjustment was seen in the most densely populated stretch of the creek — in a two-thirds of a mile having 4 territories. On May 17, two muskrats considered to be a mated pair were actually watched (or trailed) while they worked upstream some 700 yards; as I watched, one of the animals started carrying vegetation to a retreat under a bank, and this place shortly afterward had the appearance of an established territory.

The productivity of the Squaw Creek muskrats was poor in 1940. I am not at all sure that environmental extremes provide a full explanation, but there were extremes. The creek was dry except for scattered pools by the last week of July, and this seemed effectually to inhibit reproduction. Field signs indicated that nearly all of the young successfully reared had been born in April, May, and early June. Of 20 trapped carcasses taken from the main channel during the 1940-41 fur season, 6 were adult males, 4 were adult females, and there were 5 each of young males and young females. Two of the adult females had conceived two early litters each in 1940, and 2 had conceived three litters each. One of the three-litter females had conceived two early litters, and a late one assigned to late August or early September doubtless had been conceived soon after the breaking of the drought in late July.

I question whether mortality resulting from the drought was im-

portant, but the violence of floods in August imposed upon the muskrats a variety of troubles. Responses of the muskrats to flood emergencies were then carefully studied both during and after the periods of high water. Appearance of animals in odd places following subsidence of the water may indicate that these were not swept away bodily so much as that they were forced outside of their radii of familiarity and simply got started wandering, often in the direction of some of the outlying waters referred to later in this chapter. For example, a corn field lying between Squaw Creek and the outlying Rainbolt Ponds had footloose muskrats ranging throughout it, and several (at least six) of the flood-evicted wanderers moved into one of the ponds to live for the rest of the summer and fall until the 1940-41 trapping. At least two more moved into the little Hutchinson's Lake, and above it York Pond drew a few animals, but these latter left before freeze-up. The pool at the head of the county line ditch in Tract E had at least one muskrat.

In taking care of themselves during the peaks of the August floods, adult and subadult muskrats seemed able to swim wherever they needed to go, to improvise nests, and to sit around with some safety on logs, stumps, and drift. On the other hand, the young less than two and a half months of age were probably under such a handicap that many of them drowned. Two family groups of young were watched during flood crises from distances of a few feet. These were members of a litter of about eight weeks on August 13, and of a litter of about seven weeks on August 17. Both litters had about run out of alternatives, as the water was closing over the tops of the banks and the upper openings of their burrows in which they were lying with heads out.

Among the imperfectly appraisable consequences of the August floods were the changing of stream channels of Squaw Creek, the cutting through of meanders and silting in of oxbows and eddies and, possibly as significant for the muskrats as any one thing, the general scouring of herbaceous vegetation away from the banks or from near the banks. When the waters went down, the stream channel and its immediate vicinity were singularly short of muskrat food. This may have induced footloose movements or local readjustments as much as eviction by rising waters.

Even so, practically all of the places occupied by muskrats prior to the floods continued to be occupied afterward. Young animals lived along with adults, though an unusually high proportion of adults in the remaining population was evident from track signs before it was verified by a 50-50 ratio in the trapped carcasses. There is no reason to think that the adult muskrats of Squaw Creek suffered more than trivial losses between spring and fall, and the ratios for the trapped carcasses applied to a breeding density the equivalent of 23 pairs (including the occupants of the shallow oxbow lying near the creek) would give a total of about 115 as the pre-trapping population for the nine-mile stretch.

The latter figure is probably close to the truth, but many of the Squaw Creek young established themselves elsewhere in the outlying waters. It is also extremely likely that considerable numbers of the Squaw Creek young found satisfactory refuge downstream along Skunk River southeast of Ames, where water fluctuations were comparatively moderate.

No muskrat remains were found in 121 mink scats deposited along Squaw Creek from May through July, 1940, though mink signs (of at least one locally reared litter) were very heavy about the drying pools. Remains of a subadult muskrat dating back to the time of one of the floods were found in 2 of 26 mink scats deposited from late August to October. Other predation upon muskrats was suspected, particularly while the marooning of a variety of terrestrial animals — grasshoppers, mice, rabbits, and even a big house cat — on stumps, fence posts, and like refuges attracted avian predators to the bottomlands. On August 17, a Swainson's hawk (*Buteo swainsoni*) circled about 35 yards overhead while I wrote in my notes of a muskrat sitting in a patch of flooded weeds.

Despite frequently observed outside activity along the water-scoured banks of Squaw Creek during the winter of 1940-41, a good proportion of the survivors of the trapping season also survived the winter. Plenty of evidence of dispersing muskrats was seen in late March, but the dispersal signs really became heavy about the second week of April, 1941. Muskrats were indeed so conspicuously in circulation in mid-April that I made a special effort to determine whether they were being preyed upon by the resident horned owls. No muskrat remains were found in 99 owl pellets for April and May, nor in 213 dated back from March into the winter.

The 28 territories of 1941 were close together in places and far apart in others. As contrasts, Tract D had a lone territory and Tract B had five territories concentrated in its lower half. According to the 1940-41 sex ratios, there should have been about 70 adults for the 28 breeding territories along the main channel of the nine-mile stretch of Squaw Creek.

The 1941 productivity of the above stretch is hard to appraise. Floods occurred three times during June and July and, as of early August, water levels were still moderately high. Muskrat signs, where mud margins were present to take them, were spotty, concentrated in places, lacking in others and generally less than expected. Considerable fluctuation in water levels also occurred in August and September. My suspicion was that substantial, though then undetected, disease losses might have depopulated certain territories or groups of territories, as had happened along the Skunk River stretch south of Cambridge. Checkups in August and September indicated that the principal losses had taken place in Tract F, where there were muskrat-vacant stretches corresponding to four territories.

Seventeen trapped carcasses were obtained in December, 1941, from Squaw Creek: 4 adult males, 3 adult females, 5 young males, and 5

young females. Though small, this series should be fairly representative of a population sample from the main stream, if allowance be made for some late-summer and early-fall movement into such places as the county line ditch. Allowing for the loss of four of the 28 main-stream territories between the breeding census and the trapping season, there should have been about 24 adult females left to use as a base for calculations. Application of the sex and age ratios of the trapped carcasses to this base would give a total of about 135 muskrats for the nine miles in late fall.

The 1941 placental scars of the three adult females examined from Squaw Creek were all of early or mid-season litters: two litters for each of two females and three litters for the third. The fall ratio of 10 young per three adult females may not be thought to reflect actual breeding success; but, even if it be assumed that as many of the young reared by these females established themselves safely in side streams and similar places as remained in their natal ranges, the net reproductive success would not be much more than a third of the number of young conceived.

Difficult trapping conditions, 1941–42, left an unusually large proportion of the Squaw Creek muskrats to winter. Field notes refer to outside activities by a few individuals, including some possibly showing early pre-dispersal restlessness. By mid-March, 1942, muskrats were appearing literally everywhere along Squaw Creek and its tributaries. A week later, however, the heaviest signs were being laid down along stretches of stream known to have wintered substantial populations of muskrats. Among these particular animals, dispersal, so far, seemed to be manifested more by increasing local activity than by footloose movements. Neither 18 horned owl pellets nor 19 mink scats, deposited contemporaneously in areas where muskrats were active, contained muskrat remains. A raccoon grappled and killed a very large old male muskrat on the creek bank in late May.

Heavy rainfall in 1942 considerably expanded the habitats available to muskrats in outlying waters of tracts D–F. At the same time, the stream channel became less attractive, partly through obliteration of old burrow systems by repeated floods. The June and July floods themselves were destructive to young muskrats of helpless sizes. Another flood in mid-September probably came too late to have lethal significance for the species.

Fifty-six carcasses of stream-dwelling muskrats were examined for the fur season of 1942–43: 6 adult males, 5 adult females, 25 young males, 19 young females, and 1 young of undetermined sex. The uteri of 4 of the adult females were in suitable condition for examination; and, of these, one had not conceived in 1942, one had conceived 23 young in three litters (including two litters of late summer), one had conceived 27 young in three litters (including one litter early in the breeding season and the other two rather late), and one had conceived 35 young in four litters (including two litters in late summer). Six of

the 45 young of the year in the trapped sample were classed as August, if not early September, "kits."

Other than the old male killed by the raccoon in May, no losses of adults were noted for the stream-dwelling muskrats of tracts A-F for the summer of 1942, and it is felt that any losses of adults that did occur were negligible. Application of the ratios of the trapped carcasses to 24 adult females would give a total of about 265 for the pre-trapping fall population of the nine-mile stretch of creek, exclusive of the animals of outlying waters.

Considerable activity on land was noted about the Squaw Creek drainage during the winter of 1942-43. Although not all of this activity was restricted to the vicinity of the channel, it will be taken up here for the sake of convenience. One animal fed on potato peels near a house instead of engaging in the usual foraging in corn fields. Two commuters across a barren pasture separating two brooks were an old female (with 28 placental scars in three litters assigned to spring and early summer, 1942) and a young animal of undetermined sex. Some, with or without apparent reason, came out in places where living conditions were judged to vary from excellent to poor. A lone individual lived in a tile flow and raided a corn field daily from December 8, 1942, to February 1, 1943, when it was collected for a specimen. It was a young male, in fair flesh, though a trap cripple with a frozen tail.

Both minks and muskrats were as abundant in central Iowa at the end of the 1942-43 trapping season as they ever were during our intensive investigations. In the Squaw Creek valley, mink predation upon wintering muskrats was light and centered almost entirely upon individuals living at a disadvantage. Two of 21 mink scats for December, January, and early February contained muskrat remains, and those two were among six scats deposited during a flood. Of two mink victims found, one had been killed at the time of the flood.

About February 20, 1943, following springlike weather, muskrats began moving overland — clearly earlier than might have been anticipated from data obtained in other years. At least some mating took place during this period, which was also remarkably early for the north central region. Cold weather in March terminated most land activity but, with each successive thaw, muskrats came out again. Dispersing muskrats finding themselves in strange environments when the weather turned cold behaved like ordinary winter wanderers and lived where they could, in culverts and open tiles, in cavities under tree roots, in snowdrifts and lodged debris along streams, and in miscellaneous land holes. Of 13 specimens of March transients examined, 10 were sexually mature males, 2 were unbred females, and 1 female was of undetermined sexual status. Only two of the 13 specimens had strife wounds and those two were males examined late in the month — by which time signs were visible in practically all places in Squaw Creek valley where muskrats would be likely to visit. Three spring

mink victims were found along the nine-mile stretch, and there were muskrat remains in 14 of 40 mink scats deposited from late February to the middle of March, 1943, as well as in 5 of 11 scats deposited in the second half of March.

By early and mid-April, little activity of transient muskrats was seen, though most habitats were well filled with muskrats that seemed to have established themselves in regular residence. The single April specimen of a transient was an unbred, strife-torn, old female. This lack of activity on land, together with absence of muskrat remains in 10 April mink scats, may suggest that the local transients had been, in effect, eliminated. The settled muskrats acted as if they were unusually content, individually, their existing high densities in relation to specific habitats, notwithstanding.

The main channel of the nine-mile stretch had 34 territories in 1943 or, following the 1942 fall sex ratios, about 80 adults. Territories were distributed with some irregularity, Tract F having, for example, a muskrat-vacant stretch of about three-fourths of a mile, yet with eight territories in another stretch of a mile. Insofar as the fortunes of the channel muskrats for 1943 in particular were closely interlinked with those of muskrats in the outlying territories of tracts A-F, some preliminary mention may be made at this point of the outlying territories. The 17 territories recorded for the outlying waters brought the total of territories for tracts A-F up to 51.

Population adjustments occurred on a substantial scale throughout the Squaw Creek drainage during late summer and fall. Muskrats appeared to establish quarters in many places that had had no breeding territories during spring and early summer. No traffic victims were noted in this locality, and the evidence suggests that the adjusting movements had taken place in easy stages along streams or other inviting routes.

Sex and age ratios for 90 muskrats trapped during the 1943-44 fur season from the nine miles of Squaw Creek were 9 adult males, 8 adult females, 38 young males, and 35 young females. Seventy-six trapped from outlying waters were 5 adult males, 7 adult females, 38 young males, and 26 young females. The 14 adult females having countable placental scars in the combined sample had conceived a mean of 3.2 litters.

Application of the ratios from the trapped carcasses to the spring density of 34 channel territories without correction for possible losses of adult females during or after the breeding season would give a pre-trapping fall population of about 380. For the 16 territories of the outlying waters that remained functional, there would be a pre-trapping population of about 175, or a total of about 555 for tracts A-F. One of the outlying females was known to have been killed by a dog during the breeding season, and her suckling litter surely died after her. One of the adult females from the channel and two of the young from outlying waters were diseased, and it may be assumed that there had been some other (though probably not much) reduction in

late fall through this agency. Possibly the truth might be more nearly approached by reducing the fall figure for the nine miles of channel to about 370, and the figure for the outlying waters to about 160, or the total for the observed parts to about 530.

Late-born young had an obviously poor survival in 1943 in both channel and outlying habitats. All of the adult females trapped from the channel and 3 of the 7 from the outlying waters had conceived litters datable to July or later, whereas only three of 137 young of the year were late-born. Such losses of the late-born were rather expected. Not only were breeding populations sufficiently high to make density-depression of late-season rates of gain probable, but a flood of sufficient magnitude to drown many helpless young also occurred in late July and early August.

Trapping pressures were quite severe on tracts A-F during the 1943-44 fur season. The muskrats escaping seemed to be, with one exception, comfortably situated. The exception was a big animal engaging in outside activities throughout the winter. None of 60 early to midwinter mink scats contained muskrat remains.

The amount of movement observed at different periods of the spring dispersal of 1944 varied with the tract in the Squaw Creek drainage. One brook joining Squaw Creek in Tract C had heavy general signs along a previously unoccupied stretch in late March, and many muskrats were appearing in other out-of-the-way places and being killed by motor traffic on the highways; yet, along some stretches of the main channel and tributary streams, little movement occurred. During the first three weeks of April the dispersal spent its momentum until, by the end of that time, the muskrats were occupying as much of the Squaw Creek drainage as they were going to occupy in 1944. The main channel had 33 territories or about 75 adults, and the outlying waters had 12 territories, so tracts A-F had a total of 45 territories and about 100 adults.

Squaw Creek flooded sufficiently in May and June to drown most of the young muskrats born before the middle of June. Adults were seemingly little affected by the floods, and signs showed that they usually remained in their established territories or returned to them as soon as subsidence of the water permitted. They gave birth to many late litters that compensated at least in part for the loss of their earlier ones.

Movements of muskrats became increasingly apparent in tracts A-F as the summer of 1944 progressed. As early as July 18, an animal was known to have traveled along a small side creek in Tract C. Another small creek, this one in Tract F, had a heavy drift of muskrats in early August; but this creek had no established territories during the summer, and all newcomers went on through. A considerable cross-country movement occurred between mid-September and early October, accompanied by mortality from motor traffic. Some of this may be ascribed to the drying of outlying waters, but much remains inexplicable on ordinary grounds.

Eighty muskrats trapped during the 1944-45 fur season from these tracts consisted of 8 adult males, 7 adult females, 33 young males, 31 young females, and 1 young of undetermined sex. For calculating the 1944 fall densities, these ratios were not applicable to the spring census figures without some correction for adult losses in spring and summer. On May 10, a small dog was watched doing an efficient job of eating an adult male muskrat that it presumably had killed on land south of Tract A. Both members of a pair living along a brook in Tract E died from hemorrhagic disease in late June. That the hemorrhagic disease probably killed considerable numbers of muskrats elsewhere in the Squaw Creek drainage is indicated by midfall notes relating to 3 dead within a quarter-mile radius in Tract F, and by what had the aspects of a fall and winter epizootic at some field ponds just outside of Tract C. Abandonment of territories in late summer and fall must also be considered, but I do not think that this greatly reduced the local population of adult females.

The best I can do is figure a loss of six territories for the nine miles of channel, which would leave 27 adult females still in residence to which to apply the carcass ratios. This would give a total fall population of about 310 for the channel habitats. Few of the 12 original territories of the outlying waters were being well maintained by the resident muskrats by fall, so reliance must be placed upon a group-by-group estimate totaling about 120 muskrats. This would bring the population for tracts A-F up to about 430, as of late October or early November.

Up to half, or maybe even two-thirds, of the channel muskrats were believed to have survived the 1944-45 fur trapping. Some betrayed restlessness through their outside activities during the winter. One animal was noted foraging in a field of winter wheat from late December through most of January. Another foraged far out in a field of shocked corn from late December until the creek flooded on February 15. Both returned to regularly-used retreats under the ice after each trip.

Some others, known to have come out only once during the winter and then without visible incentive, are now suspected of having been sick. The role of the hemorrhagic disease in the wintering fortunes of the muskrats of the Squaw Creek drainage is not as demonstrable as might be wished, yet the fragmentary data suggest that the disease may have been quite generally distributed.

In the spring of 1945, tracts A-F had 23 channel territories and 8 outlying territories. Following the 1944-45 sex ratios for the animals taken by trappers, a total of 31 maintained territories would mean a total of about 65 adults. Trappers generally were disappointed in their muskrat catches for the 1945-46 fur season, which reflected a very spotty distribution of the population present by early November.

Of 69 trapped carcasses, 6 were adult males, 5 were adult females, and there were 29 each of young males and young females. Three of the 5 adult females had conceived three litters each in 1945, and the

other 2 had conceived four litters each; but only 2 of the 5 adult females had conceived litters judged to have been born as late as late July, and no "kits" or young assigned to August or later were found in the sample of 58 young of the year handled. Of the 69-carass sample, one lot of 14 came from the site of an outlying territory, and the single pair and associated young in this lot gave essentially the same age ratio as that of the entire sample from tracts A-F. The above ratios contributed valuable information, but they must be applied with much discrimination if they are to be used in calculating the fall population after a summer and fall of such ecological complexity as that of 1945.

Except for a very local cloudburst on August 4, which flooded Squaw Creek but not other observed streams in central Iowa, and a near-flood on August 14, the late-summer and early-fall period was dry. Light to moderate drought conditions were relieved by rains on September 27, after which the stream flows of the area never quite ceased before rains came in November. The shallower field ponds and oxbows went dry, generally to be abandoned, at least in part, by whatever muskrats were living in them.

I doubt that much actual mortality of muskrats in tracts A-F should be charged to drought. The drought was accompanied by some notable reorientation up and down the stream channel, but the greatest decline was observed at times when the animals had no visible incentives for leaving their regular home ranges. The main cross-country drift began about the first week of August; and, through October, it was manifested by highway victims in out-of-the-way places. Muskrats also appeared in August in outlying waters while the streams were in good condition.

Observations along Squaw Creek suggest that hemorrhagic disease may have cut down the 1945 population to a substantial extent, beginning about the middle of October. A single probable victim (subadult female) was found in late October on Tract A, and the signs of living animals were recorded as good in only two places along the entire tract — indicative of about 15 to 20 muskrats occupying the sites of five breeding territories. Another diseased subadult female was caught by a trapper in November from Tract E or F. A large adult in mummified condition, found in June, 1945, in that part of Tract F where muskrats had died of disease in the fall of 1944, presumably had been a late-spring victim of the contagion. A decline similar to that mentioned for Tract A also occurred in tracts B-D, from which I judged that only some five or six of the original breeding territories of tracts A-D retained their family groups until the trapping. The over-all sex and age ratios from the trapped carcasses applied to five or six territories in tracts A-D should give these tracts a pre-trapping population of around 70 to 85, probably nearer the former figure. For the main channel of Tract E and sections 1 and 36 of Tract F, the known trappers' catches of 21 are believed to reflect a pre-trapping population of about 45, or the equivalent of three family groups re-

maining. Tract E included the best-populated part of the nine-mile stretch of Squaw Creek. For Section 35 of Tract F (the site of an observed focus of infection of hemorrhagic disease), the decline is believed to have been still greater for the three main channel and the four outlying territories involved. There could hardly have been more than 25 muskrats resident in all of Section 35 by November. Trappers' catches of 15 in Section 35 were largely from the channel, for the outlying ponds were more or less dried up. Pre-trapping calculations and estimates for the nine miles of Squaw Creek channel totaled about 140, to which may be added a figure of about 20 for outlying waters, thus adding up to a fall population of about 160 for tracts A-F in 1945.

Only one Squaw Creek muskrat was noted to be engaging in outside activities during the winter of 1945-46 — that was on December 21 and in the vicinity of the focus of infection of the hemorrhagic disease in Section 35 of Tract F. Near this same place, a muskrat was eaten by a horned owl in early January, which victim may be suspected of having been a land-active, diseased one or one forced out by a flood in early January. Other floods in early February and early March resulted in no known crises among the local muskrats. The best-populated stretch of stream in Tract E had good signs of resident animals in five places on the first of March before any known dispersal from wintering quarters occurred.

The 1946 breeding population of tracts A-F consisted of the occupants of 26 channel territories and 12 outlying territories. Following the 1945-46 sex ratios, this would amount to about 75 adults in the total of 38 territories. The fortunes of the muskrats were followed with particular thoroughness during the breeding months by Sprugel (1951) and myself.

By early August, only one of the 26 channel territories showed disuse without evidence of re-establishment nearby. This one territory was close to the place where a probable disease victim had been found during the previous fall, and its occupants may be presumed to have died. One of the outlying territories was also suspected of having lost muskrats from disease. Two other outlying territories were gradually abandoned as their occupants extended their home ranges to the adjacent creek channel. Much reorientation took place during the second and third weeks of September, though plenty of water remained over the creek bed. By late September, muskrats were massing so much in some stretches and deserting others that no semblance of population stability remained in these places. Some of the most attractive habitats had no muskrats, whereas, for inapparent reasons, muskrats congregated in some places having nothing special to offer them. The rather food-poor habitat of Section 35 in Tract F had the heaviest signs that I ever saw there in late September and early October. But the greater proportion of the massed Section 35 population had departed by the opening of the trapping season on November 10.

In attempting to judge what was different about the late-season behavior of the muskrats for this year, it should be remembered that the

over-all population densities for tracts A-F were not top-heavy in terms of densities tolerated in some other years. Neither were the restless animals confronted by environmental or weather crises of the sorts that might be expected to start them moving on such a scale and in so footloose a manner. A big cross-country movement was about over by mid-October, though a few animals were still in circulation after freeze-up.

Forty trapped carcasses were examined in November, 1946: 3 adult males, 4 adult females, 17 young males, and 16 young females. Of the adult females, one had conceived two litters fairly early in the breeding season; 2 had conceived three litters each, early to mid-season; and the fourth had conceived four litters, two early and two late, including one assigned to August. Field observations on the early fall movements suggested that entire local groups as well as all manner of individuals were participating, so the sex and age composition of the departing animals and those remaining behind may have been similar. The ratios from the trappers' catch were therefore probably representative of the fall population, and the chief problem in calculating numerical values for the fall population would seem to be one of obtaining a base to which to apply the ratios.

From close study of the data from the different tracts, I could be reasonably sure of the net loss of the equivalent of only five family groups along the main channel (three of them in Tract D) and of four other family groups of outlying waters (two in each of tracts D-E). The ratios from the trapped carcasses applied to 21 of the original 26 pairs of adults judged to have been present by fall along the main channel of the nine-mile stretch would give a 1946 fall figure of about 210. For the outlying waters, six of the original breeding territories were still maintained by late fall and, of these six, four territories retained essentially full family groups. The fall population for the latter four territories figured out at about 40. To these should be added the muskrats living in two partly depopulated territories, which had something like a total of 15, as of the beginning of the fur trapping. The late fall population of the outlying waters should then have been about 55, which would bring the total for tracts A-F up to about 265.

In 1947, the nine miles of channel had twenty-three territories and the outlying waters had four. The total adult population of muskrats for tracts A-F figured out at about 2 per territory for twenty-six territories, and a lone female for the other territory. The area's muskrats betrayed a remarkable intraspecific intolerance and restlessness during the period of spring dispersal and settling of 1947. In tracts E-F, alone, three of the channel territories were known to have been moved distances of 100 to 400 yards between initial settling and midsummer. In tracts B-C, the territories, while not crowded in the usual sense, were still rather uniformly distributed at close to quarter-mile intervals; and changes in territorial headquarters would have put their occupants nearer to their neighbors than they evidently wished to

live. In contrast, the animals changing territories in tracts E-F were able to do so and still remain at least a quarter mile from the territorial headquarters of their nearest neighbors.

The June floods came too late to endanger seriously the earliest-born young, but they surely killed many young of helpless sizes along Squaw Creek. In some cases, the adults saved their young by placing them in improvised nests above the water, as on a protruding stump or at the edge of a steep bank. In July and August, the tracks of recognizably young animals ran to two extremes—either large or small—with few of intermediate sizes. The loss of a pregnant female was recorded in early July, but it was too decayed to show cause of death.

As dry weather continued through the late summer and fall of 1947, the creek flow ceased by mid-September. Some heavy rains fell (2.21 inches on September 11–12), but the dry bottom quickly absorbed the little water that flowed, until a fair flow was restored by several inches of rain in late October (2.03 inches on October 23–24, 1.18 inches on October 26–27, and 1.88 inches on October 31).

The muskrats were very unevenly distributed along the channel by early November. The heaviest signs were in Tract F, but most of the muskrats here disappeared by late November. Downstream were many stretches that were almost muskrat-vacant by late October, including nearly a mile in Tract E, both upstream and downstream from the site where the dead pregnant female had been found in July. Tract B, which originally had what came nearest to being a concentration of breeding animals, had an early October population of about 35, mostly living at four territorial sites.

Extensive adjustments—which were all but characterized by preliminary commuting of animals making changes in a careful manner—were of the nature of upstream and downstream movements, largely confined to the beds of watercourses, and almost no evidence of cross-country wandering was detected. A “kit” of about 80 days, captured in the city of Ames on September 24, was the sole wanderer personally seen alive or dead about central Iowa stream habitats during the entire fall. Some rather pronounced short-range movements from the stream channel to outlying waters occurred, however, in late fall. The outlying waters of tracts E-F, which were drying rapidly by late August and early September, had only an estimated 4 muskrats (in one roadside pool) by late September. By early winter, 1947–48, they had about 40, or all of the muskrats then remaining in the outlying waters of the Squaw Creek observational area. The channel population was estimated, pool-by-pool, at about 135, which would add up to a total of about 175 for tracts A-F.

Illegal trapping (the trapping season was closed) could have accounted for some of the reduction of muskrats occurring in late fall, and the hemorrhagic disease was surely operative to some extent, especially in Tract E. Considerable winter activity, 1947–48, was noted in tracts E-F, sooner or later to be followed by mortality. The best-

situated muskrats were the occupants of an outlying brook adjacent to a corn field. Even so, a young female caught at the brook in someone's mink trap in early winter was in lean condition. The water was so low over the channel of Squaw Creek that only one place (in Tract F) had an obviously substantial population of wintering muskrats. A subadult male, in fair flesh, was found on the ice, partly eaten by a predator or scavenger.

The spring dispersal of 1948 was manifested, in late March, by large numbers of highway victims and by the appearance of newcomers in long-unoccupied outlying waters; these movements occurred on a pronounced scale until early May. The nine miles of channel had 35 territories, of which 13 were massed in Tract F. This massing of territories seemed to reflect the local wintering concentration, whereas I suspect that tracts A-B, with six territories each, were so well populated partly because they were convenient for settling by animals working upstream. Much more unevenness in distribution of the breeding territories could be seen in 1948 than in 1947. Ten of the 1948 territories were grouped in five sets of twos closer together than 200 yards, and there were six places where distances of about a half mile separated neighboring territories. Outlying waters had five territories.

By October, 1948, when the water of the Squaw Creek channel was confined to pools and puddles, there were considerable signs of local adjustments, but very few muskrats were being killed on central Iowa highways, or, for that matter, even moving on the exposed creek bottom between widely separated water holes. Midfall estimates totaled about 150 for the channel and a half dozen more for an outlying brook. As the fall progressed, tendencies toward further local adjustment without known mortality or departure from the observed stretch of creek were noted.

None of 13 October mink scats from Tract F contained muskrat remains.

Apart from suspected illegal trapping, the muskrats of the observational area were subject to but limited effective trapping during the 1948-49 fur season. The two trapped carcasses examined were of a young male and an adult female having 22 placental scars representing three litters conceived early in the 1948 breeding season.

In 1949, the channel had 42 territories, and the outlying waters had only one. These territories were very irregularly distributed with reference to each other. Despite the semblance of uniformity implied by tracts A and B each having seven territories and Tract C having six, four of the territories in Tract A were distributed along less than a quarter-mile stretch, and tracts B and C had three stretches of less than 300 yards along each of which were groups of three territories. There were, in tracts A-E, five stretches of about a half mile having no territories. Tract F, which had had the heaviest wintering population, had 13 territories in the spring.

The Squaw Creek breeding population, together with its season's young, underwent a great decline during the summer and fall of 1949.

Little cross-country movement was detected in central Iowa, even when the drought was most intense, but movements up and down the stream beds occurred as pools dried up. Yet there were long periods in the fall when not even evidence of local adjustments was seen between the remaining pools occupied by muskrats. The nine miles of channel had a carefully estimated population of about 190, and the outlying waters about 10 more, as of mid-September. As of late September, the signs in most places differed little from those seen early in the month, except that in Tract D, they were proportionally heavier downstream and, in Tract F, considerably reduced. More decline occurred later, though water conditions improved as the weather became cool in the fall. The possible role of disease is suggested not only by the finding of many dead in neighboring areas but also by the fact that some of the best-looking stretches of Squaw Creek became muskrat-vacant in the same way as had those of the Story City block and the three-mile stretch of Skunk River south of Cambridge. Some of the late-fall reduction could have been due to illegal trapping before the muskrat trapping season opened, for skillful poachers were known to have been in the area.

I did not know of any trappers taking muskrats from tracts A-F in 1949 and, consequently, had no carcasses for examination. In late December, after the close of the trapping season, the best sign of surviving muskrats could still be seen in Tract F, where nearly half of the fall population had been concentrated. By late May, 1950, twenty-nine functional territories had been established in tracts A-F — all of them along the channel. These were most irregularly distributed, with concentrations and muskrat-vacant places reflecting chiefly the presence or absence of groups that had wintered locally. By late July, twenty-one territories were clearly productive of young, and seven more appeared to be maintained by lone adults. Six of the original territorial sites were abandoned, but this had probably been in connection with local adjustments, for five territories were ultimately established in places that had not been occupied by resident muskrats in May. Four of these five new sites were wedged into well-populated stretches, rather than established in the muskrat-vacant stretches, thus accentuating the inequalities of distribution noted earlier.

Squaw Creek was subject to moderate flooding three times in May and June, 1950, then its flow diminished during the dry weather following. The flow never quite ceased up to late September, for water from a gravel pit was pumped into the channel of Squaw Creek at the upper end of the area until past the middle of that month. With cessation of the pumping, the creek bottom became exposed except for the deeper pools and in places where springs kept up the flow for varying distances downstream.

Adjusting movements of the muskrats were studied through repeated visits to stretches known to be devoid of resident animals. No sign of any current transients was seen at the lower end of the area

in mid-August. By the first week of September, local adjustments were becoming apparent, usually involving shifts of individuals or family groups within a radius of a few hundred yards of the season's territorial sites. By the end of the week, fresh muskrat trails (heading either upstream or downstream) could be made out in some of the long-vacant stretches, while other stretches still showed no muskrat sign of any age. The upstream or downstream movements occurred in easy stages, even when individuals were certainly outside their familiar home ranges of the summer. Extreme cases were manifested by groups congregating in or about favorite pools (notably those adjacent to corn fields or other sources of choice food in tracts D and F), or by lone individuals of different age classes moving into a previously unoccupied pool, to stay there a day or two and then move on.

The source of the moving animals could be exceptionally well traced in one instance. While the county line ditch in Tract E still had a flow, a territorial site had been shifted from the creek channel to about 50 yards up the mouth of the ditch. By mid-August, the ditch was dry except for a food-rich pool about 600 yards away from the creek. The territorial site near the mouth of the ditch was then all but abandoned. Most of the occupants of the lower ditch moved back to the original territorial site of the creek channel, but some animals, after a period of explorative commuting (revealed very well by tracks of different ages laid down in the diatomaceous film covering the ditch bottom), moved up the ditch to establish themselves in the food-rich pool. The latter pool still had muskrats at the end of October, but, as early as the first of September, those returning to the creek channel were traveling upstream, leaving their signs everywhere throughout a half-mile stretch that previously had shown no sign of muskrats since the spring dispersal. Nor did these long remain in the stretches lying immediately upstream from the abandoned (but highly productive) breeding territory of the summer. Their signs then merged with the signs of resident animals in Tract F, farther upstream.

Repopulation sequences of another once-vacant stretch in Tract E are informative. One stretch of about a mile and a quarter had two territories in May, but these were not productive of young. By early July, only a single muskrat — that one easily recognizable by its huge size — remained there. The single big muskrat stayed in its regular home range at least up to early September. In early July, a probable subadult worked upstream to establish itself at the mouth of a tile drain about midway along the mile-and-a-quarter stretch. It traveled through a nearly dry tile to explore one of the drying Rainbolt Ponds some 200 yards distant, returned to the mouth of the tile, and on September 5, an animal leaving the same size tracks was still living there. Toward the middle of July, another probable subadult was known to be working upstream in this stretch, and, some time in late August, an evident family group (including several young born about

the middle of June) moved in to establish headquarters in a deep pool a full mile from any possible place where the young could have been born or raised up to that stage.

I think that the latter group comprised some of the occupants of three closely spaced midsummer territories in Tract D and that the other occupants remained to congregate temporarily about a big residual pool. No evidence was found before mid-September of any downstream movement from the sites of the three closely spaced territories.

Pronounced adjustments on the part of the muskrats of long stretches of Squaw Creek were taking place in the last days of September. Some of this could have been in response to the exposure of more and more creek bottom after the pumping ceased in the middle of the month, but most of the adjusting movements dated back to before the exposure of the bottom. Little random, cross-country movement seemed to have taken place (some did, as a subadult killed by motor traffic was found on a road well away from the stream), but there was a rather general abandonment of food-poor, shallow water retreats, partially offset by increased concentration in some of the more attractive places. Much of the late September movement was out of the area in the form of a trickling, downstream drift — without compensatory ingress from the long-dry creek above the gravel pit pump. By freeze-up, the nine-mile observation stretch had lost nearly all of its muskrats, mainly through emigration in a downstream direction. Track signs of only a single animal entering the area from above were seen on the exposed sandy bottom during September and most of October. There was no evidence of muskrats from Squaw Creek congregating along Skunk River, nor were there detected cross-country movements, except for a brief period in late October and early November that came long after the main adjustment was over.

As of early June, 1951, twenty territories were established, including six apparently maintained by lone animals. Of the fourteen territories then clearly productive of young, only one was at all isolated from other territories. The other thirteen productive territories were distributed as three groups of three each and as two groups of two each. Three of the productive territories were judged to be those of lone females that had been pregnant when they established their territories, though flood waters of early June may have separated some mated pairs. Animals behaving as if they had been flood-evicted were detected in at least four places along the nine miles of stream.

Five territories showed signs of having been highly productive, and six others showed fair to good signs up to late August, when a population estimate of about 240 was made for the nine-mile stretch. Thereafter, adjusting movements became pronounced, and the population remaining (including transients) by early November was estimated from local signs at a little less than 100. Further reduction took place through egress as winter approached, until there were left by freeze-up only about 70, of which nearly all were believed to have survived the winter.

No trapped carcasses were examined from Squaw Creek during the fur season of 1951-52, but the field data are sufficiently complete to permit estimates of the numbers of young born to the females of the twenty established territories. Five of the territories were probably of four-litter females; three showed signs attributed to single early-born litters; seven may have been maintained by females that passed unbred through 1951; and the other five territories probably had two or three litters each. A defensible estimate would be about thirty-five litters that had been conceived by the females of the sample. If the counts of placental scars obtained from the neighboring Story City block be applied to the Ames-Gilbert block, thirty-five litters would mean a total of about 305 young. This should not be at all inconsistent with the late August estimate of 240 animals of all ages for the nine-mile stretch.

Some of the adjusting movements were studied in detail, and these were thought to typify what happened in 1951 along the nine-mile stretch of channel and outlying waters. The adjustments of late July and early August were very local, manifested chiefly by family groups moving upstream or downstream to congregate in favored places. The first real traveling through was noted about the first week of August and involved only a few animals. The trail of a very large muskrat was distinguished and followed upstream out of the area. This animal was known to have traveled along more than two miles of stream between August 8 and August 11. A month later, distinguishable trails of mainly upstream transients were seen almost everywhere in the diatomaceous film covering the creek bottom in previously unoccupied tracts. Movements of entire groups of muskrats were also noted.

A paucity of food-rich habitats along the nine-mile stretch of Squaw Creek might be a partial explanation for the late summer and fall adjustments and the near-abandonment of extensive parts of the channel. Still, some corn fields were not raided by the muskrats that were living close by and presumably aware of the presence of the corn. Muskrats did not always stay in deep water pools even after they had been taking full advantage of the corn planted in the vicinity. Yet, a small stream running through corn fields just east of the Squaw Creek area was one of those obviously drawing large numbers of adjusting muskrats from Squaw Creek, much as did the small stream lying adjacent to Keigley's Branch in the Story City block. The muskrats of both Squaw Creek and the Story City block behaved as if free to move up and down the water courses as they wished, without getting into trouble with their fellows. They were able to seek and find more or less attractive living quarters somewhere, though away from the main stream channels.

The spring dispersal of 1952 was of considerably greater magnitude in central Iowa than in 1951, and it put muskrats in places that had been muskrat-vacant for years. The channel of Squaw Creek in tracts A-F had forty-seven territories, or about 95 adults. Outlying

waters had eleven territories. In the upper part of Tract F, ten territories were closely spaced along about a mile of channel, then there was a muskrat-vacant stretch of over a half mile in the middle of the tract. Below this, two territories lay close together, followed by another vacant stretch of about a half mile, and finally by three territories in lower Tract F. Tract D had seven channel territories, all massed in less than a half mile. Most of the eight territories of Tract A were in the lower mile, and seven of these were along a stretch of a little over a half mile.

The summer and early fall of 1952 was dry and especially so during practically rainless September, October, and the first half of November. Nevertheless, the weather remained generally favorable for stream-dwelling muskrats of central Iowa, including Squaw Creek. Some outlying ponds and the smaller streams of tracts A–F dried up, but the flow of water never ceased over the bed of the observational stretch of Squaw Creek itself.

Local adjustments on the part of resident muskrats were noted quite early in the summer, long before the really dry weather. The equivalent of two pairs of muskrats moved from the crowded upper part of Tract F into recently dug gravel-pit pools lying adjacent to the creek channel, and these animals were extremely productive of young in their new locations. Territorial adjustments over distances up to several hundred yards were noted in several places along the nine-mile stretch. The more pronounced adjustments occurred after the breeding was over and were of sorts to be expected of local animals stationing themselves in places having the better combinations of food and water. Adjustments seemed unaccompanied by either mortality or cross-country wandering, though occasional animals moved long distances upstream or downstream, especially in September.

By early October, the muskrats of tracts A–F were concentrated in parts of Tract F and, far downstream, in parts of tracts A and B. In Tract F, the concentration places were—in addition to the new gravel pits—two pools in the main channel of Squaw Creek in which the water was backed up by obstructions. One of these obstructions was a large beaver dam and the other was an earthen fill made in straightening the channel in connection with an engineering project. Pool-by-pool estimates for tracts A–F gave a total of about 295 muskrats as of late fall, 1952.

As of late May, 1953, the nine miles of channel had forty-one maintained territories; the outlying waters, seven. The spring population of adult muskrats for tracts A–F was about 100. Of the channel territories, fifteen had young active enough to be tracking the mud margins at the time of the late May census. These active litters must have been born in early April.

Living conditions, while excellent early in the summer, deteriorated because of drought. At first, population adjustments were orderly. As of mid-September, the nine miles of channel had a carefully estimated population of about 200 muskrats remaining, and the

outlying territories had long been abandoned. After another two weeks, the population was down to about 135. Then, beginning in late October and culminating in early mid-November, a period of frantic cross-country movement was noted, and many muskrats were killed by highway traffic. Practically no evidence was found of these desperate wanderers reaching any place where they would have stood any chance of living in peace or safety. By the opening of the trapping season on November 10, there were hardly any muskrats left in tracts A-F, except for a few still living in dry holes near corn fields or in the deepest of the residual stream-bed pools. Rains that partly relieved the general drought crisis on November 19 did not appreciably improve the wintering status of Squaw Creek's remnant population of muskrats, and the drought conditions carried on through the winter of 1953-54 with little abatement. The nine-mile stretch may be considered to have been essentially depopulated of muskrats by the spring of 1954.

After water again started flowing over the bottom in March and April, 1954, a big upstream migration of muskrats from Skunk River took place. Thirty breeding territories were counted in mid-May, all along the channel. Repeated floodings and near-floodings in June did not prove to be especially destructive of helpless young muskrats. By mid-July, 31 territories could be distinguished, including five occupied by what were judged to have been lone adults. At the latter time, twenty-three territories had one or more sizes of young working the mud margins.

In late July and early August, while water levels were still favorable, muskrats poured downstream until but a single stretch of less than a quarter of a mile retained any substantial population. This place, which had been the most consistently favored by muskrats during some previous years, still held the equivalent of about three family groups after the big downstream movement, and its occupants withstood extraordinarily high flood waters in late August. It was still holding many muskrats by late September, when most of the rest of the nine-mile stretch was all but vacant. Then, reaching its maximum in late September and early October, a strong movement upstream occurred, but the majority of the participating muskrats went on through the study area — for at least 15 miles upstream from Skunk River — far up into headwater tributaries having steady flows and conveniently accessible corn fields.

The November, 1954, public fur trapping yielded samples totaling 121 muskrat carcasses believed to have been representative of central Iowa stream populations, including those living in tracts A-F. Sex and age ratios were 10 adult males, 14 adult females, 52 young males, and 45 young females. Of the adult females, one had not conceived in 1954, 5 had conceived two litters each, 5 more had conceived three litters each, and 3 had conceived four litters each. Birth dates of three litters were assigned to April, six to May, eleven to June, nine to July, six to August, one to September, and one to October. Only

3 of the 97 young of the year in the trapped samples had been born in August or later, compared with eight late-born litters out of the 37 conceived by the adult females.

Beginning about the middle of March, 1955, and continuing through much of April, the spring dispersal of muskrats from Skunk River re-established a breeding population in tracts A-F. As of early June, thirty-five territories (including four probably of lone animals) were being maintained along the nine miles of channel, together with nine territories (including one occupied by a probable lone animal) in outlying waters. Three of the four lone-animal territories of the channel were situated along a stretch of stream ordinarily having several functional territories, but this stretch was also one in which evidences of a focus of infection of the hemorrhagic disease had begun to show up by 1954.

Of nine outlying territories, five proved to be more or less productive of young during the 1955 breeding season. The four that were nonproductive were vacated by their occupants between the middle of July and early August. This was also the time of abandonment of two of the productive outlying territories and of a large number of territories along the channel of Squaw Creek. By early August, possibly three-fourths of the muskrats of tracts A-F were concentrated along less than two miles of stream, chiefly in Tract E. The Tract E concentration area did not differ appreciably from the stretches of stream that had been abandoned earlier, and the muskrats gradually abandoned this one, in turn, throughout August and September.

Only five places in tracts A-F collected substantial numbers of muskrats as more or less permanent residents during the late-summer and early-fall adjustment. One place was a series of gravel-pit pools with deep water but only fair food resources, mostly in the form of submerged vegetation. Another was a fairly deep pool next to a well-raided corn field. It had been practically vacated by two family groups of muskrats in August, but it clearly acquired a new population from untraced sources about the first of September, and these animals behaved as if they intended to stay, busying themselves in the corn field in a most conspicuous manner. The third place was a pool about eighty yards from another well-raided corn field. The fourth was a pool from which a local concentration of muskrats raided a hill-top corn field some fifty yards away. The fifth was a series of pools into which a large number of muskrats had gathered by September, after which they established a 200-yard raiding route to the nearest corn field. Only a few remained here to winter, these rather precariously, to the accompaniment of considerable outside activity.

Up to October, the Squaw Creek examples of late summer and fall movements traced along the channel showed notably more upstream than downstream drifting, but no evidence was found of muskrats congregating in large numbers in the headwaters.

Along Squaw Creek, there was some cross-country movement during the winter. I learned of two cases of muskrats attempting to live in farmyards. A few others were able to winter in rather food-poor and almost waterless places, where they did considerable tracking in the snow during mild periods. Still others – and possibly up to a dozen all together on tracts A–F – packed their drought-exposed burrow systems with ear corn and stayed inside from freeze-up until spring, without leaving external signs of their presence in the meantime. One small woodland group, illustrating what some muskrats must have done before the white man planted corn fields, wintered on stored acorns, also without engaging in outside activities between freeze-up and spring.

As of late April and early May, 1956, the nine miles of channel had seventeen territories, and there were two more territories in associated oxbows and one more at an outlying pool. Except in the downstream part of the nine-mile stretch, the animals establishing territories appeared to be mostly the few that had succeeded in wintering in the vicinity. This was also true of the two oxbow territories and that of the outlying pool. In contrast, at least eight of the nine territories lying farthest downstream were judged to have been established mainly by animals moving upstream from Skunk River.

By late June, sixteen of the channel territories were still maintained, but seven of those were clearly occupied by lone animals. One of the two oxbow territories was drought-exposed and abandoned, but the other one in the oxbow and the one in the outlying pool were maintained and productive of young.

The reproductive fortunes of 6 of the territory-holding females could be traced with fair satisfaction. Three evidently had been pregnant when they established their territories, and they gave birth to a single early litter each. One was a probable two-litter female, giving birth to litters in late April and late May. Two others (including the one occupying the oxbow near the creek) gave birth to three litters each, dating in both cases to late March, late April, and late May. The probability is that the 4 other adult females in productive territories gave birth to single early litters.

As of late July, the population remaining in the nine-mile observational stretch of Squaw Creek was estimated at about 40. About half of them were animals of the large family group of the productive oxbow territory, these having moved to the creek channel in mid-July. This former oxbow group moved downstream to establish itself at a pool about three-quarters of a mile from the original territorial site; by mid-August its members were almost all of the muskrats remaining along the nine miles of channel. There were only 4 lone muskrats elsewhere along the stretch, and one of these was a transient. All of 4 transients recorded in August and September were moving upstream. By late August, members of the former oxbow group were in process of an upstream adjustment along about a half

mile of channel and, by mid-September, the main group was newly established at another place in the neighborhood. One large individual, which was patently a member of the group, regularly worked upstream and downstream along about 600 yards of stream channel.

Possibly fewer than a dozen muskrats wintered as a localized group along a half-mile stretch in the middle of Tract F, and there were a few more in scattered pools elsewhere in the Squaw Creek observational area.

By the middle of March, 1957, a rather general upstream movement from Skunk River was in progress. As of mid-May, water conditions were again favorable, and the nine-mile stretch of Squaw Creek had ten maintained territories representing about 20 adult muskrats. The outlying waters had none.

The whole observational area had one family group (in Tract E) and a thin scattering of individuals by late summer — about 15 all together — with water conditions still remaining favorable. More muskrats came in to bring the total population for the nine-mile stretch up to about 30. Much other movement was noted. In one case, 12 muskrats left the area in late October, heading upstream apparently as a group.

Most of the animals entering the winter were in the new gravel-pit pools at the upper edge of Tract F and at the site of one productive (Tract E) territory of the 1957 breeding season. They should have wintered satisfactorily, though I obtained no further data on the Squaw Creek muskrats during the winter of 1957–58 and the following spring.

OUTLYING WATERS OF AMES-GILBERT BLOCK

Onion Creek

It was not until 1940 that the observed stretches of Onion Creek, in tracts G–H, became habitable for muskrats. No actual data were recorded until 1935, but the drought of 1934 should justify the assumption that these tracts had not been occupied by muskrats for most of that year. For 1935, there were grounds for considering that a territory had been established in the spring and that about 8 precariously situated, scattered muskrats were present in mid-October, all animals that had been present from a few days to a few weeks. In 1936, no muskrats were found to be present along any stretches of Onion Creek visited in mid-October, though one place had been temporarily occupied weeks before — probably in early September after the first heavy rain. No breeding of muskrats was known to have taken place in 1937, nor were even temporary residents known to have been present in 1938 and 1939.

In 1940, the Section 30 stretch of Tract G, near Ontario, had no breeding territories, but there were two territories situated to the west, just across the Boone-Story County line. By fall, a population of about 25 was concentrated at the territorial sites, with a lone animal living along Onion Creek in Section 30, itself. A single breeding

territory was noted in the two-mile stretch of Tract H, east of Jordan, and the signs of late September suggested about a dozen muskrats remaining there.

The observational stretch in Tract G had two territories in 1941, and there was another territory across the county line to the west. Drought exposure during the summer was followed by abandonment of the territories by most of the young reared there, but the adults of two territories held tenaciously to their property rights. The population judged to have entered the winter of 1941-42 was about 10. These muskrats were obviously hungry much of the time and foraged on the banks under cover of overhanging ice-shelves and out in the open for grain in livestock manure. A mink victim, killed in late February, was found. Tract H had signs of animals passing through in May, but none of these settled here to breed in 1941, nor was local evidence seen of late-summer movements.

Tract G had three territories in 1942, and there were two more across the county line to the west. The parts of Onion Creek having old burrow systems were highly attractive to spring settlers. In Tract H there was, despite a lack of muskrats wintering locally, a heavy movement (involving an estimated 20 to 30 animals) during the 1942 spring dispersal. Two territories were established. No evidence was found of predation by minks upon muskrats even at the height of the dispersal, though minks were of general distribution along the stream. None of 152 mink scats examined from late March to early May contained muskrat remains.

The wet summer of 1942 was advantageous to the Onion Creek population of muskrats. Abundant signs were to be seen in the vicinity of all of the breeding territories in early September. About this time and later, many muskrats were also moving into previously vacant stretches of the small stream to dig new sets of burrows. As of early September, Tract G had an estimated population of about 65 and Tract H had about 25. Two months later, Tract H had about the same number of muskrats and these were quite well situated for wintering. Relatively food-poor Tract G was the site of considerable adjusting as fall came on — mostly as downstream movements. Few muskrats other than those having ready access to corn stayed to enter the winter. The estimated 40 animals remaining in Tract G after freeze-up engaged in considerable outside activity. One of the latter was known to have been killed by a mink in mid-January, 1943.

The two observational stretches of Onion Creek were well populated with muskrats in 1943. Tract G had five territories, and Tract H had six. Only one of the territories of each tract was situated at a place not known to have wintered muskrats in 1942-43, and the field evidence suggested that the 1943 breeders were mainly of local origin. Onion Creek muskrats were confronted by no observed crises before two flood periods in the first half of August, and these floods came after the majority of the young were sufficiently large to take care of themselves. Signs were still very heavy in both tracts by late fall,

especially in the vicinities of raidable corn fields. Undoubtedly, movements of subadults along the creek occurred in late summer and early fall, but there was evidence from trapped carcasses that the adults generally remained in or near their former breeding territories.

Specimen material gathered from the various muskrat-occupied outlying waters of Tract G showed a ratio of 6.5 young per adult female, which applied to the Onion Creek stretch would give a pre-trapping fall population of about 40. A diseased muskrat, imbedded in the ice, was found in Tract G. Trapped specimen material was lacking from Tract H, but I estimated that the pre-trapping fall population was in excess of 100. Under wet-year conditions, Tract H looked virtually as habitable for muskrats as did the Story City ditches. Light to moderate trapping on the part of unknown persons left plenty of muskrats to winter, and these got along with slight known loss. One winter-active individual was killed by a mink, and one (dated to mid-February) of seventeen winter mink scats contained muskrat remains.

Tract H had ten territories in 1944, which well filled up the observational stretch. By late October, there were good signs nearly everywhere along the two-mile stretch, without evidence of any particular concentrations. The late fall population, as reflected by signs, seemed to be about as it had been in 1943, or probably in excess of 100. I am not sure that subsequent late fall adjustments appreciably reduced the population, but would expect that they did. Apparent disinclinations of the muskrats to concentrate as winter approached suggested tension at the least, especially along a stretch where environmental differences—as exemplified by presence or absence of ear corn in the vicinity of certain sets of burrows—should have invited concentrations in some places and withdrawals from others. During the winter, the muskrats lived mainly in about half of the observational stretch, clearly in the most food-rich part.

Onion Creek in Tract G had only two territories, or about five adults, in 1944. The late fall population was estimated at between 15 and 20 (probably nearer the former), mostly localized in one place. The deterioration of the fortunes of the muskrats of Tract G continued in 1945. Two territories were established, but signs of young were found at only one territory, and my belief is that the two territories between them produced a single litter. By late fall, the stretch had possibly two animals remaining.

Tract H had eight territories in 1945. Although this still comprised a remarkably high breeding density for the observational stretch, most territories—even in a mile stretch having six—were rather well spread apart, that is, with headquarter burrows separated by distances of 200 yards or more. The greatest concentration of breeding territories—four in the east half of Section 28—occurred along what was both the most food-rich stretch of stream and the one having had the highest 1944–45 wintering density.

By mid-August, 1945, the muskrat signs were heavy and general

throughout the two miles in Tract H. By late September, when the creek was dry except for puddles, some puddles were occupied by fair numbers of muskrats, but the population of the observational stretch had been much reduced. Four of the eight territories were completely muskrat-vacant, and one of the others had lost most of its muskrats. In late September and early October, after rains had restored some of the flow, the muskrats were almost confined to a half mile of the creek.

When the trapping season opened on November 10, Earl Sturtz, the farmer having the most heavily populated stretch of creek, found 7 rotting dead lying close together — 5 in the water and 2 on land. Two that were less decayed than the others were examined, and they proved to have still-recognizable hemorrhagic lesions. Sex and age ratios from the two disease victims and 19 trapped animals were 3 adult males, 2 adult females, 10 young males (including 2 August or September "kits"), 5 young females, and 1 young of undetermined sex. Of the 2 adult females, one had conceived 12 young in two litters assigned to June and July and the other had conceived 22 young in three litters assigned to May, June, and July. Perhaps the 21 specimens may be regarded as the equivalent of the population living in two of the four retained territories, which would give a late fall population of about 40 for the tract. Known losses of 7 dead of disease plus 19 trapped would leave about 15 to enter the winter after the trapping.

In 1946, Tract H had six territories. Three of the territories were at sites that had been used in 1945, and four of the six were fairly uniformly spaced about 300 yards apart. The parts of the stream most favored by the muskrats during former years had no known breeding muskrats in 1946, though they still comprised the most attractive habitat. The latter, however, included a main burrow system in which mortality from hemorrhagic disease had been prominent in 1945. It is possible that animals settling there in 1946 died without being replaced, as the signs had been good in early April. By September, the creek had only puddles remaining, but five of the six original territories were still well used by muskrats. By freeze-up, with wintering conditions favorable, only three of the original territories had muskrats — about 30, most of which appeared to winter successfully. When the ice opened up in mid-March, 1947, good wintering signs could be seen in the three places where there had been any reason to expect them. Onion Creek in Tract G had a single territory in 1946. It produced young and had good signs into September, but I doubt that any muskrats entered the winter there.

Tract H had seven territories in 1947. The breeding population was very successful in rearing early-born young, but June floods put a maximum of about eight feet of water over the small stream and surely drowned many of the helpless young of that time. At least three of the territories had young born during the first half of July. By September, the creek was dry except for puddles. Only one ter-

ritory had any sign of muskrats — and not much there. The whole tract became drought-exposed and muskrat-vacant soon after. Tract G had two territories in the spring and no muskrats left by early fall.

Onion Creek had some sign of muskrats almost everywhere in early April, 1948, but generally these animals did not settle in my observational areas. Tract H had one territory. By late fall, the creek in both tracts G and H was dry and muskrat-vacant. A single pellet of a horned owl, datable to early fall, 1948, was found in Tract G, and it consisted of remains of a “kit”-sized muskrat.

Tracts G and H of Onion Creek each had a breeding territory in 1949, both abandoned quite early in the summer.

Tract H had one territory in 1950. The original territorial site had been befouled with farm sewage in early summer; thereafter the territorial headquarters appeared about 250 yards upstream, in an inviting pool next to a corn field. The stream flow stopped in early August. By mid-August and early September, the most attractive puddle was at the territorial site. Although local animals were still present by freeze-up, the tracks of a young animal (probably leaving the area) were followed downstream for about a half mile on July 10, and apparently a single subadult drew off by itself to travel down the stream bed early in September. No sign of other movements far away from the territory could be made out during repeated visits from August, 1950, through February, 1951.

The data suggest that a pregnant female had come in during the 1950 spring dispersal, given birth to and raised a large litter, and that she still lived with nearly all of her young up to at least early winter in the best habitat for muskrats to be found for miles. The animals seemed disposed to stay there, next to the corn field, though they had little water left in the pool of their burrows at freeze-up, and this soon froze to the bottom. All known foraging in the corn field and dragging of ear corn to the pool was done by a very large muskrat, presumably the mother. A medium-sized mink became interested in the wintering burrow of the muskrats and had packed trails leading into it from about the first week of January, 1951, through most of February. Some outside activity on the part of a muskrat was noted in late January. This animal (a big one) made itself a retreat in a snowdrift (which was also assiduously tunneled by the mink) and stocked this with ear corn. When the first spring thaws came in late February and early March, the big muskrat was still alive. By early April, it was gone.

The two tracts of Onion Creek kept under observation had only a lone and restless muskrat in mid-June, 1951, that one in Tract G. Repeated visits yielded no evidence of other muskrat movements along this stream, even at the height of the spring dispersal. Nor were adjusting animals known to have followed this travel route in late summer and fall, though they did move into some small-stream habitats that looked no more inviting. Early summer floods resulted in pronounced changes in the stream bed.

Tract H had eight territories in 1952, but pronounced adjustments were occurring as early as early July. The stream was all but dry and muskrat-vacant as early as September. By late October, the only muskrats left were in the vicinity of a schoolhouse sewage flow next to a corn field, and it could be seen that some were then abandoning that site, though it was well situated with respect to food. The tract had a lone animal territory at the sewage flow in the early summer of 1953, but not thereafter for the rest of the year.

Tract G had no more known muskrats for the period, 1953-57.

By early June, 1954, four territories had been established in Tract H but, by mid-July, only two widely separated muskrats were still in residence. Much movement by transients was in progress in early June. No muskrats were known to be left by fall.

Tract H had five territories as of early June, 1955, of which three were productive of young. One territory was lost in early summer because of the hemorrhagic disease. Three of the others (including two that had been highly productive of young in early summer) were abandoned in late July, despite a fair amount of water in the creek and the presence of raided corn fields near by. In raiding corn fields, these muskrats were merely eating the succulent parts of the corn plants, without displaying any awareness of the special food values offered by the ears). The adjusting movements of the muskrats were largely untraceable, but two upstream trails were followed for about 700 yards on August 13, and a single downstream trail was found on August 23 in a long stretch having no other muskrat signs. The fifth territory, which was next to a corn field systematically raided for ears, was maintained until the opening of the trapping season on November 20, despite death of the adult female from hemorrhagic disease and drought exposure of the maintained burrows.

The muskrats at this place did much digging, plugging, plastering, and storing. Their industry and persistence contrasted decidedly with the behavior of the two other groups of adults and young that left long before they had reason to feel forced by drought. The adult female, which died on August 22, had 29 placental scars in four sets, with birth dates assigned to early in the months of April, May, June, and July. Twelve muskrats entered the winter here, for that was the number caught by Ted Toms, a farmer who was forced to trap them out because they plugged a drain from his house.

In the west part of Tract H, the creek remained a little wet at the opening of the school sewage drain. By midsummer, 1955, this place was visited by one of the apparent occupants of a practically abandoned territory lying about a quarter of a mile downstream. By fall, what seemed to be the same muskrat was winterizing the sewage drain and stocking it with ear corn. Here the animal successfully wintered, and, after some commuting back and forth between the drain and the old territorial site in the spring of 1956, it returned to live at the drain. Despite the lack of surface water and the foulness of the sewage drain, the animal maintained a territory by itself until

July. It then disappeared, leaving all observational stretches of Onion Creek muskrat-vacant for the rest of 1956 and through 1957.

Rainbolt Ponds

The first evidence of these ponds being occupied by muskrats during the years of the central Iowa studies was found in the fall of 1938. A known minimum of five individuals then moved into the upper pond, which was the deeper of the two ponds. One of these animals came out on the ice, obviously sick, on January 8, 1939, remaining there until its death on the morning of January 10. It proved to be a lean subadult male, which recently had wrung off a forefoot in a trap. Dr. E. R. Becker examined it for parasites and found a massive intestinal infection of the fluke, *Fibricola*, and an associated catarrhal exudate.

An intensive study of responsiveness of muskrats to sinking frost lines in shallow water was carried on, beginning in mid-December, 1938, at which time the ice was about five inches thick. In early February, the mud at the sides of the submerged muskrat channels was frozen to a depth of nearly eighteen inches. By deepening their burrows and passageways to a depth of about two and a half feet, and subsisting largely upon stored ear corn, the muskrats avoided serious crises until the ponds were completely flooded and frozen over in mid-February. The flooding covered every conceivable place where muskrats could be living in lodge or burrow chambers about the upper pond, and the ice-seal was still unbroken on February 22. Either the muskrats had been permanently evicted by the flood to wander about the winter countryside or they had drowned underground. No further evidence of the species was detected at the Rainbolt Ponds until March 15, 1939, when the spring dispersal brought in a big animal from the outside.

The upper pond had one territory in 1939. What were judged to have been an adult female and a few survivors from an early litter remained most of the summer, to disappear by early fall, as the pond became drought-exposed.

Following absence of muskrats in 1940, both upper and lower ponds had their separate territories in 1941. Muskrats remained present by fall in good numbers not only in the ponds but also along a tile flow leading to the upper pond: an estimated 40 animals, of which I examined 7 trapped carcasses. These were an adult male, an adult female having 37 placental scars in four sets (including one set for a litter assigned to August), 3 young males, a young female, and a young of undetermined sex. My estimate was that about 15 successfully wintered, 1941-42.

In 1942, two territories were established in the upper pond, one in the lower pond, and one along the tile flow leading to the upper pond from the north. The situation was so interesting that these ponds were made the site of a particularly intensive study during the summer and fall months. Not only was the biology of muskrats

living under crowded conditions investigated but also some of the economic aspects of their heavy raiding of adjoining corn fields. Throughout this work I received agreeable cooperation from the owner, Simon Kemmerer, and his family.

The four breeding pairs (or equivalent) living at the Rainbolt Ponds and the associated tile flow comprised the highest local density occurring anywhere within the parts of the Squaw Creek drainage that were kept under observation in 1942. Early in the summer, these pairs and their offspring subsisted mainly upon the grasses, sedges, and young weeds of cultivation of the meadow-like shores. Beginning about the middle of July, the muskrats increasingly raided the corn fields, which had been planted in the lowlands on all sides of the ponds. On the whole, the heaviest raiding occurred after the ears had reached the milk stage, and it continued nearly up to the middle of November. Counts of muskrat-cut corn plants made from July 17 to November 11 totaled 5,243, of which 858 were water-stunted or otherwise defective plants that never would have produced corn, anyway. This leaves 4,385 potentially productive corn plants destroyed by the muskrats. Following the criteria given on page 420 of Errington (1938), 4,385 plants should have been close to the equivalent of about 3,720 ears, and 3,720 ears should have been close to about 24.4 bushels. Allowing further for unmeasured quantities of ears picked up from the ground by the muskrats that foraged without cutting stalks, a total of perhaps 30 bushels of corn destroyed, consumed, or stored by the local muskrats might be arrived at. This, I feel was the most accurate study of exploitation by muskrats of a choice source of food that I have made, and it also represents the severest direct crop damage by muskrats that I have seen.

The field data are sufficiently complete to establish the approximate dates of birth of 15 litters for the 4 adult females, and there is evidence that all 4 probably gave birth to 4 litters each. If calculations be restricted to the proven 15 litters, application of the mean of 8.33 young per litter shown by the placental scars of 5 trapped specimens of adult females from the Squaw Creek drainage would give a total of 125 young conceived or born at or near the Rainbolt Ponds, between spring and late summer, 1942. Not anywhere near this number of young muskrats lived at the ponds at any one time, however, for juvenile mortality involving members of many litters was quite pronounced during the month of August — involving not only young born in July and June but also some of the early-born young.

On August 18, I estimated the number of muskrats of adult and subadult sizes living about three of the Rainbolt territories at about 35. If allowance of about a dozen large muskrats more be made for the fourth territory (for which I did not attempt an estimate at the time), close to 50 adult or nearly grown muskrats should have been present, as of mid-August. This would suggest the actual rearing of something like 40 young from five or six early litters. In addition,

there were the young from ten mid-season to late litters, including one born about the last of July and another in August, but these late ones did not get along well. There may have been, still as of mid-August, about 20 recently weaned or suckling sizes of young, or a maximum population of perhaps 70 for the Rainbolt Ponds. By late fall, prior to the fur trapping, the remaining population was probably around 60.

Detected losses of muskrats at the Rainbolt Ponds occurred through the agencies of predation and intraspecific attack, accentuated by crowding and by low water stages in late summer. Field notes describe a young of about ten days found August 10, at the mouth of a burrow; it was freshly dead, with head, forequarters, hind legs, and tail eaten away by an adult-sized muskrat.

Of 87 raccoon scats deposited about the ponds during August and September, a single one dated to August 16 contained remains of a young muskrat of about six weeks. A raccoon was known to have dug out parts of a well-used burrow system about that time and also on August 18. As the burrow was the same one outside of which the muskrat-eaten young of ten days had been found, the raccoon may have been attracted by more dead young within, such as other victims of intraspecific strife or cannibalism; but then, too, I know that the digger may have caught the particular six-weeks muskrat that it ate, either as the victim swam past or was cornered in one of the numerous blind alleys of the burrow that the weaned sizes of young regularly frequented.

Aside from an adult female killed in October in a corn field by a medium-sized predator (raccoon or canid?), the rest of the detected predation suffered by the Rainbolt muskrats was from minks. No muskrat remains were found in 96 mink scats deposited in May, June, and July, nor in 15 for September and October, but 11 of 58 August scats did contain muskrat remains. The muskrats eaten by the minks represented members of at least five litters of young of three weeks up to subadults, largely of the sizes that were less proficient in taking care of themselves.

Eleven muskrats legally trapped from the ponds during the 1942-43 fur season were 2 adult males, 6 young males, and 3 young females. Illegal trapping probably had greatly reduced the muskrat population of the ponds long before the opening of the fur season.

In 1943, the upper pond had one territory and the lower pond had two. The lower pond was in process of drying and abandonment by mid-September, but there was no important drift of muskrats from it into the much more attractive upper pond. Seven trapped specimens from the upper pond were examined during the 1943-44 fur season: an adult male, an adult female having 15 placental scars representing two early-season litters, 4 young males, and a young female.

Both ponds had lone territories in 1944. By late fall, the upper

pond had an estimated 20 muskrats; the lower pond, none. By the opening of the trapping season on November 10, few muskrats were left. Three trapped carcasses were of an adult male and 2 young females. An adult female, trapped from a neighboring brook but believed to have passed the 1944 breeding season at one of the Rainbolt Ponds, had 28 placental scars of four ages, the latest datable to about July.

The upper pond had a territory in 1945, but it dried up. No muskrats entered the winter. In 1946, the upper pond had a territory, and good muskrat signs continued to be present until at least late fall, despite low water levels and foulness of the remaining water. In 1947, neither pond had a territory, but about a dozen muskrats moved into the upper pond in late summer, though its water level had been much reduced. These animals did not remain to winter.

A territory was established at the lower pond in 1948, but why the animals settled here was not wholly apparent. The upper pond was in far more attractive condition for muskrats. Neither pond had any muskrats remaining by late fall, nor any in residence again until 1952.

The 1952 signs indicated that a pregnant female came into the north pond in late June, gave birth to and raised most of her litter, and then departed with them in early fall. After two muskratless years, 1953-54, what appeared to have been a lone animal maintained a territory during the first half of the summer of 1955. No sign of muskrats even visiting the ponds was found in 1956 and 1957.

Nobel Christianson Ponds

The wet season of 1942 seemed to make these ponds really habitable for muskrats for the first time in our central Iowa studies. They had one recorded territory, which was evidently very productive, for by late fall there were four large lodges and many smaller ones. A population estimate of about 20 would seem to fit in fairly well with the destruction by the muskrats of a tenth of an acre of corn planted next to the ponds.

The ponds were in fair to good condition for muskrats in the spring of 1943, though tiling operations began in early May. None of twelve mink scats deposited in early April contained muskrat remains. Three breeding territories were established, and 3 trapped adult females corresponding to these were examined during the fur trapping in November. One specimen had twenty-eight placental scars in three late spring and early summer sets; another, twenty-one scars in three sets, of which the latest was assigned to late July; and a third, forty scars in four sets, representing litters judged to have been born from mid-April to mid-July. In addition to the 3 adult females, the trapped sample included an adult male, 9 young males, and 7 young females. The young females included an animal born

about late July. These 20 specimens comprised possibly two-thirds of the animals remaining by the beginning of the trapping on November 10.

The tiling begun in May was not completed in 1943 to the extent that it perceptibly affected the water levels of the ponds, and the deeper parts remained habitable for muskrats during the several intermittent dry periods of late summer and fall. Of the 89 young in 10 litters that presumably had been conceived or born at these ponds in 1943, one litter was probably lost because of human (my own) disturbance. Even so, a reduction of the local young by November 10 to not much more than a third of the total conceived or born reflects a sharp decline. The mechanism behind the decline was not specifically determined. Undoubtedly, there was some emigration in response to repeated exposure of the shallower parts, and there may have been undetected mortality from mink predation, intraspecific attacks, or disease.

Between late December, 1943, and late January, 1944, the marsh bottom became drought-exposed, and 2 January mink scats contained muskrat remains. For several weeks, I had not thought that any muskrats could be still alive, there having been no recognized external sign, whatever. Then a rain (2.06 inches) on January 27 refilled the ponds, and on February 1, a most revealing film of ice had covered the water. Under the ice, I saw 4 different muskrats swimming, and bubble signs indicated the presence of still more. Quite evidently, the whole population surviving the trapping and the attentions of the mink had done so by staying practically sealed in nearly dry retreats — notably in a single burrow system that had been well-stocked with ear corn from the late-fall raiding of an adjacent field. By mid-February, the wintering muskrats were congregated in one big lodge, though later in the month they rehabilitated some of the previously unused lodges. It may be judged that at least a half dozen muskrats successfully wintered.

The Christianson ponds had the equivalent of two breeding pairs or about five adults in 1944. Though practically full of water in late March and refilled by the rains of May and June, these ponds had no surface water left by July 25 (just before another heavy rain began), and the muskrat sign was that of animals living under drought conditions. A single mink scat from late July contained muskrat remains. By late August, after partial drought relief early in the month (nearly 2 inches of rain fell on August 4), the ponds were again dry, and the muskrats were living in heavy weed growths and ground holes. Rains totaling 3.46 inches, August 25–27, did not appreciably change the local situation. The better places still had abundant muskrat signs as late as early October, but thereafter the exposed population suffered severe mortality.

(It should be mentioned that the tiling operations begun in May, 1943, had been deferred until late October, 1944, so that the water fluctuations of the ponds were still reflecting more or less natural

happenings in marginal habitat over most of these two years.)

On October 17, 1944, a freshly dead subadult victim of the hemorrhagic disease was found outside of a burrow entrance, and 27 of 29 mink scats deposited between that date and October 27 contained muskrat remains. At the latter time, I excavated the 2 main lodges and found inside of one the mink-eaten remains of a freshly dead subadult. With the tiling becoming effective in late October, the Christianson Ponds ceased to represent even marginal habitat, and no muskrats succeeded in wintering there either in 1944-45 or later, for the duration of the investigation.

What had the appearance of a breeding territory was established in 1945 in a roadside ditch adjacent to the newly-drained ponds, but this site dried out and was abandoned in mid-July.

J. H. Turner Pasture Pond

The 1942 spring dispersal put the equivalent of two pairs of muskrats into the pond. As of mid-November, the population was estimated at about 35. Five trapped carcasses from the 1942-43 fur season were an adult male, an adult female (with 13 placental scars representing two early litters), 2 young males, and 1 young female.

In 1943, there were seven territories established on something over two acres of habitable environment. In early November, the pond had sixteen large, eleven medium-sized, and nine small lodges, with numerous bank burrows stocked with duck potatoes. Eighty-four muskrats were trapped from two acres of pond, of which 72 were examined: 6 adult males, 5 adult females, 22 young males (including 3 "kits" judged to have been August-born young), and 39 young females (including 7 more "kits"). The sample of 5 adult females did not include the mother of the "kits," for only one of those examined had given birth to a litter dated as late as late June. The "kits" were thought to have represented the members of a single large late litter, as these were trapped from about the same part of the pond. Of the sample of 5 adult females, one had conceived a single litter of 5 (that one born about May); one, two litters; and 3, three litters each. These twelve litters totaled 75 young.

It would be a good guess that the female giving birth to the August young had conceived four litters and that her litters had been big—perhaps totaling 40 or more for the 1943 season. It is also likely that the female of the seventh territory had given birth to two or three litters—probably three, as had most of the adult females examined, or to about 20 young during the season. This would add up to a total of nineteen litters or about 165 young born at or very near the pond. My estimate of the population remaining after the fur trapping was about 30 animals. This figure, added to the trapping catch of 84, would give a fall population of about 115.

The water was about a foot and a half in depth in the deeper parts and barely covered the mud of the shallows. There was such an abundance of duck potatoes available to the muskrats—either

in unfrozen mud under the ice or stored in chambers — that the muskrats probably had no food crisis all winter. Nevertheless, the sinking of the frost line may have resulted in some vulnerability to mink predation. On December 30, 1943, only one lodge was seen to have had an unrepaired mink hole. By January 21, 1944, eight of the larger lodges and one of the bank burrows were “bored.” Of four mink scats deposited in December and early January, none contained muskrat remains, but one did of six scats dated to late January.

As in 1943, there were seven maintained territories in the spring of 1944. Water and vegetation remained in attractive condition for muskrats throughout the summer. Insufficient trapping was done to provide the specimen data needed to calculate the 1944 fall population, but very similar signs about the pond in 1943 and 1944 might suggest similar populations for both years, or about 115 for the fall of 1944, as in 1943. By late November, a tremendous number of signs could be seen, and a density of about 50 muskrats per acre may be judged to have been present in January, 1945, after a small amount of trapping.

This density really made an impact on the habitat. A small low island was burrowed about as completely as a piece of land could be. In the surrounding pasture, hogs learned to root for duck potatoes stored in the upper parts of the muskrat burrows. Some ramifying sets of burrows had bushels of duck potatoes packed in them. Despite its top-heaviness, the muskrat population seemed to winter fairly well, though a putrid adult female that washed ashore in late March may have been a victim of undiagnosed disease.

The pond had six territories in 1945. By mid-September, it had water covering about half of its bottom, but the borders were badly trampled by livestock. The small low island was the only place then showing continued use by muskrats, and it too was trampled, though not as much as the outer borders of the pond. Pigs also opened up the island burrows to eat the duck potatoes stored by the muskrats. By early November, the only surface water was in a central puddle and in the channels of the muskrat lodges. All of the pond's muskrats, as of this time, were concentrated in four muddy lodges and in a series of burrows at one side of the low island.

Partly as accommodation to me, the pond was trapped drastically during the 1945–46 fur season, and 28 muskrats (nearly the total remnant population) were caught. Twenty-two carcasses were examined: an adult male, 3 adult females, 12 young males (including 2 born in late July or August), and 6 young females. One of the adult females had conceived 12 young in two fairly early litters, and the other two adult females had conceived three litters each, mostly early in the breeding season and totaling 24 and 25 young, respectively.

There was no 1946 breeding population of muskrats at the pond, but muskrats came in to establish themselves during the extensive overland movements of August and September. By early winter, an estimated 8 muskrats lived in 2 large lodges. These were left un-

molested during the 1946-47 fur season, and most of the animals were judged to have wintered.

The pond had two territories in 1947. Early in the summer, it was in good condition for muskrats, despite the livestock damage of the previous year, but by mid-August the bottom was exposed and hogs were working it over for duck potatoes. No muskrats were left by late fall.

From 1948 through 1957, the pond was in more or less attractive condition for muskrats in the springs and early summers of most years, yet no further evidence of muskrats occupying or even visiting it was found.

Montgomery Creek and Allen Turner Estate Oxbows

Neither the observed stretch of Montgomery Creek in Section 35 of Tract F nor the oxbow pools of the pasture lying to the north of the creek had any known muskrats in them from 1934 through 1940.

In 1941, the most attractive of the oxbow pools had a territory, and it had many muskrats remaining by the opening of the 1941-42 fur season. Seven trapped specimens were an adult male, an adult female (with 17 placental scars representing two midsummer sets), 2 young males, and 3 young females. By mid-December, when the trapping was about over, many fresh bubble and feeding signs were still to be seen under the ice, and I estimated that as many wintered as had been trapped. These ponds were away from any regularly used travel route of muskrats, so I doubt that any muskrats had moved into them in late summer and fall. The pre-trapping population may therefore have consisted of the original pair of adults and about a dozen of the 17 young conceived.

The territorial site of 1941 at the main pool was also used in 1942. The whole series of oxbows had high water during the general flood periods, though not enough to have been really damaging to the muskrats. Some of the muskrats living at the oxbows also frequented Montgomery Creek to the south, which also had a lone animal territory. The latter animal is thought to have been an unmated adult female, as one of these was found in 11 carcasses of muskrats trapped at the pond during the 1942-43 fur season. The other specimens in the trapped sample were an adult male, five young males, and four young females. Several more muskrats survived the trapping, and my estimate of the pre-trapping population was about 17, including the unbred adult female that presumably had maintained the Montgomery Creek territory.

The main pond had another territory in 1943, at the same site as those for the preceding two years. This was not only a productive territory but it was one that probably drew in some muskrats during the late summer and fall adjustments. The observational stretch of Montgomery Creek itself had no maintained territory in 1943, though by fall it had a heavy population. Twenty-six trapped carcasses from the pond and Montgomery Creek were an adult female (with 25

placental scars in three sets, the latest dated to late July), 14 young males, and 11 young females.

In 1944, the pond had its territory at what had come to be the usual site. Montgomery Creek also had a territory about a quarter mile away. Thirty-five trapped carcasses were examined during the 1944–45 fur season from Section 35 in Tract F, mostly, but not exclusively, from the Turner Estate oxbow and adjacent Montgomery Creek. These were 2 adult males, 4 adult females, 12 young males, 14 young females, and 3 young of undetermined sex. One of the above adult females had conceived a single litter of 8, born about May; another had conceived 19 young in three litters born during the first half of the breeding season; and 2 four-litter females had conceived 32 and 33 young, respectively, with the fourth litters of each having been born about August.

The pond and adjacent Montgomery Creek each had a territory at the old sites in 1945. These territories became drought-exposed and abandoned during the summer.

Two of the ponds had territories in 1946, both at sites not previously occupied, but by midfall the pond muskrats had moved into adjacent Montgomery Creek. From late fall, 1946, to the fall of 1947, the Turner Estate ponds were without resident muskrats. About mid-fall, 1947, an estimated 10 muskrats moved into the main pond; by late fall the main pond was nearly dry, and the muskrats had moved on again.

In 1948, the wet outlet of the main pond had a territory, which was closely observed while in process of establishment during the second week of May. No muskrats were left here by late fall.

Neither the ponds nor the adjacent stretch of Montgomery Creek had muskrats from 1949 through 1951, but in 1952 a probable lone-animal territory was established along the creek just south of the main pond. Another lone-animal territory was established at one of the smaller pasture ponds. These territories were dry and muskrat-vacant by fall.

In 1953, the observational stretch of Montgomery Creek had three territories, and one of the pasture ponds had another. These, too, were drought-exposed and abandoned by late fall. In 1955, the creek had a probable lone-animal territory, which was abandoned in mid-summer. No muskrat remains were found in 24 mink scats dated to about the time of disappearance of the muskrat. Neither ponds nor the stretch of creek had resident muskrats in 1956 and 1957.

York Pond and Hutchinson's Lake

Neither of these ponds, which are connected by a ditched channel, had observed evidence of muskrats in 1934 and 1935. In 1936, the larger, Hutchinson's Lake, had a territory, the occupants of which departed during the early weeks of the drought.

After a muskratless 1937, Hutchinson's Lake again had a territory

in 1938, this at the site of the 1936 territory. My interpretation of the 1938 signs is that a pregnant female (perhaps one of those earlier assigned to a breeding territory along the Squaw Creek channel) came in about midsummer, gave birth to and raised most of the young of a single litter. The bubble and feeding signs under the ice during the winter of 1938-39 indicated the presence of about a half dozen animals. The place flooded so badly in cold weather — 11 degrees below zero Fahrenheit — in mid-February that I do not see how any of its muskrats could have stayed there and remained alive.

York Pond, but not Hutchinson's Lake, had a territory in 1939, but this pond went completely dry during the last of May. The muskrats did much digging and deepening of their main burrow system before abandoning it about May 27, following which it was taken over as a rearing den for a family of minks. No muskrat remains were found in 140 mink scats examined from the den latrines. Neither York Pond nor Hutchinson's Lake had muskrats for the rest of 1939, nor in 1940.

In 1941 York Pond again had a territory, this one on the opposite side of the pond from the site of 1939. It nearly dried up in mid-August between floodings, and it appears that only four or five young were raised there. This group also shifted its living quarters to the deeper part of the ditch connecting the pond with Hutchinson's Lake. Some animals wintered here, 1941-42.

In 1942, York Pond had a territory at the same site as in 1941. The late-fall signs of 1942 were those of a thriving family group. By mid-October, two main sets of burrows were in regular use and stocked with ear corn. By the opening of the trapping season on December 1, the population had been much reduced, probably by illegal trapping in early November, and the legitimate trapper caught only 3. I would estimate the pre-trapping population at about 20.

Both Hutchinson's Lake and York Pond had territories in 1943. York Pond was dry and abandoned by muskrats in late fall, but it may be suspected that the occupants had moved down the ditch to Hutchinson's Lake, where water conditions were much better. The severe trapping pressure of the 1943-44 fur season seemed annihilative for the muskrats of Hutchinson's Lake, though I was unable to examine specimens known to have been taken from this particular place.

In 1944, York Pond had two territories (including one at the usual site), and the ditch leading to Hutchinson's Lake had one territory. These territories were at least moderately productive, but all three showed a substantial diminution of sign by late fall, and probably no more than a dozen muskrats remained by the opening of the fur season, November 10.

Neither pond had resident muskrats in 1945. In 1946, Hutchinson's Lake had a territory, and so did York Pond, that of the latter being at the principal site used since 1941. Both ponds were aban-

doned in late summer and fall of 1946. Neither pond had a territory in 1947, but about 5 muskrats came into Hutchinson's Lake and built a lodge there in October.

After three muskratless years, 1948–50, two territories were established at Hutchinson's Lake in 1951 — including one probably by a pregnant female coming in alone. The territorial site of the latter had been abandoned about the first of August, and the family group had established itself about 200 yards away in the ditch leading to York Pond. Then, by mid-September, these animals had moved back about 90 yards toward Hutchinson's Lake and had dug a new burrow system next to a raided corn field. By the end of September, the muskrats appeared to have abandoned the new burrow system after stocking it with ear corn. Pigs and raccoons dug around the exposed burrow entrances but did not get far inside. The second 1951 territory was highly productive, but was abandoned by the entire group about mid-August. Trail signs across 150 yards of pasture identified this territory as the source of the large group of muskrats appearing at the main pool of the county line ditch north of Squaw Creek, which is referred to later in this chapter.

The ditch connecting York Pond and Hutchinson's Lake had a territory in 1952, but the animals were evicted by drought in late summer. In 1953, both the above ditch and York Pond had territories. The one at York Pond seemed to be maintained by a lone animal, which abandoned it to move down the ditch in late June or early July, while a family group of muskrats at the original ditch territory remained until fall. By early October, only what seemed to be a single muskrat remained at the ditch. The only muskrat signs observed in 1954 were of a lone animal at the ditch in mid-November. In 1955, a few muskrats lived along the ditch for a time in late July and early August, then disappeared. No sign of muskrats was seen throughout 1956 and 1957.

Old Oxbow Series West of Squaw Creek

This series of oxbows, lined up in about three-quarters of a mile of an old channel of Squaw Creek in Tract D, had no known muskrats from 1934 through 1939. In 1940, a few muskrats frequented these oxbows at the time of the August floods, and at least one of them was then killed by a mink.

In 1941, an oxbow pool had a territory, and in October, a large family group almost disappeared without detected reason and without corresponding establishment along the practically unoccupied three-quarter-mile stretch of Squaw Creek lying to the east.

In 1942, the oxbow series had two territories, and a third territory (one of those listed as a Squaw Creek channel territory earlier in this chapter) was situated at a junction of the oxbow series with the creek. The occupants of the latter worked along both the creek and the adjacent oxbow series. In early June, it was seen that the water levels of the oxbows were high but without any overflow into the creek. By the

first of July, despite some floodings, one of the territories had active young of about five weeks. On September 23, after a severe flood beginning September 14, the pools showed good signs, and several burrows and flood nests were in use. Signs under the new ice of late October indicated that muskrats were living in only three places along the oxbow series, possibly about 15 in all, including an animal living alone. By mid-November, the water was down to about a foot and a half below the summer level, thus leaving the oxbows nearly dry. My estimates were of a lone animal at one place, two or three at another, and several at the place having the most signs — about ten, all together. Beyond doubt, many of the muskrats moved over to Squaw Creek in late summer and early fall. A half-mile stretch of creek having hardly a muskrat in it then lay invitingly within a few hundred yards of one of the well-used oxbow pools; and muskrat paths between pool and creek could be distinguished at this time.

The oxbow series had no territories in 1943, but it had rather general signs of newcomers in late August and more or less heavy signs in three places by September 8. I think that these oxbows were virtually depopulated by severe trapping during the 1943-44 season.

The oxbow series had a territory in 1944, centering about a burrow that had been dug and temporarily occupied in previous years. Few muskrats were left by late fall. The series was muskrat-vacant in 1945, but in 1946, three territories were established there, to be abandoned later in the summer. In 1947, no territories were established in spring or early summer, but possibly a half-dozen muskrats came in during late August or early September, despite the shrinkage of the waters because of the drought; none was left by late fall. In 1948, the series had another territory, near a territorial site of previous years, but again, the muskrats were gone by late fall.

The series had no more known muskrats until a territory was established in the spring of 1952. The latter was abandoned, after occupancy by a considerable group of muskrats, in late June or early July. Then, a probable lone muskrat frequented one of the pools for a time during the summer of 1954. There was none thereafter through 1957.

It should be mentioned that the oxbow series lost habitability for muskrats during the early fifties. All but one major pool filled with silt, until it became difficult even to find the original locations of some of them. Even during wet seasons, the pools would be little more than puddles.

Pasture Brook Near Rainbolt Ponds

This brook (including its deep head pool next to a large tile) was muskrat-vacant from 1934 through 1941. In late summer, 1942, some animals established quarters and probably wintered at least fairly well.

In 1943, two territories were established along about a quarter mile of the brook; one of these was not much more than 100 yards from

one of the territories of the Squaw Creek channel. The latter brook territory had only one or two muskrats left by mid-September, while the upstream territory then had splendid signs. An adult male, an adult female (with 18 placental scars representing three early to mid-summer litters), 2 young males, and a young female were examined during the 1943-44 fur season, together with 2 young males and 3 young females from a stretch of neighboring brook lying outside the observational area to the east.

In 1944, the brook had a territory, but both adults were found freshly dead of hemorrhagic disease during the summer. The brook nevertheless remained well populated with young animals and, by fall, some more muskrats almost certainly had moved over from the Rainbolt Ponds. Carcasses of muskrats taken by trappers during the 1944-45 fur season were 4 adult males, one adult female, one young male, and one young female. About as many more muskrats were left to winter.

In 1945, the brook had a territory in spring and early summer, later to be depopulated. In 1946, it had another territory, which had few muskrats left by late August, and the hemorrhagic disease was suspected as a reducing agency in this case.

In 1947, the brook again had a territory and splendid signs throughout the summer and fall. My estimate was of about 20 muskrats entering the winter. These were the best-situated muskrats in tracts A-F, but even so, a specimen of a young female examined in early winter was in lean condition.

In 1948, the brook again had a territory, and a population of about a half dozen remained by fall. It had another territory in 1949 and one in 1952, both of which were muskrat-vacant before the summer was over. In 1955, it had a lone animal territory which was maintained until early in August; thereafter, no more muskrats through 1957.

New Gravel-pit Pools on Turner Estate

These pools, so new as to be barren of muskrat foods though with attractive depths of water, had two subadults moving in during late fall, 1947. Both were captured by hand and marked by toe-clipping as they foraged in a stock-pastured corn field. When last handled alive after the middle of February, 1948, they were both in extremely poor condition, continuing to risk their lives in all kinds of winter weather for the trifling plunder—including pieces of muddy corn stalks and roots—they were able to find in the field. The one toe-clipped specimen actually retrieved after death for posting had typical liver lesions of the hemorrhagic disease. In view of the isolation of these 2 gravel-pit muskrats and the absence of old muskrat retreats at the ponds, the occurrence of a case of the hemorrhagic disease—evidently just getting a start—is hard to explain. The animals certainly withstood much hunger, and one of them seemed blind from freezing its eyes.

By 1952, there was sufficient natural vegetation in the water of the new gravel-pit pools to make them more or less habitable for muskrats. Two territories were established in midsummer by muskrats moving in from overcrowded Squaw Creek, and by late summer and fall these were full of young muskrats of various ages. My estimate of the population present in mid-October was between 30 and 40, mostly centered about the original territories. These animals were practically trapped out during the 1952-53 fur season.

In 1953, the gravel-pit pools had a territory, but by September signs of only a single large animal could be seen. By early winter, the latter animal was gone, and the pools remained without known muskrats throughout 1954. In late summer, 1955, a substantial number of muskrats came into the pools and stayed for a few weeks; they were gone by midfall. No signs of muskrats were seen about the pools in 1956.

A big muskrat stayed around throughout the summer of 1957, then an estimated 10 to 15 established themselves during the fall, apparently to winter well.

Brooks Northwest of Gilbert

The two brooks here referred to are in the west half of Section 36 of Tract F. One is a county drain, first appearing on the surface as a pool in front of a tile, which will suffice to distinguish it from the natural brook in the following text.

To the best of my information, neither brook had muskrats in residence from 1934 through 1940, though I may have overlooked some signs of muskrats in the earlier years of the central Iowa investigations. The natural brook had a territory in 1941, and 8 muskrats were here taken by a trapper during the 1941-42 fur season.

In 1942, both the natural brook and the pool at the head of the county drain flow had territories. The natural brook had localized signs of probably a single litter by mid-October, but what seemed to be only a single adult remained to winter. I think that the others abandoned their old territory when it dried out in late fall, to congregate downstream at the junction of the brook with Squaw Creek, where there were some muskrats that might be accounted for on this basis. The remaining large animal foraged actively during the winter.

In August, 1942, at the site of the county drain territory, a big dog devoted much time to digging out muskrat burrows, and the muskrats responded by digging new burrows. The muskrats of active sizes seemed to take care of themselves without difficulty, for, concealed by submerged plant growths, they could move unobtrusively through the shallow water from one burrow entrance to another. In late summer, the territory was re-established in a pool between two and three hundred yards downstream from the usual sites of activity of the dog. No trapped carcasses were examined from the county drain during the 1942-43 fur season, but Wallace Hadaway told me that he caught 6 from the vicinity of the pool. From his description,

I judged that 2 of his muskrats had been born in August or September. I think it likely that the dog killed most of the members of 2 late-born litters, and that a total of about 10 may have represented the pre-trapping fall population of the upper part of the county drain. Wintering signs of a very few muskrats could be seen about one burrow. No muskrat remains were found in five winter mink scats.

The natural brook had three territories in 1943. Two of these territories were dry and abandoned by September, as was the third by late fall, except for a few muskrats remaining in residence at one place. One of the latter apparently was killed by a mink, as one of ten mink scats dated to November contained muskrat remains. On the other hand, a collection of 216 mink scats gathered locally from May through October contained no muskrat remains. These scats were mostly from a family group of minks having a den in one of the previous year's muskrat burrows along the county drain. The drain itself had a probable lone-animal territory in 1943.

After two years of no resident muskrats, the natural brook had a territory in 1946, which was maintained in excellent condition next to a corn field until at least midfall; it had no muskrats in residence in 1947. The county drain, which had been muskratless in 1944, 1945, and 1946, had 2 known muskrats in late fall and early winter, 1947-48.

In the summer of 1948, the pool of the county drain was dredged, and the brook into which it drained was deepened and straightened into a ditch. This meant considerable modification as muskrat habitat, without making it wholly unattractive for the species. Neither this place nor the natural brook had more than an occasional transient from 1948 through 1951.

In 1952, both had territories of which that of the natural brook was highly productive of young but almost abandoned by October. The territory of the county drain seemed to be maintained by a lone animal throughout the summer and well into the fall, if not through the winter of 1952-53. In 1953, the natural brook had a lone-animal territory, and the county drain had no known muskrats. Both were without known muskrats in 1954.

In 1955, the natural brook had two territories, and the county drain had a probable lone-animal territory. The natural brook territories were highly productive early in the summer, but most of the animals left about the first of August. By late August, the observational stretch of brook was all but abandoned, with the remaining few muskrats localized in one fairly deep pool and raiding an adjacent corn field. By early September, the signs indicated that muskrats were coming into the pool from outside; and heavy signs were characteristic of this place through most of October. As the water level went down until the burrow entrances became exposed in late October, the muskrats largely disappeared — though some few animals continued repairing the burrows, raiding the corn field, and depredating upon

the bullheads, carp, and other stream fishes stranded in the shallow water. By the first of November, a big mink was using the then-exposed burrows. I could make out no positive sign of living muskrats until late in the winter of 1955-56, when it became apparent that some muskrats did remain alive in the corn-stocked burrow chambers.

The dry pool of the natural brook regained enough water in the spring to serve as a productive territorial site in 1956. The resident pair had three litters, these born about mid-April, mid-May, and mid-June. By mid-July, the pool was drought-exposed once more and, a week later, the residents were engaging in limited upstream and downstream adjustments. There was some mortality involving at least the youngest litter at this time. By the end of the first week of August, the territory was abandoned, except for a probable lone animal living at a muddy hole a short distance downstream from the dry pool. Despite great effort, I did not succeed in tracing the route of movement of the muskrats when they abandoned the territory, seemingly as a family group.

Neither the county drain nor the natural brook had any muskrat signs throughout 1957.

Ditch and Brook Habitats North of Onion Creek

These marginal habitats along the west edge of Tract G consisted of a quarter mile of pasture brook leading from a country drain and a series of roadside ditch pools along the Boone-Story County line.

After the beginning of the central Iowa studies, muskrats were first known to be trying to live along the pasture brook in 1941, when about five animals took up residence in the fall. These foraged in the pasture and stream-edge growths next to the brook by working under the protection of snowdrifts when winter came. They were not confronted by the most desperate of emergencies, but they were vulnerable to mink predation. Three of thirteen winter and early spring mink scats from this place contained muskrat remains. The muskrats that succeeded in wintering left during the spring dispersal of 1942.

A single large muskrat moved in again about mid-July, 1942. It raided a corn field throughout August and September, cutting a recorded total of 115 stalks up to September 22, after which it supplied itself almost entirely from ear corn lying on the ground. A big animal that was probably the same one was caught by a trapper in late December.

During the spring dispersal of 1942, a minor route of travel away from Onion Creek proved to be the roadway on the Boone-Story County line, which led directly to the roadside ditch pools lying three-quarters of a mile north of the creek. What was evidently a lone muskrat appeared here to settle during about the last week of June, after the place had previously been visited by spring-dispersing muskrats up to but not noticeably later than April 21. This animal fed in a corn field from the time that it arrived, and 208 cut stalks

were counted up to late August; it then subsisted largely upon natural vegetation supplemented by ear corn picked up from the ground.

Water levels of the above ditch pools were much dependent upon current rainfall and only a wet season could keep this partly isolated niche habitable for muskrats — which is an adequate explanation for the absence of muskrats here during the early years of the study. On August 12, 1942 — during an exceptionally wet year — the level was 18 inches below its highest level earlier in the same summer. By August 14, the water went down three inches more, and an inch and a quarter more in the following twenty-four hours. From August 19 to 25, among other times during summer and fall, the water in the ditch was rapidly reduced to small puddles, until a heavy (2.37 inches) rain on August 26 refilled the ditches, and the drying sequences started all over again.

After evidences of a moderate amount of cross-country movement began to be seen about August 15, a subadult male (collected for examination December 12) joined the adult living in the ditch. The adult itself succeeded in wintering, despite the fact that it improvised living quarters in a snowdrift that was repeatedly visited by a big mink. (Four mink scats contained no muskrat remains.) The snowdrift nests and tunnels were used after the water in the ditch had frozen. The adult continued feeding upon corn, whether from stored supplies or carried from the fields during the milder weather.

The pasture brook had, in 1943, what seemed to have been a single old muskrat from mid-March at least to July 10. The roadside ditch had a breeding territory; one member of the pair was almost certainly the muskrat that had wintered there, while the other came probably about mid-March. At another part of the same ditch but farther north, a chewed-up, sexually active but unbred female was collected for a specimen on April 19, after it had dug a shallow burrow.

Three litters were born to the ditch pair in 1943: in early April, early May, and early June. The water had almost disappeared by July 13, but was replenished by rains that night (0.67 inch) and on July 16 (1.62 inches). By mid-August and later that month, many more signs were centered about two parts of the ditch. By September 9–10, as the water again went down, signs of many muskrats became increasingly evident. On September 30 and October 30, rains (1.10 inches and 0.41 inch, respectively) relieved drought conditions at the ditches, but partial abandonment of the ditch habitats already had taken place by late October. Nearly all of the muskrats except the old ones had left by the opening date of the trapping season, November 10. Three trapped specimens were an adult male, an adult female (with 28 placental scars representing three early-season litters), and a young female. What appeared to have been the last resident was killed by a mink about December 28, at which time little or no unfrozen water remained in the ditch.

The pasture brook had no known muskrats in residence after 1943 to the end of our period of study in 1957.

In 1944, the ditch showed the first sign of a newcomer about March 25. On April 7, two muskrats were seen here, and, by mid-July, signs of both young and old were conspicuous. On July 23, when the ditches were nearly dry, abundant track signs could be seen about all exposed retreats. A month later, the signs looked very similar, and excellent signs were still in evidence on September 10 after a rain. By September 18, the water was getting low again, and by October 23, the ditches were all but dry; still, signs continued to be heavy, especially as the muskrats began raiding an adjacent field of soybeans. This group of muskrats was believed to have consisted essentially of the adult female of the original territory and her reared young from one litter.

The raiding of the field of soybeans continued at intervals through the winter of 1944-45. Two of the animals established quarters in the bean field, living in nests under the snow or even in holes dug in the ground. One of the two muskrats of the bean field died from unknown cause — possibly exposure — about December 20. (December, 1944, was a cold month, with a mean temperature nearly six degrees below normal and extremes as low as seventeen degrees below zero.) The other muskrat in the bean field lived in a ground hole and fed on conveniently available beans until about the middle of January, 1945. Ex post facto "reading of sign" during a thaw in mid-February suggested that this animal had moved over to the far side of the bean field before January 23, there to improvise a nest in a big snowdrift well over 200 yards from the ditch; its later fortunes were not traced. The occupied ditch continued to show push-ups, snow trails on mild days, and other signs, and, on March 14, four muskrats were simultaneously in sight.

The roadside ditch had, in 1945, a breeding territory that was to some extent productive despite many exposures through drying. Several muskrats lived there through September and into October. Then, new dredging improved the drainage of the ditch, and it lost whatever habitability it ever did have for muskrats for the period of study through 1957.

County Line Ditch North of Squaw Creek

This ditch really came into existence as muskrat habitat with some dredging operations in 1938. The pool at the head of the ditch drew about four muskrats during the fall adjustments, and one of these muskrats escaped the 1938-39 fur trapping to winter. In late summer and fall of 1941, a few muskrats moved into the ditch and pool; and a similar ingress occurred in late summer, 1942.

The ditch had a functional territory in 1944, but many of the muskrats abandoned it by late fall. There was another good territory at the same site in 1945 and still another in 1946. During all three of these years, the territories were highly productive and were situated

close to raided corn fields, yet they became practically vacated by early fall.

In 1947, following a muskratless spring and summer, perhaps four muskrats appeared in early fall at the pool, the attractiveness of which had been improving because of an increasing stand of cattails in its vicinity. The muskrats of the pool came out occasionally on the surface during the winter of 1947–48, and two man-killed animals were found, a subadult male and a subadult female.

In 1951, the ditch pool and environs probably reached its maximum attractiveness during the period of study when extensive stands of cattails grew in a series of erosion-cut ditch pools above as well as below the big pool at the head of the dredged part. The ditch had no resident muskrats until late August, when a large group moved in across the pasture from Hutchinson's Lake, lying to the west. Then, after about three weeks of digging, burrowing, plastering of mud, and cutting and carrying of vegetation, this group suddenly departed, leaving the pools entirely muskrat-vacant for the time being. Then, once more, in late September, the ditch began drawing in muskrats, which worked from Squaw Creek up the length of the ditch to the pools. This up-ditch movement was rather gradual but it culminated in another large assemblage of muskrats about the pools, for the period of about two weeks. By late October, the ditch and pools had no muskrats remaining.

In 1952, the ditch had another territory situated next to a raided corn field, and at least two litters were born in early April and early May. There were about 20 muskrats here by late August, plus a probable lone individual at the main pool. They all seemed to have gone by mid-September, but there was at least a lone individual to track up the snow about the pool in early January, 1953.

What seemed to have been a lone individual moved up the ditch about the first of June, 1953, to establish headquarters in the cattail growths downstream from the main pool. The signs indicated that this animal stayed around all summer, to be joined by several more muskrats in early fall. During September, the animals wore a heavy trail to the edge of a corn field about 200 yards downstream, but, by early October, they were feeding mainly on natural vegetation in the vicinity of the pool. All were gone by freeze-up.

No muskrats were known to have been in residence — or even to have visited the ditch and pool — in 1954.

The ditch had a splendid territory in 1955. In mid-July, signs of large young animals from the territory could be seen extending to the main pool, which lay over 100 yards upstream. At the end of the first week of August, there were muskrat signs along the entire ditch, including worn trails over the exposed bottom between residual pools in the lower third of the ditch. The signs indicated that a great troop of muskrats had moved up the ditch from Squaw Creek about the first of August. These animals represented most of a population that had

been massing for a week or more along about a mile of creek beginning immediately downstream.

The newcomers did no raiding in the corn field at first, feeding mainly on greater ragweed growths along the lower part of the ditch and upon cattails in the vicinity of the main pool. The differences in age of signs about the pool suggested that the occupants of the original territory had moved out a week or so before the heavy ingress from Squaw Creek occurred. By late August, the pool had no current signs, though there was still evidence of a tremendous amount of activity at the lower part of the ditch and adjacent Squaw Creek. By mid-September, muskrats were back up-ditch, not at the pool but living in a dry set of burrows eighty yards below the pool, at the edge of a raided corn field; downstream, heavy trail signs extended up the mouth of the ditch from Squaw Creek. By early October, and continuing until freeze-up, heavy trail signs were laid down between some pools in the stream bed of Squaw Creek and a corner of the raided corn field. The raiding route between stream-bed pools and corn field was about 200 yards long, but the weed-grown condition of the ditch offered the muskrats good concealment over about two-thirds of the distance.

There were muskrats left by freeze-up both at the main pool of the ditch and at the burrows in the creek pools that the newcomers had stocked with ear corn from the field adjacent to the ditch. A lone animal wintered at the ditch pool. It left early in March, 1956, but another one appeared in mid-July, to stay the rest of the summer. No sign of occupancy was found thereafter through 1957.

Roadside Ditches Northwest of Gilbert

The main ditch habitat here referred to had some fairly deep pools near its junction with Squaw Creek in northwest Section 1 of Tract F, and one of these pools had a territory as early in the study period as 1936. Later in that summer, in response to drought conditions, the occupants of the pool moved to the creek, there apparently to take up living quarters in what was still within their familiar home ranges.

This place thereafter was muskrat-vacant until 1942, when a territory was established in the ditch near the southwest corner of Section 36. The territory probably lost a litter through flooding in early June, and by midsummer all of the muskrats of the ditch seemed to have left. By fall, the ditch was nearly dry, but water remained in the deeper parts, and some animals reappeared to try wintering there. Six carcasses of animals trapped during the 1942-43 fur season were all of young of the year, including a "kit" born about August.

A territory was established in 1943 at the site of the 1942 territory, but the female was killed by a dog about May 11. The victim had ten very recent placental scars and six small embryos due for birth in early June. Earlier in 1943, on March 14, presumably the same dog had killed a young unbred female, the body of which was cleaned up

by a mink within the following two weeks. The ditch habitat was muskrat-vacant for most of May, June, July, and August, but then some muskrats came in to establish living quarters at the site of the lost territory. They withdrew again to Squaw Creek in late September, as the ditches were going dry.

The next muskrat occupants were some that took over a pond between ditch and Squaw Creek in August, 1945, but they left before freeze-up. However, the pond was the site of a maintained territory during at least the early part of the 1946 breeding season. In 1947, a territory first established at a ditch pool was later transferred to nearby Squaw Creek.

Dredging operations in 1952 terminated the ditch and the pools as muskrat habitat.

The other roadside ditches of Tract F that were occupied by muskrats from time to time were along the north central and north-west boundaries of Section 35.

One near the northwest corner was occupied in 1943, probably by a lone female that had been pregnant when she arrived; by September, the territory was dry and abandoned. In 1944, the site of the 1943 territory was again occupied, to be again abandoned in late summer and fall. This ditch was situated next to a sedge-grown swale offering a good food supply, but it hardly had more than a puddle of water even during wet seasons. Its main advantage was a burrow system under a cement culvert that afforded good protection from digging dogs.

The ditch at the north central boundary of Section 35 was also connected with a shallow natural oxbow, and the latter had territories in 1943 and 1945 which were abandoned in late summer and early fall. In 1947, a lone, unbred female maintained a territory here from early April to early May, when she was caught in a set trap that someone had failed to take up at the close of the 1946-47 fur season. An estimated four animals moved in to occupy the drying oxbow about late August or early September, 1947, to move on by late September. The next time that this ditch was known to have been occupied was in early August, 1952, when a lone animal stayed briefly at a wet pool beside a culvert, about 100 yards from the previously used territorial sites.

Miscellaneous Outlying Waters of Squaw Creek Drainage

An oxbow east of Squaw Creek in Tract C had a territory in 1936, the occupants of which moved to the creek during the early weeks of the summer drought. It was the site of a productive territory in 1943, though abandoned by early fall. The same territorial site was occupied in 1944 and 1945, also to be abandoned by early fall of those years.

Farther north, in lower Tract F, a woodland oxbow pool had a territory in 1943, for the only time in its recorded history. It still had several muskrats in late fall, but none remained by freeze-up.

There was, in 1940, a territory in an oxbow pool east of the junc-

tion of Squaw and Montgomery Creeks. In 1943, this oxbow had another territory, and by the beginning of the 1943-44 fur season, it was full of muskrats, but I failed to obtain any specimens for examination. While no breeding territory was present in 1944, many muskrats came in during the fall, and at least a few wintered, 1944-45. The oxbow again had a breeding territory in 1945 and another in 1947, both to be abandoned before fall. Thereafter, the oxbow was not known to have had any muskrats, even though in some years it was in attractive condition for them.

Also in Tract F, and about a half mile from the Turner Estate ponds, some old gravel-pit pools had at least two muskrats—a large and a small one—by late August, 1943, and some muskrats entered the winter. In 1948, these pools had a maintained and productive territory for the early part of the summer.

Near the middle of Section 30 in Tract G, one very temporary pool entered our records as muskrat habitat only for the fall and fur season of 1943-44. Eight trapped specimens from here were six young males, and two young females, surely representing newcomers.

South of and draining into Montgomery Creek in Section 35 of Tract F, a boggy ravine drew in several muskrats in the late summer and fall of 1944, and signs of surface activity were seen here in early winter. This was the only time during the period of study that this place was known to have had muskrats.

Three places lying within three miles of tracts A-F were observed during the winter of 1947-48 to learn more about the fortunes of precariously situated muskrats of brooklike habitats. One of these brooks adjoined the highway, U.S. 69, at which place six traffic-killed muskrats were found between January 14 and March 28. The victim of January 14 (the only one intact enough for post-mortem examination) was a thin young male.

Another site of outdoor activity was next to a farmyard, where a lone muskrat came out from beneath a shelf of ice to feed on corn in cow dung from early January until the last of February, 1948, when central Iowa habitats of this sort became flooded with melt water.

The third place in this category was a brook running through the College Arboretum southwest of Ames. Outside activities were noted early in the winter, but the signs did not become pronounced until early February, 1948. On February 7, three individuals were foraging on the land bordering a half mile of brook, and a dead one (cause of death undetermined) was found frozen in the ice. The most comfortably situated of the three land-active animals lived in a tile opening that had been partly plugged with ears of sweet corn. Another made repeated journeys into a rather bare corn field, and the third ranged as far as 300 yards up and down the brook, feeding mainly on fringing sedge growths and coarse grassy or weedy vegetation.

Des Moines River West of Ledges State Park

This river is larger than any stream kept under regular observation in central Iowa, and a sample mile was worked on July 29, 1947,



in an effort to obtain more information on the possible effects of the June floods on muskrat populations. On this sample, where the flooding had been exceptionally severe, at least three territories having young over two months of age were distinguished. An estimated population of between 40 and 50 adults and fairly large young was not a very large one, but neither did the population look like one completely overwhelmed by the floods.

The sample stretch was revisited in mid-October, 1948, at which time muskrat signs were remarkably scarce. I figured that not more than three or four lived along the west three-quarters of the sample mile, with maybe as many more along the other quarter mile. To the east, just off the sample, was a burrow system having signs of an estimated half dozen more muskrats. The reason for this sparseness was not evident, for living conditions on the whole did not look grossly unfavorable for muskrats. Beavers were abundant in places; their conspicuous trails and burrows did not seem to be used by the few muskrats present.

Another revisit was made in mid-October, 1949, covering the same mile visited during the previous two years, plus another mile added to insure more representative data. The signs were restricted and usually light. Relatively few places had attractive and livable habitats for muskrats, as the flow was mostly confined to gravelly stretches of the central stream bed, thus missing the sites of old burrow systems. The remaining places that would have been suitable for muskrats — banks with willow thickets or corn fields near the water — were dominated instead by beavers. Muskrats did co-occupy some of the best habitat with the beavers, but there seemed to be, if anything, more beavers than muskrats, even where the muskrat signs were heaviest. My estimate of the muskrat population was eight or ten centering in one deep pool and perhaps another half dozen scattered along the rest of the two-mile stretch.