Part 2

Case Histories of the Iowa Observational Areas

Chapter 4

Objectives and Techniques of Regular Observations

THE PROBLEMS INVOLVED in researches in population dynamics can not be approached through any single scientific discipline. Some problems may be investigated in the laboratory through experimental manipulations, as has been illustrated by numerous publications of Pearl, Chapman, Allee, Gause, Park, and their colleagues and students, among others. Even these primarily laboratory investigators used the more reliable field literature in supplementing and orienting their own work. Park (1939; 1941), in particular, urged better integration of field and laboratory studies, and so have Nicholson (1954) and Andrewartha and Birch (1954). Raymond Pearl, himself a great pioneering experimenter with laboratory populations, remarked in one of his last papers (1937) upon the natural equivalents of long-term experiments afforded by populations existing under widely differing circumstances.

I have emphasized field studies. Of the field problems within my experience, some were amenable to experimentation and some were not; and, if they were not, the closest equivalents to experiments were sought.

The Iowa observational areas, the case histories of which follow this chapter, were selected because they were workable and representative. Year-to-year studies were begun on each area, with the intention of continuing them as long as they were feasible and satisfactorily productive of data bearing upon the problems considered. The overall objective behind the field program was to learn as much as possible about muskrat populations.

The density factor, rated decades ago by Pearl and Parker (1922) as of outstanding population significance, had proved to be so important in my earlier field studies of the bobwhite quail (Errington, 1941b; 1945) that the muskrat studies were likewise directed to investigate this factor as it applied to muskrat populations. Throughout the years, routine acquisition of annual statistics on muskrat populations of each Iowa observational area was the job of first priority. Special studies of responses of muskrats to droughts or other emergencies, as well as studies of epizootics, predation, intraspecific strife, and movements, were worked in wherever timely and possible.

ON FIELD STUDIES AND THE "READING OF SIGN"

Relatively few of my field observations in the routine studies of muskrat populations consisted of observing directly the animals themselves. The living habits of muskrats are such that they spend most of their time out of sight of human eyes, concealed in habitations or under cover of water, ice, vegetation, or darkness. Even during weather promoting large-scale diurnal activity in places where visibility may be good, more animals may remain in lodge or bank retreats at a given time than come out in view. One may gather excellent data for the duration of weeks-long crises and seldom see a living muskrat.

A certain amount of mapping, blocking off sample areas, and recording changes in land use, weather conditions, and food-cover-water relationships for the various areas was done, along with other work fundamental to an ecological study. The earlier years of the investigations were those in which the most detailed mapping and recording systems were tried, then gradually discontinued or modified with increasing experience. The earlier extremes in intensive work involved, for examples, efforts to mark, number, and note for a full year the histories of 271 sites of muskrat activity along several miles of small streams (Errington, 1937a); to map in scale the muskrat habitations of a 450-acre marsh and to follow the fortunes of these habitations throughout the breeding months (Errington, 1937b); and to measure muskrat exploitation of the relished corn in fields bordering a half mile of drainage ditch (Errington, 1938).

With experience, as the feasibility of short-cuts in gathering the more conventional ecological data became demonstrated, emphases in detailed studies were shifted considerably toward mapping the spread of epizootics, the examination of large population samples, the tracing of mortality during crises, the search for truly limiting factors. Systems of large-size sample areas were found to be advantageous in both marsh and stream work.

The mainstay of my field observations on the muskrat was "reading of sign," that is, studying the meaning of tracks and trails, of diggings and cuttings and heapings, of food debris and droppings, of miscellaneous traces, of blood, fur, wounds, and carcasses. Information thus obtained was used in conjunction with quantitative indices from specimen material.

To be effective, such observations must be specifically directed to the extent that they produce pertinent data without undue waste of time and effort on trivialities, yet they must permit the scouting needed to discover unexpected happenings. A planned program may be weakened by errors of judgment or oversights, as may be illustrated by my own early neglect of placental scars as supplementary evidence on breeding. I also failed to recognize the lesions of the hemorrhagic disease until 1943 and certain of the most dramatic implications of the disease until still later. Nor are distinctions between values of facts always easy to make, nor, for that matter, distinctions between what are facts and what may only appear to be facts.

In describing the season-to-season routine work on the central Iowa observational areas, I shall begin, for convenience, with midwinter, after fur trapping by the public is over. At the latitude of central Iowa, midwinter "reading of sign" of muskrats must usually be limited in scope. Flashlight and mirror combinations and some other gadgets for looking under water or ice were tried, as were some tricks in taking advantage of muskrat psychology. It was possible to learn about the contents of deep bank burrows through inducing the animals to plug breaches with movable items that they found within — nest linings, food debris, and bones along with the sticks, stones, and mud. Excavations with axe, pick, spade, or hay knife were especially revealing at some times. On occasion, a dog or a woodchuck obligingly dug out a burrow chamber, spreading out to view a collection of items. Mostly, the informative winter signs were those on the surface of the land, ice, snow, or lodges, and part of the significance of the signs depended upon what was *not* to be seen. Scarcity of external tracks about an Iowa marsh where a substantial population of muskrats is known to be wintering may be an indication that the animals are getting along well; and the converse almost inevitably is an indication of something being wrong, at least with regard to the individuals engaging in much outside activity in cold weather. Particular efforts were made to locate and study mortality victims while they were still relatively fresh and intact.

Incidences of muskrat remains in mink scats were useful indicators of security or of crisis in the lives of the muskrats (Errington, 1943; 1954b). Minks tended to frequent the habitats that were the more food-rich for them, which in Iowa were usually the marshes rather than the streams, so it was about the marshes that the mink scats commonly (not always) were picked up in greatest quantities.

Concerning the hundreds of muskrats examined as winter mortality victims, whether killed or fed upon by the minks or not, the following may be said: They included trap cripples, with stumps from the wringing-off inflamed or cleanly healed. Victims' bodies were free of other wounds or with all parts bitten by other muskrats. Victims were found as fragmentary remains but with partly bare tail vertebrae from which the once-frozen flesh had been gnawed in life. They were individuals attaining sexual maturity and corresponding restlessness ahead of schedule. They were those breaking out of lodges or at the edge of the ice, to die outside of old or new injuries, hunger, exposure, disease, or by direct attack of mink, fox, dog, or other predator finding them at a disadvantage.

Specimens examined singly often did not reveal anything diagnostic, but, if adequate series were obtained, the story behind any large-scale winter-killing usually became clear. This was especially true in the case of epizootics, which often depleted local populations without leaving many external signs, or left the evidence so obscured by the scavenging of minks that casual observers easily mistook it for evidence of simple predation. When die-offs were in progress, the bodies of the dead sometimes greatly exceeded the abilities of the local scavengers, which included not only minks and foxes but also cannibalistic muskrats, to find and consume them, and it was then possible to obtain variable quantities of fresh and intact specimens for study.

Although activities of muskrats on top of the ice or in the snow may suggest trouble, indirect evidence of well-being on the part of a wintering population may include some signs visible from above. Fresh plugs of vegetation in cracks in the ice either near or away from lodges or burrows, repairs of maintained retreats damaged by mink intrusions or by cave-ins during thaws, the presence of fresh frost on parts of a lodge, of thin ice or open water in front of lodge or burrow entrances — all of these sorts of signs afford an index as to how the muskrats are getting along. If the ice is clear and not too thick, the animals may be seen swimming, or their droppings and food particles be noted beneath. And, if sample lodges are opened at intervals for inspection, much may be learned from their internal appearance, particularly toward mid- or late winter.

The evidence obtained through cutting into lodges or the ice over burrow systems should be interpreted in terms of the level of water beneath the ice. If the under-ice spaces are well filled with water, the retreats of the muskrats are accordingly restricted to the higher parts of lodges or burrow-chambers. On the other hand, if the water beneath the ice recedes, leaving extensive air spaces, the animals may withdraw to the lower parts of burrows, to the very bottoms of the lodges, or may be living almost anywhere under the ice in the vicinity of their lodges and burrows.

Partial melting of the ice during thaws of late winter or early spring affords opportunities for learning about subsurface adjustments. The melting may expose details of main burrow systems deepened by the muskrats as the winter progressed. So may be exposed the retreats under ice heaves, hollows and nests in snow drifts, feeding and dropping signs, latrines and left-over food items of minks, concentration sites of desperate fishes. A rich medley of revelations may be dated backward by one knowing something about weathering processes, about rates of discoloration, softening, and decay of organic material at ice water temperatures, and about time intervals between major changes in air temperature, storms, and other events useful for dating.

The winter's dead muskrats often may be retrieved in quantity soon after the ice goes out, sometimes refrigerated in lodges having interiors that remain partly frozen, but more often as the dead float on the surface of the water. These floaters may be so rotten as to lose hair and appendages, but their viscera may still be sufficiently intact to show distinguishable disease lesions in a fair proportion of the cases. A most workable technique is the approximate dating of winter losses on the basis of sexual advancement of specimens at times of death.

Despite the usual irregularities in daytime visibility of muskrats, the break-up of the ice may provide opportunities for rather satisfactory censusing on occasion, by direct enumeration of local muskrat populations surviving the winter. The efficacy of the method varies largely with the weather, the hour of day, and the habitat. I have found it best for use on central parts of marshes on a still, warm day. At the right place and time, an observer may count virtually all of the muskrats of a sample tract just before the main spring dispersal begins.

Subsequent to the main spring dispersal in the north-central states, or beginning about the last of April or – preferably – early May when settling for the breeding season is pretty much accomplished, territories were blocked off and counted on the basis of foci of activity. This was done fairly well in Iowa until late June or early July, when the activities of the half-grown or larger young of the season obscured the original territorial foci. Under special circumstances – as in 1942 and 1944, when recurring floods drowned almost all of the young born until the middle of June along central Iowa streams – territorial calculations were continued into August. Where sparse numbers of muskrats lived in extensive tracts of good habitat, the distribution of the breeding territories could be apparent even by late fall or winter, but the farther one leaves the breeding months behind the greater becomes the chance for error.

After the routine territorial checks were finished or comfortably under way, more time was given to other and often far more interesting phases of the field researches. Then, and for the duration of the summer and early fall, about the only strictly routine work was collecting and examining scats or pellets of minks, foxes, and horned owls (sometimes of raccoons and other predators or scavengers). Areas were visited frequently enough to record evidence of any unusual mortality of adults, of movements, of the onset of epizootics.

Some of the procedures followed will be self-evident from the case histories of the observational areas to be presented in this section of the book, or from the papers on tagging (Errington and Errington, 1937; Errington, 1944) or those dealing with restricted aspects of the investigations (for examples, see Errington, 1937b; 1938; 1939b; 1941a; 1942b; 1954b; Errington and Scott, 1945).

Late summer and early fall almost always has been one of the slackest periods from the standpoint of the Iowa muskrat investigations. Not only were field observations then hindered by wider distribution and greater abundance of signs and profusion of vegetation, but, under normal conditions, not much usually happened to the muskrats at that time. Despite home range adjustments and often wholesale trespassing by "kits" and subadults, intraspecific relations tended to be rather peaceful. Now and then, animals died from miscellaneous agencies, which could be hard to trace because of the rapidity of putrefactive changes. (In contrast with the state of those dying during the cooler months, hot-weather mortality victims may be fresh-appearing externally yet with viscera too far advanced in decay to be diagnostically revealing.) The best post-mortems have indicated that most of the dead adults of this season were victims of old age and that most of the dead young were those having accidental mishaps befalling them, including drownings. Representations of muskrats in predator diets were commonly light, or quite lacking, except in the event of something like a drought or an epizootic. A great deal of the field work of this time of year fell in the category of patrolling, to watch for departures from the ordinary.

Field studies of muskrat populations also have been about as difficult to conduct on a quantitative basis in late fall as in early fall or late summer. Nevertheless, as the first frosts came on, the productivity of investigations in proportion to effort often increased decidedly. Epizootics have had a way of starting up about the first of October in Iowa, and, in their spectacular forms, have swept a section of marsh in a couple of weeks. When this sort of die-off occurred, not only did it provide opportunities to study epizootiological sequences in detail, but the dead of lodge-dwelling populations were at times almost completely retrievable for counting and examination. Thus samples were obtained from which much was learned about densities, sex and age compositions, and breeding histories (from placental scars of adult females).

It may also be possible actually to census the muskrats living in representative tracts of shallows dominated by duck potato. If the water is low enough, and the tops of the plants have wilted enough to leave surrounding water and mud flats clearly visible, sample lodges may be systematically dug out, and the resident muskrats forced out to be counted. The same technique may be used for census-sampling of populations living away from bank burrows in almost any body of very shallow water not covered by emergent vegetation. In making these counts, care must be taken to choose typical large, small, and intermediate sizes of lodges, to expose all chambers and passageways above the water or to trample down the parts where muskrats might be hiding with nostrils in the air. Enough time (a minimum of 15 minutes) should be allowed for submerged animals to use up the oxygen in their bodies and emerge. Of course, any technique involving so much disturbance should be used only sparingly and for good reason.

Summer droughts may or may not be broken by late fall, and long dry Indian summers may be superimposed upon them with lethal consequences for muskrats. When muskrats suffer emergencies in late fall, the manifestations may be impressive. By then, the period of minimal friction has terminated, and strangers may expect to meet with hostility if they venture into places held by property-conscious residents. Whether eviction from, or abandonment of, deteriorating habitat be gradual or sudden, the homeless ones wander or gather about marsh edges or lake shores. Details concerning such aggregates of unfortunates may be both interesting and informative. An observer may witness threat displays and fights between newcomers and residents. He may record the post-mortem condition of animals found dead or dying. He may compare collected samples of transients and residents. He may study predation by minks, canids, and birds of prey, and study the circumstances favoring capture or escape of the muskrats.

Ephemeral snows afforded opportunities to trace travel routes of wanderers along the lake and marsh shores — including sick animals leaving their old home ranges to go off and die. The bodies of the dead retained freshness for a day or two if lying in cold water, and liver lesions and some types of intestinal lesions could be made out surprisingly long after the bodies softened and became fungus-grown.

Much of the efficacy of reading signs in very late fall naturally depends upon what remains to be seen after freeze-up. When freeze-up comes with a storm that leaves rough or snow-covered ice over lake and marsh, the handicaps of winter observational work may prevent doing a great deal except examining mink scats, watching for tracks of surface-active muskrats, push-ups of vegetation or debris, and openings in the ice.

Freeze-ups characterized by days or weeks of clear ice may afford exceptional opportunities to learn about muskrat populations. Under the right conditions, muskrats can be driven out of lodges or burrows by stamping and minimal counts of them obtained as they swim away under the ice. Such counts, if carefully made with possibilities of error in mind, may comprise fair to good sampling. Food habits of the muskrats may often be followed closely through under-ice observations, and correlations made with availability or lack of availability of different kinds of foods. One may study the respective feeding trends of the established residents and of the late-comers, transients, or unpopular individuals that live by themselves — as in newly-improvised nests, in short or shallow burrows, in hollows in submerged logs, or in the spaces under overturned boats.

Where muskrat diets run to animal food (as is particularly likely when freeze-up occurs during low-water stages of streams), the bones and scales of fishes, frog eggs, clam shells, and bloody smears may be conspicuous about openings in the ice or about landings above the water. Often the principal signs under stream ice relate to caches of grass or ear corn, to diggings for roots in the banks, and to places about driftwood jams and riffles where items of interest (not excepting dead bodies of muskrats) may accumulate.

Muskrats dead of epizootics may be visible through clear ice in the vicinity of lodges or the entrances of burrows, and these may be easily retrieved for examination. And there is always the occasional dead one about any well-populated marsh. It may be a victim of age or strife or gunshot wounds. It may have little discernibly wrong with it. Or, it may show hemorrhagic lesions — maybe and maybe not the forerunner of a deadly epizootic. Or, during epizootics, the fresh bubble signs from muskrat activities may simply cease appearing over the passageways.

In reading bubble signs, bubbles signifying muskrat activities must not be confused with gas bubbles that happen to rise from the bottom and line up in misleading bunches under the ice over burrow entrances and passageways. Distinguishing between the sources of bubbles under the ice is neither always easy nor wholly satisfactory even for an experienced field man, but this is certainly one of the techniques in which experience counts. Nor should an investigator overlook the possibilities that some populations may have storage habits — relieving them of the necessity of much foraging away from their food-packed chambers in lodges or burrows. The foods most frequently stored on the Iowa areas have been ear corn and duck potatoes.

Another first-priority job in the gathering of routine data from the Iowa observational areas has been the examination of specimens taken from the populations in late fall and early winter. This has been an outstanding source of statistics on placental scars, sex and age ratios, incidence of "kits" and evident wanderers in a population, and of other quantitative data.

Used discreetly, and with awareness of what they do *not* show, such specimens may provide the best means of piecing together what may be lacking in an adequate picture of a population's reproductive history. If adult mortality and movements in or out of the observational area are negligible (or reasonably well appraised), sex and age ratios that are prorated from the number of breeding territories previously arrived at for late spring and early summer may serve as the principal basis for calculating late fall densities. Pro rata computations may be risky, however, if complicated by unappraised variables, as those introduced by droughts, epizootics, and movements.

The best Iowa series of fall specimens came from carcasses of muskrats trapped by the public for fur from November 10 through December. During these months, the placental scars from the last breeding season may be counted and fairly satisfactorily aged, and the differences in gonadal development of old animals and of young of that year may be readily distinguished. I have examined as many as a thousand specimens from an Iowa marsh in a single trapping season, and cooperating trappers have made available for study many lots totaling hundreds of specimens in each lot. Many specimen series are of course smaller, but, if these represent (as they sometimes do) practically entire population groups, they have their own distinctive values.

When adequate series of fall specimens were not available for age ratios, or when emergencies or movements invalidated calculations of fall populations from age ratios, estimates from signs were attempted. At very low densities confined to restricted habitats — those existing in the last stages of a lethal drought, for example — this method may give acceptable results, particularly in places where most of the remnant individuals occupying certain retreats are sooner or later found dead or otherwise accounted for. At higher densities, the technical difficulties of making good estimates may mount up, and subjective criteria must more and more be resorted to.

My own procedure in estimating numbers of muskrats from signs has been to consider the signs about each lodge or burrow system, then think back to my trapping experience and estimate that I could have expected to catch at least so many muskrats and no more than so many at a particular place. The two figures would be put down in my field notes. Then, I would put a check mark beside the figure that I considered nearest to the truth. In arriving at an estimate for the whole marsh or stretch of stream, I would add up the minima and maxima to get the range of estimates and, finally, in a separate column, add up the checked figures. The latter would be as close as I felt able to come to the true population through estimates.

MOSTLY ABOUT LABORATORY TECHNIQUES

Apart from experiments employing the muskrat as a laboratory subject, a large part of the laboratory work done on the species comes under the heading of the post-mortem examinations introduced in preceding paragraphs. The fact that many post-mortems are actually conducted out of doors, along a lake shore, or at some other site of finding specimens, should not alter their classification as laboratory work.

Figures 4.1–3 illustrate typical uteri and testes of adult muskrats and of young of the year, as in Iowa specimens taken about December 1. In Figure 4.1, the fatty material usually associated with the testes is shown; in Figure 4.2, the testes of adults (bottom) and young (two upper rows) have been dissected out. The testes depicted have all dried slightly after exposure to the air, but those of adults tend to be somewhat wrinkled, anyway, as well as more darkened than the turgid flesh- or cream-colored testes of the young. As winter progresses, the size range of subadult testes overlaps more and more that of the adults, until, by late January, this has lost much of its reliability as a criterion.

From Figure 4.3, it may be seen that the uteri of females born during the year (right and middle) are small and thin-walled, rather like cellophane in appearance. The uterus on the left had placental scars but they are indistinguishable in the photograph. I am sure that any uterus as enlarged and as thickened as this one denotes passage through a breeding season, whether showing placental scars or not. Figure 4.4 gives a better view of placental scars. Occasionally, a uterus intermediate in size and thickness (usually without placental scars but sometimes with) may be hard to classify, but, as a rule, the

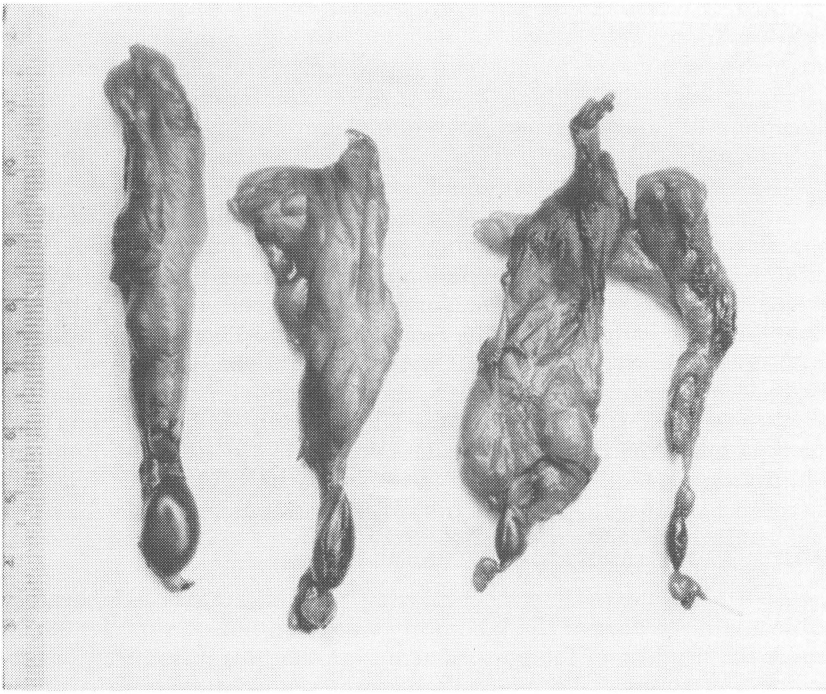

Fig. 4.1. Testes and associated fatty material cf fall-trapped Iowa muskrats. The two specimens nearest the scale on the left illustrate the appearance of adult testes, as compared with those of the young on the right.

Fig. 4.2. Testes of adult (bottom row) and young (two upper rows) of fall-trapped Iowa muskrats as they appear when dissected out of their associated fatty material.

categories are easy to separate for fall and winter specimens, and questionable specimens may be checked by tooth characters (Sather, 1954). Then, too, females may be more satisfactorily aged than males as the breeding season approaches, for uterine enlargement takes place late. Some investigators having access only to spring-trapped carcasses have ignored the males and tried to obtain age ratios of population samples from females alone.

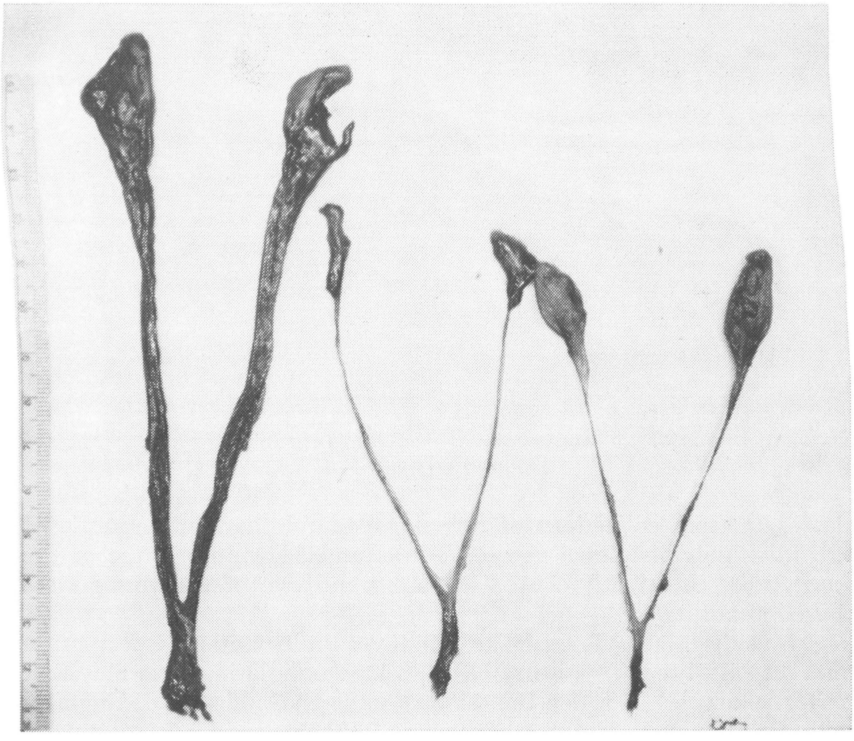

Fig. 4.3. Uteri of adult and young fall-trapped Iowa muskrats. Note the enlarged and thickened uterus of the adult (left, nearest the scale) compared with the two thin-walled small uteri of the young in the middle and right of the picture.

There are substantial potentialities for error in attempting age classification of adult and the larger sizes of muskrats on the basis of size and pelage differences. Some of my trapper friends have been astonished to see the undeveloped testes and uteri that could be demonstrated in large, adult-looking carcasses. A tagged young male had testes measuring only 8x5x4 mm. when recovered as a specimen at the known age of 185 days, although in size, pelage, and priming pattern it was mistaken for a second-year adult when first handled. Shanks (1948), in testing a pelt-primeness method for obtaining age-

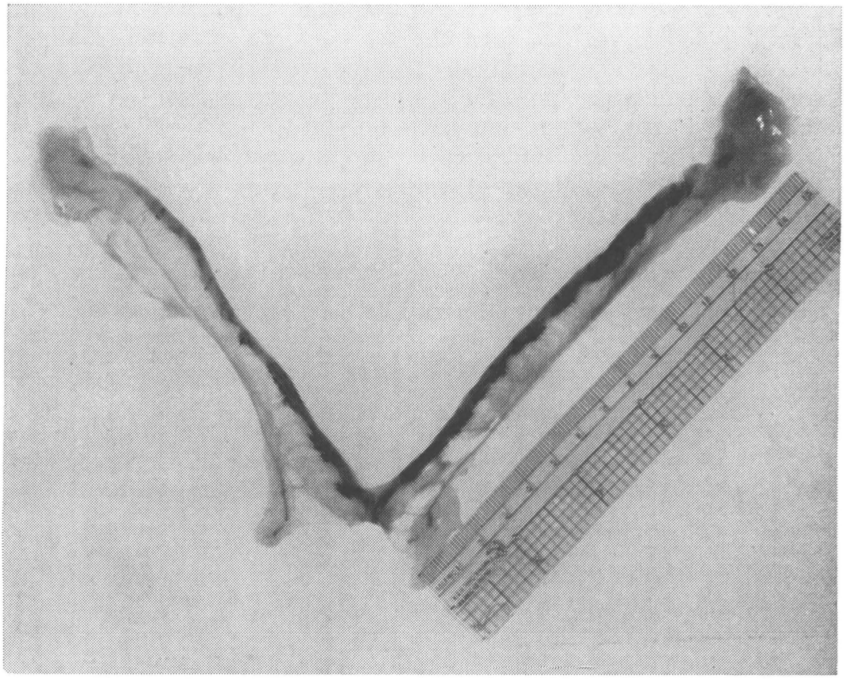

Fig. 4.4. Uterus of fall-trapped Iowa muskrat illustrating the appearance of placental scars.

class data from collections of raw skins, found that, in a sample of 69 individuals of known age (15 adults and 54 young), three of the adults were incorrectly classed as young and two of the young were classed as adults.

In using placental scars to obtain supplementary information on a season's breeding history of a muskrat population, one may find perfect examples in which the season's sets remain clearly distinguishable. Or, one may find uteri in which bloody residues have run together, or in which traces of the scars of the previous year's breeding may be mixed with scars of the current year. I doubt that one may reliably count or age the scars in the uteri of north-central females taken much after early winter, but, for November and December specimens, the scars in fresh uteri may be aged with passible satisfaction on the basis of size and color. A bright, bluish-black scar two or three millimeters in diameter signifies a late litter, as of August or perhaps late July; and gradation in the shrinking and fading of the earlier scars may commonly be noted without much difficulty until one has to consider the very earliest of the season or those of the year before. Faintness and a light brown coloration may suggest scars of more than one year of age, especially if only a few of them are visible and those are irregularly distributed along the uterus.

At times when post-mortem changes make it hard to separate the scars into age classes, some section of a uterine horn may be in relatively better condition than the uterus as a whole. An observer may then be able to note in that section the pattern shown with respect to numbers and ages of distinguishable litters. The best examples show the scars of given ages lined up in sequences: In two-litter females, a two-by-two line-up, with noticeable intervals of unstained uterus between the groupings; in three- and four-litter females, the scars of successive litters may become progressively fainter or clearer, according to the order in which they may be followed. Thus, in four-litter females, the repetitively grouped scars may appear as one bright, one less bright, one still less bright, one rather dim, then one bright again. Most inconveniently, not all of the uteri of adult females, even when examined in fall and early winter, furnish the best of examples, and some scars may be close together or take on a fused appearance. I do not know whether two placental attachments of a breeding season ever occur at the identical site but doubt that this may very often be the case.

Counting placental scars in atypical or partly decomposed specimens may require blocking off and estimating the numbers in clouded or bloody tracts, prorating from counts obtainable from comparable lengths of the uterus having the most clearly visible scars. Ordinarily, the uncountable scars are localized in strings short enough to reduce likelihood for error. It is important to avoid mistaking for separate placental scars the little dark marks from other causes, including parenthesis-like ones often to be seen enclosing the site of the real scar itself.

In learning what I have about working with placental scars, I found the literature of little direct help past the point of very general information, or as it specifically treated animals other than muskrats. Most helpful was the preliminary advice (letter, January 30, 1940) received from Dr. H. W. Mossman, of the University of Wisconsin, an anatomist of long experience with the reproductive tracts of rodents. My technique is chiefly the resultant of discussions and correspondence with colleagues, of limited microscopic examinations, of macroscopic post-mortems of hundreds of adult females distributed chronologically over the calendar year, of the guidance afforded by some highly informative tagged animals, and of detailed field records on reproduction in populations from which fall and winter series of specimens were taken.

Use of placental scars had value chiefly in following seasonal trends in the breeding fortunes of local populations, in checking up on the representativeness of given series of field data, and in obtaining otherwise unobtainable information on reproductive histories, especially as such were influenced by emergencies. Placental scars should, whenever possible, be considered in conjunction with field data and always with proper awareness of their technical deficiencies.

Pathological material may offer a big diversity of problems for any investigator who is not a pathologist. Any specimens showing extraordinary lesions should be taken to a competent pathologist, preferably in the freshest and most undisturbed condition possible. In dead muskrats coming to hand in the north central region, it was of great practical importance to look for wounds or for evidence of the hemorrhagic disease.

Victims of minks are commonly found bitten about the neck. In many cases, injuries to the nervous system appear to be the direct cause of death, although wounds involving important blood vessels and muscles are often seen. The teeth of the attacking minks do not necessarily penetrate the skin in all places that are bitten, even when extensive damage to underlying tissues may result. Canids are likely to "mouth" and shake their prey, breaking the spinal column or such large bones as the innominates and leaving big blood clots in such a region as the kidneys. Their teeth often do not penetrate the muskrat's skin unless they eat the victim. Raptorial birds leave talon marks on muskrat prey and tend to start eating at head or neck; when scavenging on a cold carcass, they may feed on almost any part where meat is easily accessible. Wounds of intraspecific strife on muskrats are of slashing types; they may be superficial or sufficiently deep to expose a hip bone, a kidney, or other viscera, or to cut clear through the musculature of a leg; they may occur anywhere on the muskrat's body, but especially on the parts that an animal exposes while either facing or retreating from an assailant.

Amputations represent mostly trap-crippling, "wring-offs" of feet after leg bones have been broken or disjointed by the snapping of the trap jaws or by the struggling of victims in nondrowning sets. Usually, they are the result of frenzied twisting of the weaker forelegs, with occasionally some biting, and are a common cause of mortality from infection, loss of blood, and, likely, shock. Great abscesses may be found associated with "wring-offs" or with strife wounds, but sometimes they have no evident connection with any wounds, and they may occur in the body cavity singly or in multiple form.

Old age, undernourishment, freezing of eyes and appendages, shot wounds, accidents, miscellaneous ailments, and other factors bringing about the death of an animal, or contributing thereto, may leave more or less recognizable manifestations. Nevertheless, many die for undetermined reasons, and an investigator should reconcile himself to putting down many queries in his notes.

The hemorrhagic disease is of such deadliness to muskrats on so many occasions that all persons conducting post-mortems should always watch for anything resembling its lesions. Necrotic foci on the liver are among the most suggestive lesions, even though they do not invariably signify the hemorrhagic disease. (They *could* be due to infections with the *Pasteurella* and *Salmonella* genera of bacteria — exemplified by tularemia and mouse typhoid — or to some other infec-

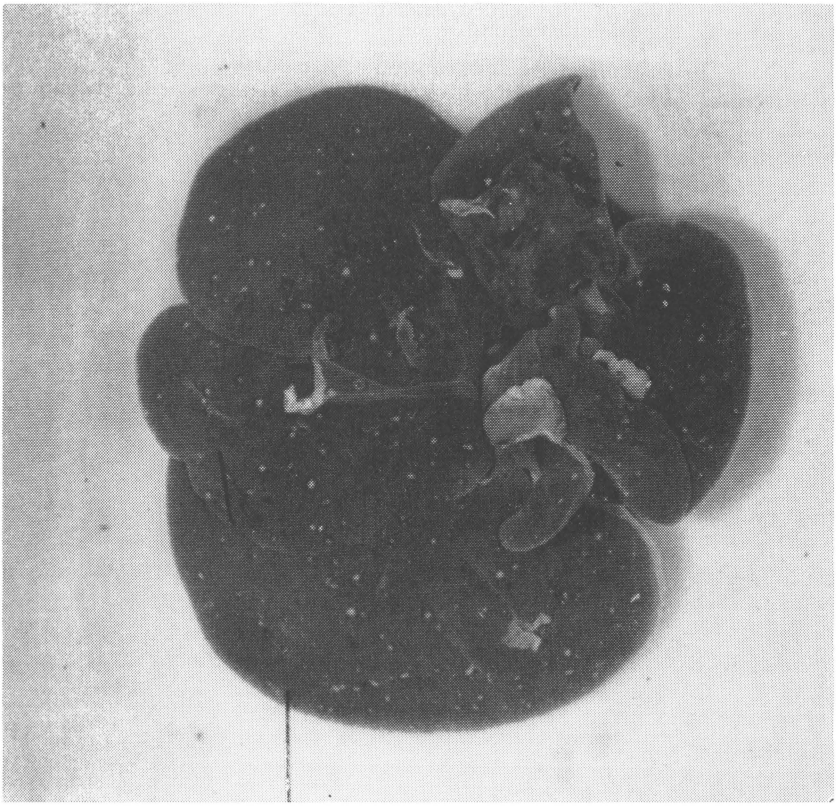

Fig. 4.5. Muskrat liver, illustrating numerous lesions of the hemorrhagic disease.

tious or irritating agency.) Hemorrhages may take place about anywhere in the muskrat's body, the more extensive tending to be localized in lungs, intestines, and kidneys. Figures 4.5, 4.6, and 4.7 illustrate, in addition to the tularemia-like liver lesions, hemorrhages involving cecum and large intestine in one case and small intestine and rectum in the other.

The manifestations of the disease in Iowa victims are of three main types: liver necrosis, intestinal hemorrhages, and lung hemorrhages. In a particular victim, the severity of each type tends to be rather inverse to the severity of the other two types. Thus, a specimen showing a very heavily spotted liver may show moderate to no hemorrhaging in intestines and lungs. A specimen with few if any liver lesions may have tremendous purplish blotches over the cecum or a dull-red coloration of a length of its small intestine. A specimen with indistinguishable liver or intestinal lesions may have lungs filled with solid clots of blood. All intergradations between the above

Fig. 4.6. Specimen of muskrat dying from the hemorrhagic disease, illustrating liver lesions (small light spots) and hemorrhages involving cecum and large intestine.

extremes may be found, but the field studies of epizootics reveal that one type may dominate for protracted periods. External bleeding from mouth or anus of a muskrat found dead should always arouse an observer's suspicions, but these are not invariable accompaniments of disease hemorrhages.

The commonest syndrome in Iowa is entero-hepatic, with fair numbers of liver lesions and moderate intestinal hemorrhages. With this syndrome, about eight days elapse between time of exposure and death. There may be recoveries, and liver-spotting may be noted in individual specimens taken months after known die-offs. Then, there is a syndrome characterized by massive intestinal hemorrhages from which the victims apparently bleed to death before liver lesions have a chance to appear. The pneumonic type can be spectacularly lethal in its operation when dominating an epizootic.

For all of the skinning of hemorrhagic victims that trappers do without taking any antiseptic precautions and without suffering any known ill effects, I feel afraid of the disease and certainly would advocate that anyone having occasion to handle such muskrats do so with discretion. My practice is to avoid touching suspected material directly with my hands and to avoid letting any object that may later be touched come in contact with such material. Or, if contact cannot feasibly be avoided, or if the material is touched accidentally, a disinfectant of proven value should be applied.

I may here express appreciation to Dr. E. A. Benbrook, of the Department of Veterinary Pathology at Iowa State University, not only for personally conducting the strategic post-mortems of muskrats in the beginning years of our studies of the hemorrhagic disease, but, particularly, for the very helpful demonstrations and advice given me whenever I brought to him my problems in diagnosis and epizootiology. I have also received strategic help from other Iowa State University staff members in connection with the disease studies, particularly from Doctors Paul C. Bennett and Howard L. Hamilton.

Food habits investigations are among those classifiable as laboratory work, and, in connection with the Iowa cooperative research program, my colleagues and I have analyzed large quantities of scats and pellets of predatory vertebrates, including around 5,000 from each of minks, foxes, and great horned owls. Considerable work in laboratory and field was also done with muskrat droppings and stomach contents.

The more detailed analyses require a tremendous amount of preparation, adequate reference collections, and the cooperation of taxonomic specialists. My own effective background in this may be said to have begun at Washington, D. C., in the spring of 1929, with a course in museum methods directed by Dr. Paul Bartsch, in which I spent three half-days a week for a semester studying skeletons and skins of North American vertebrates at the U.S. National Museum. In the actual researches that followed, I have received a great deal of highly technical help from the Division of Food Habits Research of the

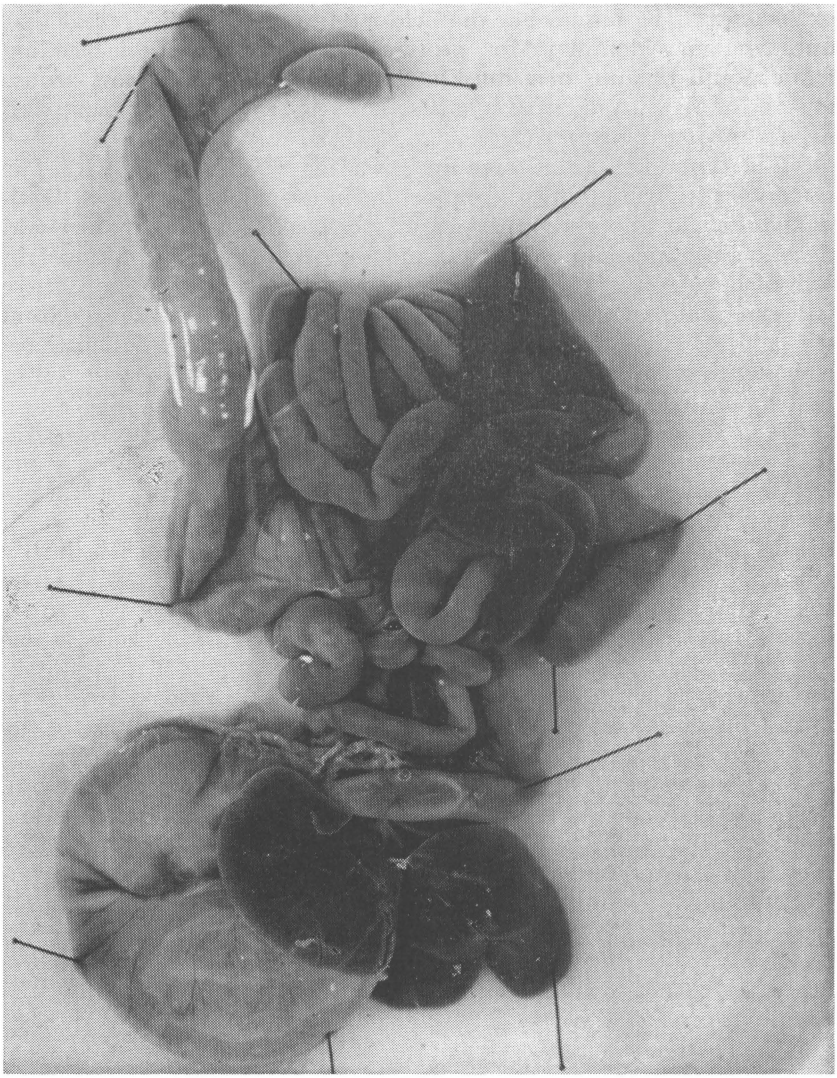

Fig. 4.7. Viscera from a muskrat dying from the hemorrhagic disease, illustrating liver lesions (the numerous small light spots) and hemorrhages involving small intestine and rectum.

former U. S. Biological Survey, first under the administration of W. L. McAtee and, later, under that of Dr. Clarence Cottam. In the laboratories of Iowa State University, much of the work on food habits was done cooperatively with Kenneth Krumm, Mrs. Ruth Dudgeon Adams, Dr. Logan J. Bennett, Dr. and Mrs. F. N. Hamerstrom, Jr., and Dr. Thomas G. Scott. Dr. H. H. Knight helped with invertebrate identifications.

About 20,000 additional mink scats were looked over in the field for muskrat remains, only, but this did not present the technical problems of the detailed food habits investigations. It is not overly difficult for a person familiar with muskrat morphology to recognize remains of the species in a mink scat. The fur is most useful as a diagnostic item, and, when dry and fluffed out, may be readily distinguished at a glance by a practised analyst, except when the victim is a very young individual. Both guard hair and underfur are distinctive in muskrats of "kit" size and larger, and, with experience, I felt entitled to guess at age classes from the appearance of the fur. Ends of long bones, pieces of skull, teeth, toe-nails and tail vertebrae were especially worth sorting out for identification.