BULLETIN

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ILLINOIS STATE LABORATORY

OF

NATURAL HISTORY

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DIRECTOR

VOL. IX. OCTOBER, 1910 ARTICLES I–II.

ART. I. ON THE COMMON SHREW-MOLE IN ILLINOIS

BY

FRANK ELMER WOOD, A.B.

ART. II. A STUDY OF THE FOOD OF MOLES IN ILLINOIS

BY

JAMES A. WEST, A.M.

ERRATA AND ADDENDA

Page 54, lines 3 and 2 from bottom, and elsewhere in Article III, for *Cassia chamaechrista* read *Cassia chamaecrista*.
Page 62, between lines 4 and 5 from bottom of table insert *Erigeron annuus*.
Page 101, table, after *Croton glandulosus* read var. *septentrionalis;* and for *Equisetum laevigatum* read *Equisetum hyemale* var. *intermedium*.
Page 131, line 3, for *coerulea* read *caerulea*.
Page 138, last line, for *Ziza* read *Zizia*.
Page 141, line 21 from bottom, dele *Diodia teres*.
Page 169, between lines 3 and 4, insert as follows:
Erigeron annuus (L.) Pers. An interstitial in the bunch-grass association in the Hanover area.
Page 177, line 5, for *eastward* read *westward*.
Page 209, line 3 from bottom, for *copalina* read *copallina*.
Page 210, line 13 from bottom, for *Diospyrus* read *Diaspyros*.
Page 211, line 5, for *Foresteria* read *Forestiera*.
Page 256, line 3 of table, for Dr. H. *M*. Pepoon read H. *S*. Pepoon.
Page 278, line 16, the fifth word should be in Roman type.
Page 286, line 6 (second column), page 295, list of secondary species (second column), and page 353, line 8 from bottom, for *hiemalis* or *hiemale* read *hyemale*.
Page 313, line 4 from bottom (first column), for *pedicularis* read *pedicularia*.
Page 315, line 10, second column, for *Apocynum* read *Apocynum*.
Page 323, line 3 from bottom, for *Cyperus* read *Scirpus*.
Page 330, line 14, for *virginianum* read *virginicum*.
Page 336, lines 3 and 2 from bottom, for *virginicum* read *virginianum*.
Page 337, line 2 from bottom, for *philadelphicum* read *philadelphicus*.
Page 339, in first list of invading species, for *Rhus hirta* read *Rhus typhina*.
Page 351, line 4 from bottom, for *xerophtic* read *xerophytic*.
Page 355, above line 6 from bottom, insert *Scirpus heterochaetus* Chase.
Page 356, line 14 from bottom, for *Symlocarpus* read *Symplocarpus*.
Page 360, line 14, for *Pirus* read *Pyrus*.
Page 362, after line 7, insert *Acer saccharinum* L.
Page 363, line 2 from bottom, for *quadiflorum* read *quadriflorum*.
Page 365, line 14, for *thapus* read *thopsus*.
Page 369, last line, for *Tanecetum* read *Tanacetum*.
Page 417, line 1, dele *the*.
Page 497, line 9 from bottom, for *neglible* read *negligible*, and in foot-note, for *Austalt* read *Anstalt*.
Page 498, line 4 from bottom, for *Lockport* read *Chillicothe*.
Page 500, line 13 from bottom, after *up* insert *in*.
Page 501, line 2 from bottom, for *dissolving* read *dissolved*.
Page 504, line 23, for *gryina* read *gyrina;* line 17, for *dentata* read *knickerbockeri*.
Page 506, line 11, for *vernata* read *ternata*.
Page 507, line 3 from bottom, for *Mazon* read *wagon*.
Page 513, line 19, for *Nepa* read *Zaitha;* line 18, and page 517, line 13 from bottom, page 520, line 12 from bottom, and page 532, line 4, read *naid* or *naids* for *naiid* or *naiids*.
Page 517, line 6 from bottom, for *pondweed* read *pickerel-weed*.

Page 519, for first sentence of last paragraph read as follows:

We have no exactly comparable chemical data for July; but analyses for August give percentages of saturation for Morris and Marseilles as follows: 20.4 per cent. at Morris on the 11th and 11 per cent. at Marseilles on the 12th; 16.35 per cent. at Morris on the 22d and 23d and 7.4 per cent. at Marseilles on the 24th and 25th.

Page 521, line 6 from bottom, and page 529, line 9, for *chrysoleucas* read *crysoleucas.*

Page 525, line 22, and page 536, lines 21 and 24, for *Ekmann* read *Ekman.*

Page 532, line 1, for *Ancyclus* read *Ancylus.*

Page 551, line 7, for *00* read *512.*

Page 615, second line above foot-note, for *106* read 94.

Page 616, line 1, for the second *Bündeln* read *Bündel;* line 2, for *Bündeln* read *Bündels;* line 3, for *aussern* read *ausseren;* line 6, for *zwcierlie* read *zweierlei.*

Page 629, line 12, for *kein* read *keinen.*

Page 634, line 9, for *unternommen* read *unternommenen;* and in line 14 from bottom, after *575* insert *13 fig.*

Plate III, Fig. 1, after the word *mixed* in legend insert *consocies of the.*

Plate IX, Fig. 2, dele the legend and read instead: Root-system of *Tephrosia virginiana,* exposed by blowing of the sand.

Plate X, Fig. 2, dele the legend and read instead: A blowout almost stabilized by bunch-grasses, especially *Leptoloma cognatum.*

Plate XXXIX, for *Calamogrostis* read *Calamagrostis.*

Plate LIV, exchange places of cuts, but not the legends.

Plate LXXXV, for *7* read *7c.*

ARTICLE I.—*On the Common Shrew-mole, Scalopus aquaticus machrinus (Rafinesque), in Illinois.* By FRANK ELMER WOOD.*

There are two species of moles in Illinois: one, the starnose mole, *Condylura cristata* (Linnæus), is found sparingly in the northern part of the state; the other, known as the common or shrew-mole, *Scalopus aquaticus* (Linnæus), is the one with which this paper deals. It is distributed throughout most of the state, and apparently all our specimens may be referred to the western subspecies *machrinus* (Rafinesque).

The general range of the species, under various forms, extends over most of the eastern half of the United States. Its northern boundary is a line running from the southern point of Maine westward through New Hampshire, Vermont, New York, Ontario, and Michigan, and thence northwestward to a point on the Red River of the North near the Canadian boundary. Its western limit is near a line from that point to the mouth of the Rio Grande. The mole is found also for a short distance along the Gulf of Mexico, but not in southern Florida. Over this range there is considerable variation in size, color, and some other characters. In general, specimens from the arid regions of the West are lighter in color than those from sections in the east and south which have a moister climate. The smallest variety is found in Florida, and, judging from data at hand, specimens from Illinois attain the largest average size. In the Atlantic States northern specimens average larger than southern ones, and it is true in general for all states east of the Mississippi that eastern specimens are smaller than western ones from the same latitude. There appears to be considerable variation in size even within the state as is shown by the following tables.

True gives the average length of six specimens from Illinois as follows: total length, 188.7; head and body, 154.9; and tail, 33.8. Apparently these specimens were all from the western border of the state. This would indicate a gradual increase in size from east to west across the state, and that the maximum size was reached near or beyond the Mississippi River.

*Some matter on the mole, additional to that used in the present article, may be found in "A Study of the Mammals of Champaign County, Illinois," by F. E. Wood, published in May, 1910, as article 5 of Volume VIII of the Bulletin of this Laboratory.

MEASUREMENTS OF TWENTY-SEVEN ADULT SPECIMENS FROM CHAMPAIGN COUNTY

Acc. No.	Sex	Length					
		Total		Tail		Head and Body	
		mm.	in.	mm.	in.	mm.	in.
37761	Female	168	6.62	33	1.30	135	5.32
37762	Female	167	6.58	32	1.26	135	5.32
37814	Female	178	7.02	32	1.26	146	5.76
37984	Female	187	7.34	32	1.26	155	6.08
37985	Female	190	7.50	40	1.58	150	5.92
37986	Female	173	6.83	31	1.22	142	5.61
38219	Male	182	7.17	34	1.34	148	5.83
38235	Female	167	6.58	30	1.18	137	5.40
38318	Male	197	7.78	31	1.22	166	6.56
38347	Female	190	7.50	36	1.42	154	6.08
38348	Female	182	7.17	33	1.30	149	5.87
38349	Female	176	6.94	33	1.30	143	5.64
38351	Male	187	7.50	32	1.26	155	6.24
38352	Female	181	7.13	37	1.46	144	5.67
38353	Female	187	7.50	37	1.46	150	6.04
38354	Male	196	7.74	42	1.64	154	6.10
38355	Female	172	6.79	38	1.50	134	5.29
38356	Female	180	7.10	28	1.10	152	6.00
38357	Female	181	7.13	36	1.42	145	5.71
38362	Female	184	7.24	34	1.34	150	5.90
38366	Female	182	7.17	32	1.27	150	5.91
38367	Female	178	7.02	37	1.46	141	5.56
38368	Female	179	7.06	34	1.34	145	5.72
38369	Female	167	6.58	26	1.02	141	5.56
38375	Male	184	7.24	36	1.42	148	5.82
38377	Male	202	7.97	36	1.42	166	6.55
38480	Female	182	7.17	36	1.42	146	5.75
Averages		181	7.13	34	1.34	147	5.79

MEASUREMENTS OF THIRTEEN ADULT SPECIMENS FROM JACKSONVILLE, ILLINOIS

Acc. No.	Sex	Length					
		Total		Tail		Head and Body	
		mm.	in.	mm.	in.	mm.	in.
37768	Male	169	6.65	29	1.14	140	5.51
37769	Male	185	7.28	27	1.06	158	6.22
37770	Male	196	7.74	32	1.26	164	6.48
37772	Female	181	7.12	27	1.06	154	6.06
37773	Male	184	7.24	34	1.34	150	5.90
37774	Male	190	7.50	30	1.18	160	6.32
37775	Male	178	7.00	28	1.10	150	5.90
37776	Female	185	7.28	29	1.14	156	6.14
37777	Female	176	6.94	33	1.30	143	5.64
37778	Male	172	6.78	30	1.18	142	5.60
37779	Male	181	7.13	38	1.50	143	5.64
37780	Male	184	7.24	34	1.34	150	5.90
37798	Female	216	8.50	36	1.42	180	7.08
Averages		184	7.24	31	1.22	153	5.98

MEASUREMENTS OF SPECIMENS FROM VARIOUS LOCALITIES WITHIN THE STATE

Acc. No.	Locality	Sex	Length					
			Total		Tail		Head and Body	
			mm.	in.	mm.	in.	mm.	in.
37758	Exact locality unknown	Female	172	6.78	24	.94	148	5.84
37759	Normal	Male	190	7.50	37	1.46	153	6.04
37760	Exact locality unknown	Male	182	7.17	34	1.34	148	5.83
37763	Exact locality unknown	Female	172	6.78	27	1.06	145	5.71
37764	Exact locality unknown	Female	171	6.74	30	1.34	141	5.40
37765	Normal	Female	170	6.70	27	1.06	143	5.64
37894	White Heath	Female	181	7.13	36	1.42	145	5.71
38242	Quiver Tp.	Female	164	6.48	25	.98	139	5.50
39604	Flora	Male	190	7.50	37	1.46	153	6.04
Averages			177	6.98	31	1.22	146	5.71

Combining all the above individual measurements, we obtain the following average for all of our forty-nine specimens from the state: total length, 181 mm. (7.13 in.); length of tail, 32 mm. (1.26 in.); length of head and body, 148 mm. (5.83 in.). The proportion of the specimens of the various lengths is indicated by the accompanying frequency polygon.

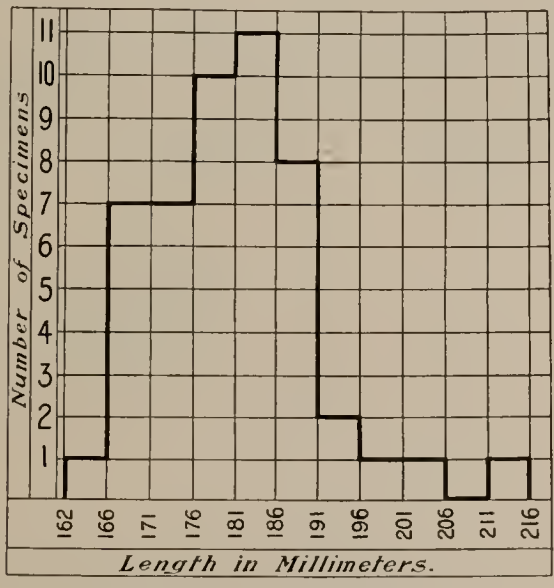

FIG. 1. POLYGON OF LENGTHS OF FORTY-NINE INDIVIDUALS OF THE COMMON MOLE.

There is also considerable individual variation in color, not correlated with any other evident characteristic, or with peculiarities of habitat, so far as I have been able to make out. The fur, except on the snout and extremities, is dense, fine, and silky, with but very little slope, so that it offers little resistance to rubbing in any direction. The hairs on the back attain a length of 1 cm. (.39 inch) or more, becoming shorter on the under parts.

The general color corresponds to that called "hair-brown" in Ridgway's nomenclature. This is sometimes grayish, sometimes warmed to bister or sepia, and is always obscured by a shifting, sheeny luster. Closer examination shows that the basal four-fifths of each hair is kinky, and is plumbeous in color, while the distal fifth is straight and bent at an angle to the general direction of the main portion. The direction of this tip constitutes the greater part of whatever slope there is to the hair. Under a low power of microscope it will be found that the hairs are flattened, and that the color of the basal portion is due to alternate black and translucent bands, while the apex is broader, lanceolate in shape, and contains a core of brownish-orange coloring matter. The chin, throat, upper surface of fore paws, and wrists are much lighter, and often suffused with shades varying from ochraceous to ferruginous, or even, in spots, to a decided orange. The tail is whitish at base, nearly naked and pinkish at the tip, as is also the tip of the snout and the toes. Specimens taken in spring often show patches of new fur replacing the old, and the fur in these patches is shorter and darker than the old fur. The snout is prolonged about 8 mm. beyond the lower jaw. It is flattened and deeply grooved below, and is naked and truncate at the apex at an angle of 45 degrees. This truncated surface looks upwards and contains the nostrils. At the tip is a hard nail-like body. The upper lip is split and represented by two thin folds in front. The long snout of the mole is very flexible, and is in constant motion when the animal is in action. It is abundantly supplied with nerves and terminal sense organs. The sense of smell and the sense of touch in the snout must be, for the mole, the chief means of an acquaintance with the outside world.

The fore limbs are concealed to the wrist under the skin. The fore paws are enormously developed. The toes, five in number, are webbed their whole length, making the entire length of the palm 15 to 20 mm. (.6 to .8 in.). The width is still greater, being 20 to

25 mm. (.8 to 1 in.). This great width is produced by a flap of skin on the lower edge, the rigidity of which is maintained by an extra sickle-shaped bone. The palm is margined with stiff hairs. The nails are stout, flattened, semicylindrical, and translucent enough to show the bifid tips of the last finger bones within. The hind feet are of normal size, five-toed, with nails that are flattened, hollowed below, and rather slender. The tail is squarish, especially at the base.

The general impression given by the appearance of the arms and shoulders of a mole stripped of its skin and superficial fat is that of a wonderfully compact and powerful digging machine, to which the animal is strapped by comparatively slender muscular bands. The development of the muscles of the breast and shoulders has kept pace with the massiveness of the bones. The pectoral muscles are attached to a keel-like projection of the sternum, and by their thickness remind one of the breast of a bird. Certain muscles of the shoulder are also greatly developed, and in some of them it seems that muscular overgrowth has reached its limit.

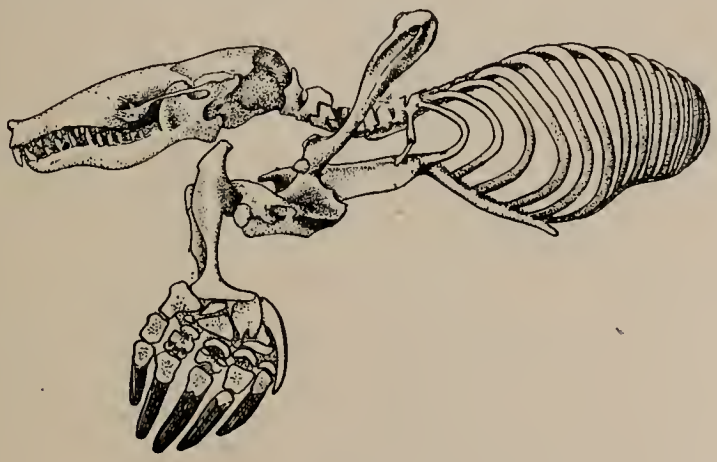

FIG. 2. PART OF SKELETON OF MOLE, SHOWING ATTACHMENT OF FORE LEGS.

The thick fur hides the eye and ear, but they may be located if the hair is cut off close. The eye appears as a protuberance, about the size of a pinhead, 20 to 25 mm. (.8 to 1 in.) from the end of the snout. If the skin at that place is lifted up, the eye will be found

on the under side—a black speck between the skin and the skin muscles. It is not within the bony orbit of the skull, but outside and in front of it. Microscopic examination reveals an opening through the skin over the eye, but it is difficult to find without a lens. The eye itself, though containing rudiments of the essential parts of the normal mammalian eye, is so degenerate that distinct vision is impossible, and at most it can only serve to distinguish light from darkness.

Owing to the fact that the shoulder bones and the attachment of the fore limbs are so far forward of the usual position, the external opening of the ear appears to be on the shoulder, though in reality it is not misplaced with reference to the skull. There is no true pinna or external ear, but the external auditory meatus is prolonged beyond the head a few millimeters by a cartilaginous tube. Between the eye and the ear is a protuberance containing vibrissæ, and probably functioning as an organ of touch.

The mole has thirty-six teeth. In each upper jaw there are three incisors, one canine, three premolars, and three molars. In the lower jaw there are two incisors, no canine, three premolars, and three molars. The two middle incisors in the upper jaw are large and seem to resemble those of the rat and other rodents at first sight, but they differ greatly in structure, having enamel on all sides, instead of only in front like the rodents. The second and third incisors are small and often missing. In the lower jaw the middle incisors are small and the lateral ones of moderate size. The molars and premolars form very irregular surfaces, the projections of the lower teeth fiting into corresponding hollows in the upper teeth, and vice versa. This construction of the teeth and the strictly up-and-down motion of the jaws are well adapted to the chopping up of insects or other animal food, but do not permit any grinding motion as is the case with animals living on seeds, grain, or other vegetable food. On account of this structure of the teeth naturalists have been loath to believe that the mole ever eats vegetable food, for which its teeth seem so ill adapted.

Although the shrew-mole ranges throughout the state, there are certain sections where it is rare or unknown. In most cases the cause for this is not far to seek. Moles require a soil easily penetrated by their burrows and containing an abundance of worms or insects for their food. Evidently a soft, rich loam, not too thoroughly cultivated, is their ideal habitat, and such localities usually contain an abundance of them. Stony or coarse gravelly soils are avoided, but

they are found in light sandy soils where ease of burrowing compensates for the poorness of the subterranean fauna. They are in no sense aquatic, so far as has been observed in this state. They may be tempted, by an abundance of food, to run their burrows into low ground, even into tracts submerged during parts of the year, but almost invariably such runs will be found to communicate with others furnishing a retreat to higher ground. Burrows are often seen running down the bank of a stream or across the muddy shore of a pool, nearly or quite to the water's edge; but I have never seen a fresh opening under the water or, indeed, quite reaching it, except where there had been a recent decided rise of the water-level. Undoubtedly, like most mammals, moles can swim, but I doubt if our form ever habitually enters the water for food.

The species has been taken, or reported on reliable authority, in the following places within the state.

Place	County	Authority
Chicago	Cook	Field Museum
Hanover	Jo Daviess	F. C. Gates
Milan	Rock Island	H. A. Gleason
Warsaw	Hancock	F. W. True: Revision of American Moles
Hamilton	Hancock	F. W. True: Revision of American Moles
Quincy	Adams	J. A. West
Brussels	Calhoun	J. A. West
Galesburg	Knox	J. A. West
Quiver Tp.	Mason	State Laboratory
Normal	McLean	State Laboratory
Bloomington	McLean	J. A. West
Havana	Mason	State Laboratory observation
Decatur	Macon	J. A. West
Atlanta	Logan	J. A. West
Lincoln	Logan	J. A. West
Mt. Pulaski	Logan	J. A. West
White Heath	Piatt	State Laboratory
Monticello	Piatt	State Laboratory
Virginia	Cass	F. C. Gates
Many localities	Champaign	State Laboratory
Danville	Vermilion	J. A. West
Jacksonville	Morgan	State Laboratory
Alton	Madison	Spencer F. Baird: Mammals of North America
Belleville	St. Clair	F. W. True: Revision of American Moles
Mascoutah	St. Clair	C. F. Hottes
Windsor	Shelby	H. A. Gleason
Charleston	Coles	T. L. Hankinson
Odin	Marion	J. A. West
Murphysboro	Jackson	J. A. West
Flora	Clay	A. O. Gross
Carbondale	Jackson	J. A. West
Marion	Williamson	J. A. West
Olive Branch	Alexander	State Laboratory observation

During a week's collecting in the vicinity of McHenry, in McHenry county, not a trace of a mole or of mole work was seen, and apparently the farmers were quite unacquainted with either. More recently, however, the presence of moles in that town has been reported. Probably there are other sections of the state in which they are rare or lacking, but we have no authentic record of such.

The burrows of the mole are almost always excavated, not by bringing the dirt to the surface, but by pushing it aside. The method seems to be as follows: The head is lowered and retracted—the flexibility of the neck permitting this—the fore paws are thrust forward in front of the nostrils, and by a sort of swimming motion the earth is pushed aside, the head at the same time being advanced and raised. The flexible snout is kept in continual motion, probably for exploring rather than for loosening the soil, as was once thought. The mounds of dirt thrown out are usually from burrows moderately deep. Presumably this is done only when the animal finds it difficult to dispose of the dirt otherwise. However, in central Illinois, I have never been able to correlate the presence or absence of such mounds with hardness of the soil. Possibly they are rather an indication of the depth of the excavations. When present they are in general at the top of vertical shafts ascending, not directly from the main tunnel, but from a short lateral one. How the earth is brought to the surface is not known.

Audubon and Bachman, in their great work on the quadrupeds of North America, mention the finding of two nests with young, one containing five and the other nine, and this observation seems to be the sole basis for all statements on this point made by most writers since. Kennicott's informant who reported a gravid female in February with two young "clothed with hair" and about to be brought forth must have made some mistake. There are four young moles in the Laboratory collection averaging over 100 mm. in length, but they are still nearly hairless. The result of an examination of all females in our collection accompanied with data of capture is shown in the table on page 9.

These observations seem to indicate one litter a year, brought forth in the latter part of April or early in May. All data available for this state suggest that the average number in a litter is nearer three to six than "from five to nine." In No. 38347 all six of the teats bore evidence of being used.

RESULTS OF EXAMINATION OF FEMALE MOLES IN THE LABORATORY

Acc. No.	Date of Capture	Condition
37984	April 4, 1908	Uterus large; empty
37985	" 16, "	3 embryos, 45 mm. long
37986	" 17, "	3 embryos, 15 mm. long
37347	May 23, "	Uterus medium size; empty; mammæ very large
37798	" 30, 1907	" small; empty
38348	June 1, 1908	" empty, but of considerable size
38349	" 1, "	" small; empty
38350	" 2, "	" " "
38352	" 3, "	" " "
38353	" 4, "	" large, but empty
38355	" 9, "	" small and empty
38356	" 10, "	" shrunken and empty
38357	" 10, "	" much shrunken
38366	" 13, "	" " "
38367	" 13, "	" " "
38368	" 15, "	" " "
38369	" 16, "	" " "
38376	" 17, "	" " "
38235	October 26, 1908	" very much shrunken

The economic relation of the mole—whether beneficial or injurious—has been a disputed topic for many years. It could not be denied that the burrowing habit of the mole is an annoyance and indeed a positive injury to lawns, cemeteries, etc., but besides this mechanical and incidental injury, gardeners and farmers have maintained that moles do a more definite and deliberate damage by eating newly planted seeds, by following along the rows of corn, peas, etc., taking all the seeds from hill after hill in succession, and by eating parts of plants, the roots of vegetables, the tubers of potatoes, and the like. On the contrary, naturalists in general, reasoning from the anatomy of the animal, the structure of its teeth, and the proven fact that it feeds largely on insects, worms, and other underground animals, have doubted the possibility of its eating vegetation to any great extent, and have accounted for the injury to seeds and vegetables commonly charged to moles as really due either to insects which the mole itself was seeking, or to mice which entered the mole's burrow after it.

In this state the most bitter complaint against moles has been that they destroy recently planted corn. In some cases it was said that 25 per cent. of the first planting of a field had been destroyed. In the spring of 1907, when the writer was serving as a zoological as-

sistant in the State Laboratory of Natural History, a reported injury to corn by moles was assigned to him by Dr. Forbes for investigation. The field work was chiefly done in the vicinity of Jacksonville, Illinois, during corn-planting time and while the grain was beginning to grow. Extensive trapping was done in corn fields, gardens, and various neighboring fields, including pastures, fallow ground, and woodland. Corn was put in the burrows to see if the moles would eat it. Moles were said by farmers where we worked to be much less common than usual, but a number were caught and their stomachs were preserved for examination.

The injury done was limited chiefly to the edge of the field, mostly within fifty feet and virtually all within a hundred feet of the margin. Moreover, it was much greater in those parts of the field next an old hedge, a woodland, or pasture, or any uncultivated land, where, of course, the tunnels of the moles were undisturbed. Very little damage was done in the interior of large fields. Although moles work in corn fields all summer and fall, yet, so far as my observations go, the damage is practically all done within the first ten days after planting, and by far the most of it within the first five days. During this time the moles enter the field by burrows branching off from their permanent runs along the hedges or in the adjoining uncultivated fields, and spread out among the newly planted corn rows. These runs in the freshly planted field tend to follow the rows of corn in the direction in which the planter was driven, and not along the rows checked off by the chain. Tunnels entering at right angles to the direction of planting soon turn and follow that direction. Approximately 75 per cent. of the burrows made during the first few days after planting were directly in the furrow made by the planter. The remaining 25 per cent. were divided about equally between two courses, those parallel to the rows but not entering them, and those making various angles with them.

As an illustration of the extent and nature of the damage done, the following rather extreme case may be given. Three adjoining rows, the farthest within thirty feet of the edge of the field, had been entered from that side. In the first row the line of hills had been followed for one hundred and twenty feet, and there were only three or four hills uninjured within that distance. In the second row all hills had been taken for thirty feet, and in the third row all were missing for seventy-five feet. These burrows following the rows and

those connecting them with the edge of the field were nearly all the burrows in that immediate locality. Wherever a burrow passed through a hill, the corn was missing. The three or four hills still growing in the one hundred and twenty-foot distance mentioned above, had been missed by the burrows, which passed around and not through them. This corn had been planted about a week. In an adjoining field planted twelve days before, there were also extensive mole-runs, all made after a recent rain. Here the burrows ran irregularly in all directions, no preference being shown for the direction of the rows. No damage had been done by these freshly made burrows in the first-planted field, though the mole had sometimes lifted young plants by burrowing under the hills. It is possible that if the weather had been hot and dry the corn in these hills might have withered. Farmers, indeed, maintain that this is sometimes the case. This observation of the work of moles in corn fields was continued throughout the season in various parts of the state until December. In midsummer the moles burrowed to a depth of about six inches, but did not tend to follow the rows, nor was any injury done to the corn except possibly a trifling one due to undermining the plants. Peas and beans planted by drills in gardens were sometimes injured in the same way as corn in the field, but here too the injury was done during the first week after planting, and the later burrows did not tend to follow the direction of the drills.

On visiting a badly infested corn field it is easy to understand how an uncritical observer might attribute to the mole a deliberate malice and a cunning almost human in finding and destroying the newly planted corn, but probably a simpler explanation of the facts may be given. In soft ground the runs of the mole are often carried for long distances in a straight line. I have seen such runs several hundred feet long in the sandy fields of Mason county. Probably the course of the drill of the planter is followed because it offers the line of least resistance immediately after planting. Later, when the ground becomes settled, so that all parts of the soil are equally firm, there is no apparent choice in the direction of the runs.

It has been suggested in defense of the mole that grubs or other insects may destroy the germinating corn, and that the mole visits the hills to capture the insects. If this be so, the mole is certainly a marvelously effective agent for the destruction of insects, for often not a hill of corn will be missing out of many acres except where

there is a mole-run. It has been also said that field-mice may enter the runways of the mole, and that they and not the moles may eat the seed grain. Field-mice doubtless make use of old mole-runs, but would scarcely enter such a run while its owner was still present; and as the seed is eaten and the plants are destroyed at the time when the burrows are dug, the injury cannot be attributed to anything else than the mole.

Moles are accused not only of destroying recently planted seed, but also of eating the roots or tubers of garden vegetables. Late in the season of 1907 I visited a field at White Heath, in which it was said that much damage had been done by moles. The potatoes had been dug just before my arrival but partly eaten tubers were abundant, all near the edge of the field, and next to woodland and pasture. The moles had tunneled extensively among the potato hills, and many of the potatoes had been eaten by them, as appeared plainly from the marks of incisor teeth, which just fitted the teeth of the mole, but were much too broad to be the work of the mice or voles found in the vicinity. Chipmunks and gophers were in the adjoining fields, but of course would have taken the potatoes, if at all, by digging down into the hills and not by an underground tunnel. The loss in parts of the field was some 25 per cent. During the past season the same field was planted to potatoes again. I visited it in September, before the potatoes were harvested. Mole-runs were numerous in the field, running among the rows in all directions, but in no definite relation to the hills. Tubers had often been laid bare by the moles but they were generally uninjured. A few had been eaten by grubs, but only one by a mammal. Evidently the moles, while not searching for vegetable food, do sometimes avail themeslves of it when it is present. Usually their tunnels are so placed that little vegetable matter is encountered in making them—too small an amount to supply any considerable part of the energy expended by this powerful and active animal. The injury done by moles to lawns and other grass-lands is undoubtedly done in their search for insects and worms. It is not, indeed, great except in small lawns, cemetery lots, and the like, the appearance of which they may injure sufficiently to call for their destruction.

But little is known definitely in regard to the enemies of moles. Cats and dogs kill but do not eat them. Weasels, skunks, and foxes probably kill them occasionally and, when hard pressed for food, may

eat them. In Dr. Fisher's study of the contents of 2645 stomachs of birds of prey, moles were found only four or five times. ("Hawks and Owls of the United States".) There seems to be a considerable local variation in the numbers of moles from year to year, and they are often found lying dead, but unmutilated, above ground in considerable numbers. Many of them are badly infested with intestinal parasites, which possibly tend to reduce their numbers. Two such parasites, specimens of *Filaria* and *Spiroptera,* were abundant in the stomach and intestines of many of the moles collected by us for a study of their food.

My own attempts to poison moles have had uncertain success, as it was difficult to tell, even approximately, the number killed. They eat bits of raw beef readily in captivity, and might be poisoned by putting strychnine on bits of meat and placing these in their runs. I have found trapping the best way to destroy them. A single mole will do a surprising amount of burrowing in a week, and the number of moles doing noticeable damage in any locality is generally not large. It is difficult to trap them in midsummer, when they frequent only their deeper burrows, but easy in spring or autumn, when they work near the surface. There are a number of good mole-traps on the market, all made with reference to the mole's habit of persistently repairing a burrow if its roof is broken in. Where the work of the mole is evidently recent, a virtual extermination by trapping is neither difficult nor tedious. Even in places where they have been long established, and where the ground may not be plowed up, persistent work during the spring months will accomplish much. Where there is an intricate network of old runs it is very difficult to trap them; yet even here occupied runs may sometimes be detected. If the trap is undisturbed for twenty-four hours it may be safely inferred that it has been placed on an abandoned runway, and another trial must be made elsewhere. During the season of 1908 experiments were made by treating seed-corn with kerosene, carbolic acid, formalin, oil of lemon, and other vegetable oils, to see whether moles would be so repelled by these substances that they would not disturb the corn. No definite results were obtained, however, except where an amount of repellent was used sufficient to injure the seed.

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