POLSKA AKADEMIA NAUK — ZAKŁAD BADANIA SSAKÓW

ACTA THERIOLOGICA

VOL. V, 2. BIAŁOWIEŻA 14. IV. 1961

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On Food Storage of the Mole, *Talpa europaea* Linnaeus 1758

O zapasach pokarmowych kreta, *Talpa europaea* Linnaeus 1758

[With 2 tables and 7 figs]

I. INTRODUCTION

The problem of food storage of the mole is up till now an uncommonly interesting though a questionable one. Stores of that kind were found relatively seldom and always in specific soils. They sometimes appear in one sector of a small area with special ecological conditions. One can dig through hundreds of mole fortresses and encounter food stores near one nest only.

Stores were found up till now in autumn, winter and early spring periods, before earthworms began their active life. They sometimes

contain very great quantities of earthworms, more rarely larvae of cockchafer grubs or other insects. These stores are usually connected with winter fortresses of the mole.

Many authors, especially in previous times, have written about such findings. Thus, for example, Dahl (1895) found in 1886, near a mole nest a great collection of earthworms, 1280 in number and 18 cockchafer grubs, weighing in total 2.13 kg. In 1888 this same author, during a mild winter, after a period of severe frost, found in the neighbourhood of one of the nests 578 earthworms, 67 *Hepialus lupulinus* larvae, 4 cockchafer grubs and 3 *Carabidae larvae*. Similar stores were also found by the same author in the following year.

Adams (1903) states that in over a hundred mole nests he had found, dug through and thoroughly investigated there were no earthworm collections of that kind. In early spring, however, he had frequently found bunches of 4—5 earthworms in the soil, but never in runs. The author supposed that the earthworms were thus assembled „of their own free will". As to the food stores of the mole, Adams considers them to be only earthworms which had fallen into mole runs and could not get out of them or bury themselves in.

Doose (1908) cited after Schaerffenberg (1940) found in a mole nest such a quantity of earthworms that he filled a watering-can with them. Hauchecorne (1927) dug out, in March 1923, about 300 earthworms. As to more recent authors, Evans (1948) gives the results of analyses of 6 stores sent to him, the species of earthworms and their mutilations.

Löhrl (1956) communicates that he found and dug out near Lindau, in April 1947, in the winter nest of a mole, a similar store composed of 34 earthworms and 37 large cockchafer grubs with heads bitten off, in a state of partial decay. In a second nest he discovered, the author found 287 big earthworms, weighing in total 820 g.

Grulich (1959) found in the beginning of March in mole runs leading to the nest chamber and surrounding it 44 earthworms with a total weight of 86.5 g and 31 cockchafer grubs weighing 83.7 g. The entire store weighed 170.2 g. The second store found by the author was considerably smaller, being composed of 12 earthworms and 7 cockchafer grubs and weighing 34.5 g in total. Both worms and grubs were found in the walls of the runs in small hollows, a few of them in each.

Other authors treat the problem of food stores of the mole with great caution. Thus Schaerffenberg (1941) approaches the question very critically in spite of the fact that he found, at a distance of 0.5 m from the nest, a bunch of 45 quite uninjured earthworms. This author is of the opinion that in many cases they may be collections of earthworms hibernating in mole runs. He cited, as a proof, the back of cockchafer grubs mutilated by a mole in such collections. Facts observed by Löhrl (1956) and Grulich (1959) provide an answer to these restrictions.

The observations of Stein (delivered verbally) and of Pavlinin (1959) seem to prove that the mole, when free in nature, collects earthworms,

placing them in the neighbourhood of the nest or the store. These authors state that when caught in a trap the dead mole may hold in its teeth or have near its mouth a mutilated earthworm. P a v l i n i n (1959) considers the question of food stores of the mole as an open one, but his own standpoint is rather negative. G o d f r e y & C r o w c r o f t (1960) consider, on the basis of the number of earthworms wounded by moles in such collections, that these stores, apart from the activity of the mole, are the result of still other ecological factors.

II. FIELD OBSERVATIONS

During our investigations in terrains near Kraków we happened to find such a store of earthworms. Results of our researches are the following:

On July 20, 1958, on pasture land near Borek Fałęcki in humus soil closely resembling rich black ground, I dug out 45 earthworms (5 of these specimens were small) at a depth of 30 cm and a surface of 1600 cm², on the course of mole runs.

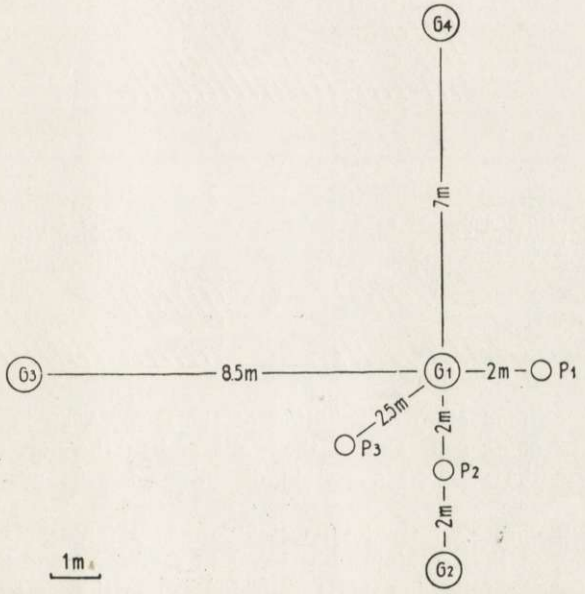

Fig. 1. Plan of nest distribution on February 6 ,1958 in Łęg.790 earthworms were found in sum near the nest G_1 and dug out places P_1 and P_3.

On February 6, 1958 in Łęg near Kraków, when investigating nests I dug out from the walls of mole runs 470 large earthworms and 2 larvae of *Noctuidae*. Their weight amounted to 820 g. The earthworms were equally disposed in small bunches in the whole area of the nest and the adjoining runs. They were situated in the walls of the runs and the niche of the nest (Fig. 2. B). Their greatest number was found in the bottom wall of the runs.

Some of them were characteristically curled up, others lay in the shape of a loop, while others were not curled up at all. The greatest concentration of earthworms was found in runs near the nest niche. I did not find a single freely lying earthworm in the niche nor in the light of the runs. They were all situated at a depth of 15 to 30 cm from the surface of the terrain. A layer of light humus and rich black soil, originating from peat, was 30 cm thick. Beneath this layer, a greyish-blue, greasy, doughlike stratum of loam of peat origin lay, in which 1—2 specimens of earthworms (per 400 cm^2) were found, while the number of earthworms in the lower sides of the runs was of 30 large specimens per 400 cm^2. Apart from the nest — marked G_1 on the plan (Fig. 1) — in which food stores were found, at the same distance approximatively 3 other nests were found. Further research activities gave the following results: in a dug out place P_1 and P_3 of 1600 cm^2 each I had found

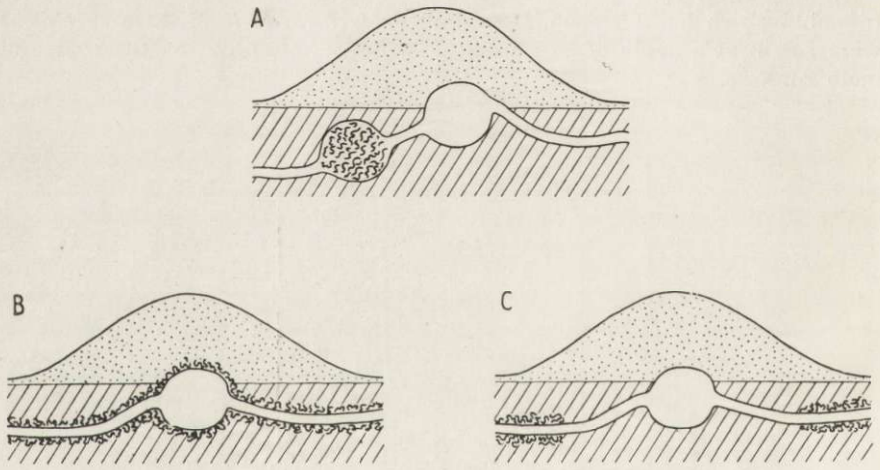

Fig. 2. Types of food store distribution of the mole. A — in the so-called cauldron, B — along runs and in the walls and in the nest chamber, C — only along the runs, at a certain distance from the nest chamber.

190 large earthworms with a total weight of 437 g. These places lay in the runs. Research in the remaining nests and in samples 4 and 5 gave a negative result. On the following day I collected 130 earthworms weighing 294 g near the sample No.3 under the run, on a surface 3600 cm^2. In total I collected in the vicinity of this nest 790 earthworms, weighing 1551 g (Table I). On April 26, 1958 I found in the same terrain 124 large earthworms under a nest with a diameter of 70 cm, in a place where runs crossed at a depth of 15 to 20 cm in soil resembling rich black soil, which passed into clay and loam, on a surface of about 0.5 m^2; they lay in an analogical fashion as in the preceding finding. The runs were partially obstructed by earth that had been dug out. In every control digging, at a distance of 2 m from the nest, I found in three places 3—5 small earthworms on a surface of 0.25 m^2.

I encountered similar stores in the following year on the same terrain. On January 7, 1959 having dug through several nests and more than ten bigger molehills in different parts of Łęg with a negative result, I went to the sector which I had investigated in the previous year and there, in the same place, I found a large collection of earthworms near the first nest. I collected 236 big earthworms, with a total weight of 680 g, in 3—4 m of runs. At every movement of the finger about 10 large specimens fell out of the wall. The greatest amount of specimens was found in the bottom walls of the runs. The earthworms were dug in in earth softened and granulated by the paws of the mole, which had then trod it down. After removal of the earthworms and dug-out earth, a characteristic hollow made by the mole became visible in which the amassed worms lay. The mole runs descended into greasy loam in which earthworms appeared. The walls of some runs were coated with loam near the nest, which seemed to indicate that the mole pushed into these walls the earth it had dug out.

Earthworms brought from the terrain were thoroughly examined. 218 earthworms (33%) out of 660 that had been collected on February 6, 1958 showed visible signs of mutilation. These could be seen in the part near the head, the central part and the rear segments (Phot. 5, Plate I). There were also specimens with rear segments of the body cut off. Some of them were bitten in different parts of the body. The mutilations were in different stages of regeneration, and a few were quite recent. 107 out of 218 specimens had mutilated segments of the head (49%). Out of 130 earthworms brought from the site on February 19, 1958 mutilations were found in 49 individuals (38%), and 29 of them were wounded in the sector of the head (60%). It became apparent that the earthworms which showed no damages externally were nevertheless injured. I had chosen from the entire material 40 fine and undamaged specimens and sent them for determination to mgr J. Plisko, Zoological Institute of the Polish Academy of Sciences. It turned out that 100% of these earthworms were bitten on the frontal lobe of the head. In some cases the wounds were hardly visible, being like a delicate pinprick. In December 1959, in the same site, under a molehill 90 cm in diameter and 30 cm high, covering a nest with a surface of 900 cm^2, at a depth of 0.5 m in a pan (cauldron) excavated by the mole (Fig. 2, A) I collected 160 earthworms weighing 380 g and 2 larvae of *Noctuidae*. The pan was of the size of a big nest niche, in which earthworms lay separately or up to 5 specimens together, on soft soil that had been granulated by the mole, which fed on this store. This was proved by fragments of earthworms, usually from the rear part and by earthworms with cut off segments of the body. 65 specimens (40.7%) out of 160 showed mutilations, of which 25 (38%) on the front segments of the body.

This collection, like the preceding ones, was mostly composed of big specimens, sometimes weighing 6.5 g. I found only 5 small earthworms, which appear very seldom in accumulations of that kind. This is caused, I suppose, by the fact that the mole prefers eating them than large earthworms. I ascertained that captive moles did not, as a rule, make provisions of small earth-

worms. Large specimens were pulled along and stored in a determined place by a mole that was no longer hungry. Godfrey & Crowcroft (1960) account for the above-mentioned facts by asserting that big earthworms probably stir up in the mole the instinct of storing and that the lack of small earthworms can be ascribed to their being more tasty. I even encoun-

Table 1.

Amount and weight of earthworms collected in different years near mole nests.

Locality	Date	Surface size in m^2	No. of collected earthworms	No. of arthropode larvae	Weight of the collection in g.
Borek Fałęcki	20. XII. 1958	0.16	45	—	—
Łęg	6. II. 1958	2.2	790	2	1551
	26. IV. 1958	0.5	124	—	242
	7. I. 1958	1.5	236	—	680
	9. XII. 1958	0.09	160	2	380
	17. III. 1960	0.09	146	—	328
	„	1.00	459	3	900
	„	0.09	134	8	306
	17. X. 1960	—	80	—	95
	„	1.00	473	—	768
	19. X. 1960	0.1	82	—	98
	„	—	54	—	37
	„	0.05	42	—	90

tered similar findings in March 1960 on the same terrain. Under a molehill of 1 m of diameter and 25 cm high there was only one small nest niche, occupied by a young female. At a distance of 1.5 m, on the crossing of two runs I collected, in a pan characteristically dug out, about 30 × 30 cm of size, 146 earthworms. They were lying dug up in soil relatively firmly downtrodden. A run from two opposite sides reached this place (Fig. 2A).

On the same day in a second nest, at a distance of 20 paces from the former, I encountered, at a depth of 45—50 cm, a whole mass of earthworms, disposed along the run, principally in its wall. The runs were so large in diameter that two folded hands could be inserted. I collected here 459 earthworms, 1 cockchafer grub and *Carabidae* larvae on a band about 2 m long and 20 cm wide. As previously, large earthworms, firm in texture, fell

out, several at a time, et every movement of the finger or the spade. Some of them showed even at first sight characteristic, already regenerated mutilations. Only one specimen of the entire collection was in putrefaction, owing to considerable injuries visible on the body. On the same day also, near one of the nests, at a distance of about 60 m from the former, at the edge of a molehill and a ta depth of 30 cm I encountered a group of earthworms. Here they were not spread in a layer, as in former findings, but disposed in depth in the loam. I cut out a cube of 30 × 30 cm in dimension and counted in it 134 big earthworms, 3 large cockchafer grubs and 2 larvae of *Carabidae* (Table 1). The total weight was of 306 g. I did not search through the whole store. I suppose it must have been, as the preceding ones, collected locally near the nest. Two probing apertures of 20 × 20 cm, 50 cm deep, dug out on both sides of the nest at a distance of 2 m, gave a negative result. The earthworms in the collection were disposed in special chambers, 2—3 in each one. These chambers were made of enlarged tube-like passages, running deep into the loam. The cockchafer grubs were also lying in natural burrows, contrived by themselves, and showed no injuries. It is interesting to note that the loam in which the earthworms and grubs were found had not been touched by the paw of the mole.

Of the collected earthworms 40% showed regenerated mutilations. These places were made conspicuous by a lighter colouring; this concerned especially the frontal segments of the head. In 3 specimens the wounds were relatively fresh, so that, when the front part of the body was held with a pincette, blood trickled out of the wound. The remaining earthworms did not show any external wounds. Doubts arose therefore, in view of the facts mentioned above, whether in this case the earthworms had been collected with the co-operation of the mole or had assembled by themselves in the given place. It may not be excluded that under the influence of differences in temperature and air content in the soil, especially in the loam, and in mole corridors, they could have left their burrows by themselves and fallen into the runs. Their uniform disposition in the walls of the runs, on their whole length, would seem to indicate this. On the other hand, observations have shown me the reaction of earthworms of avoiding mole runs, in which they seemed to „feel" imminent danger. A low percentage of earthworms demonstrating external wounds could confirm the supposition that the earthworms had not been extracted by sheer strength by the mole.

A characteristic feature of earthworms from collections described above was that when kept for a few hours in a vessel with a low temperature 30% of the individuals had a prominent gullet

in the shape of a small mushroom or vesicle of a vivid pink hue (Phot. 3, Plate I). I did not state a similar phenomenon in the same kind of earthworms collected in the ground in spring beyond mole nests. I suppose that it must have been due to wounds inflicted by the mole.

I have also encountered the instinct of food storing in the mole in February 1960 on the Błonie in Kraków. After a severe frost (up to —27°C) the temperature had suddenly risen. Moles began constructing very big molehills. The soil had thawed up to the depth of 10 cm. In one case a new molehill, 60 cm in diameter, had been made on the top of an old one. When excavated I found at the bottom of the mound 8 large earthworms characteristically buried by the mole. Above them ran a newly dug run. Four of the specimens had cicatrised wounds on the head and farther segments of the body. On the following day, in a molehill of dimensions similar to the former and in identical conditions, I found 5 live earthworms of the same size externally uninjured and also belonging to the species *Lumbricus terrestris* L.

350 specimens of earthworms, sent for determination to mgr J. D. Plisko and originating from different findings in Łęg, belonged to only one species, *Lumbricus terrestris* L.

III. TIME ORIGIN OF FOOD STORAGES

Observations of other authors (Dahl, 1825; Hauchecorne, 1927; Evans, 1948) suggest that food stores in mole nests appear after a period of intense frost.

As demonstrated on the basis of investigations carried through in the autumn of 1960, food stores of the mole augment successively, from the first cold autumn days onwards.

On October 15, 1955, during fine and warm weather, I already found, when investigating a newly built mole nest in Łęg, 9 large earthworms (*Lumbricus terrestris* L.) inertly lying in a bent run. The anterior part of the body of all specimens seemed to be numb. They could move only backwards and the frontal part of their head had been probably bitten.

On October 17, 1960, also on a fine and warm day (air temperature of 16°C), I dug out 5 nests, in that number 3 newly constructed ones, in a part of the terrain where I had previously found, several years during, collections of earthworms. In four of the nests I came upon several earthworms lying in the earth of the mound above the niche, in the walls of runs or in the niche.

In one nest I found several earthworms buried in the lateral wall of the niche. I collected in total 53 large earthworm specimens weighing together 85 g and 27 small ones weighing 10 g in all four nests. They belonged to the following species:

Lumbricus terrestris L.	23 adult specimens
Lumbricus terrestris L.	30 undeveloped specimens
Allobophora caliginosa (S a v.)	11 specimens
Allobophora rosea (S a v.)	3 specimens
Undetermined undeveloped specimens	13 specimens.

All collected specimens had bigger or smaller injuries in the anterior part of the body (1—5 segments).

In a part of the terrain, where pressed peat lay under a stratum of humus, I encountered a fifth nest, 120 cm in diameter and 30 cm high. Earthworms were dug into all the walls surrounding the niche. On a surface of 1 m^2, up to a depth of 40 cm I collected 350 large specimens weighing 710 g and 135 small ones with a weight of 58 g. The biggest one, a specimen of the earthworm *Lumbricus terrestris* L., weighed 6.5 g. Earthworms of all the collections had no earth in their oesophages, which is very important for their weight results.

A characteristic feature of the whole collection was the fact that the earthworms were dug in the walls of corridors running at different depths, from 10 to 40 cm. Some of them lay, 6 at a time in soft, dug out earth lying in parts of the runs. After excavation of the run and touching of its walls they fell inside in quantities surpassing ten. I saw for the first time whole bunches of small specimens, 5—6 cm long (over ten in each bunch) among large earthworms in the same run. All specimens at a first glance showed considerable mutilations. Some of the runs were filled with green grass which the mole had dragged in for lining the nest. The earthworms found in the run were alive although nearly motionless. In this collection only 2 species were present:

Lumbricus terrestris L.	379 adult specimens
Allobophora caliginosa (S a v.)	106 specimens.

All earthworms showed mutilation of head segments with quite recent wounds, or wounds in the course of regeneration. Some of them had a completely regenerated head.

On October 19, when the temperature of the air was of 10°C and the weather changeable and partially clouded, I undertook researches in a part of the terrain where I had not encountered this kind of findings. Out of 7 excavated nests groups of earthworms were found in 3 of them. Thus in the first nest, on peat that was much drier than the preceding one, with no loam at the bottom, I found grouped earthworms in two neighbouring runs (at a depth of 25 cm from the surface of the ground) beginning at the niche and with no outlet. In these runs, each one 50 cm long, I collected 82 earthworms. Of them 38 were large specimens. The

weight of the entire collection was of 98 g. The list of the species was the following:

Lumbricus terrestris L.	40 specimens with slightly healed wounds
Allobophora caliginosa (S a v.)	34 specimens, out of which 5 had no traces of mutilation (they were collected accidentally) the remaining ones with hardly visible traces of healing
Allobophora rosea (S a v.)	1 adult specimen with 3 first segments destroyed
Allobophora rosea or *caliginosa*	5 mutilated specimens
Octolasium lacteum (O e r l e y)	2 specimens with three segments of the head destroyed.

In the next nest, at a distance of 8 m from the former, I found 12 big earthworms and 42 small specimens near the niche of the nest — they weighed in total 37 g. The earthworms were grouped in the nearest vicinity of the nest, in a small hollow in the wall of the niche. This indicates the fact that at liberty, as well as in captivity, the mole prefers storing food near its nest. In this collection the following species were found:

Allobophora caliginosa (S a v.)	37 specimens, of which only two were uninjured. In the remaining ones 1—5 segments of the head were destroyed.
Lumbricus terrestris L.	15 specimens, all with a more or less mutilated frontal part of the body
Octolasium lacteum (O e r l e y)	2 specimens deprived of the first segments of the head.

Near the third nest, situated in a dry terrain, with light soil of a strong rusty-red hue, I collected, on 50 cm of the run, 41 specimens of *Lumbricus terrestris* L. and one *Allobophora caliginosa* (S a v.) specimen. The whole amount was situated under a mound, 150 in diameter and 60 cm high, in a single run (at a depth of 25 cm from the surface of the ground) leading to the chamber of the nest. The collection weighed 90 g. The earthworms seemed to be of a uniform size and were all more or less mutilated.

IV. MEASUREMENTS OF TEMPERATURE OF SOIL AND INTERIOR OF THE NESTS

On October 17 and 19 I stated, when collecting earthworms from nests that they were less motile than those found in the surface layer of the soil, up to a depth of 10 cm. I carried out several measurements with soil and atmospherical thermometers in places where earthworm stores were found or in their neighbourhood with the aim of ascertaining the temperature of the soil at different levels (Tables 2, 3).

Table 2.

Soil temperatures (°C) in neigbourhood of earthworm stores.

Depth	Site I (dry peat)	Site II (peat still drier)	Site III (light soil of a hustgred hue)
till depth of 10 cm	11°	9.95°	10.6°
„ „ 20 cm	10.6°	9.90°	11.25°
„ „ 50 cm	11.4°	10.85°	11.0°

Table 3.

Temperature measurements of mole's nests (in °C).

Site	I			II
Nest	1	2	3	4
Temp. of nest niche	12.1°	11.2°	11.2°	10.8°
Temp. of interior nest sphere	16.2°	14.8°	13.3°	11.1°
Temp. of runs surrouding nest	11.4°	10.8°	11.6°	10.4°
Temp. of runs at 1 m dist. from nest niche	10.6°	—	—	—

V. OBSERVATIONS ON FOOD STORAGE HABITS OF CAPTIVE MOLES [1])

Externally uninjured specimes were chosen out of earthworms brought in from the terrain and handed to captive moles. After alleviating the first pangs of hunger the moles, if they had no place to bury the earthworms, amassed them in the broadest part of the run, usually in a bend. Moles that had a sufficient amount of earth in their cages always buried earthworms. In that case, after pulling the earthworms into the runs they abandoned them, ran off and after vivacious movements and incessant penetration with the snout they searched for a convenient place in the cage, generally in a corner and there dug a hollow in the earth. They then returned to the earthworms they had left, caught them up usually by the front part of the body and, moving backwards,

[1]) Interesting observations concerning this problem can be found in the work of Degerbol (1927).

pulled them onto the chosen place. At a distance of a few centimetres from the hollow, they let go the earthworms and then pushed them into the hollows with movements of paws characteristic for moles — the same as during the pushing out of earth (Skoczeń, 1957; 1958). Each earthworm after being thrust into the hollow, was pushed about several times by the mole with its paws and controlled with its snout. Then, returning to the place where earthworms lie and catching new specimens, the moles pulled them along the same route to the chosen site. Some moles pushed in the direction of the hollow a greater amount of earthworms previously gathered in the run and then accumulated the earth and trod it down with their paws so that the whole store

Table 4.

Amonut of mutilated earthworms in stores collected by the captive mole.

Date	8.II	9.	10.	11.	12.	13.	14.II
No. of collected earthworms	28	21	20	30	31	50	24
wounded head segment	27	20	17	30	30	46	24
wounded further segments of the body	19	11	9	17	9	13	14

was usually placed under a small mound of earth rather strongly trodden down. It is known from numerous observations that the mole visits the stores it has prepared and feeds on them. I frequently observed, when breeding moles, the moment when the mole bit several times and in quite a visible manner on the frontal segments of the head the earthworm it had dragged into the run. Earthworms thus mutilated have a characteristically immobile or less mobile anterior sector of the body and very often, when fleeing, use the posterior of the body. All earthworms that had been gripped by the head sector, had the first segments of the body mutilated (Phot. 1, 2; Plate I). Moreover, the mole mutilates the head sectors of earthworms at the moment when they are gathered in a hollow in the earth or in any other place in the run. I have observed this very precisely in the cage. After having gathered the earthworms it had been given in a corner of the run, the mole investigated incessantly the collection with its snout, controlling

the surface. The earthworms were alive and crawled away — and those were bitten several times by the mole in the frontal segments of the head. The mole caught the earthworms that managed to run away, planting its teeth in the sectors of the head, and dragged them back to where the whole collection was gathered. The case of earthworms buried in the earth by the mole was analogous. Stores of that kind made by a mole living in a cage were subject to putrefaction in a few hours, especially in summer months. From February 8—14, 1958 I dug out specimens of earthworms that had been buried in great quantities. The state of their wounds is presented in Table 4 — nearly 100% were mutilated, especially in the anterior segments of the head.

VI. DISCUSSION

The following inferences may result from the totality of observations: moles collect food stores in the early autumn period, when the first cold days set in. This does not signify that moles do not endeavour to store food in periods of warm weather. It is known, from observations of captive moles, that these animals store surplus food in any season. It would be interesting to ascertain the behaviour of earthworms mutilated by moles and buried in the earth during summer months. Lowering of temperature of the soil in the autumn and winter periods undoubtedly has a decisive role for the storing of food by moles.

I stated, during my field researches, that a considerable amount of earthworms appear in the autumn period in the surface layers of the soil, in the root zone of grass. Thus for example on October 17 (temperature of air of 16°C) near site II, on a surface of 10 × 15 cm up to a depth of 7 cm I collected 12 earthworms of medium size, nearly all belonging to *Allobophora caliginosa* (S a v.) and 2 big specimens of *Lumbricus terrestris* L. On November 6 (temperature of air about 15°C) near site I on a surface of 20×20 cm and up to a depth of 10 cm I found 27 specimens of medium sized earthworms and 3 large specimens of *Lumbricus terrestris* L. It appeared then that earthworms, especially large ones are much less motile in colder weather than during warm periods. In the month of March, 1960, when catching earthworms (in very warm weather) I had to turn over the sods very rapidly so that the large *Lumbricus terrestris* L. earthworms had no time to escape — other-

wise it was impossible to collect a single specimen. The case of the mole is similar. I frequently observed, in spring or in summer, in the surface layer of the soil and sometimes even on the surface of the terrain, a mole pursuing a big earthworm that was running away. In autumn the earthworms are much less motile. They do not run away during the digging and that is why the mole can collect them in large quantities. Runs filled with grass in the nest on site I, where large amounts of earthworms were found, indicate that they were collected at the period when surface runs are dug, by means of which the mole collects grass to line its nest. Evans (1948) is of the opinion that earthworms in cold weather fall into the runs and are collected and stored there by the mole. If the earthworms, as Evans maintains, were collected during digging, their mutilations would have been much greater. It is impossible to exclude this possibility, although I did not find, during my field investigations, any earthworm lying freely or crawling along in a mole run. A factor which could influence earthworms in such a manner might be a higher temperature in mole runs, especially in those surrounding the nest. This is confirmed by the temperature measurements of October 19, 1960.

Orientative results of measurements of the temperature of the soil and of nests of moles with the runs surrounding them demonstrated that the temperature of places where the earthworms were stored was slightly higher than the temperature of the soil especially in inhabited nests. In this light the problem of greater inertia of earthworms stored by the mole in runs or in the walls of the niche in the nest, than of earthworms from surface layers of the soil, is of interest. Earthworms dug out of moles' nests and transported into a room remained inert. But when laid on the palm of the hand, they became lively and ran away, even if the hand was closed and strongly pressed. Undoubtedly the wounds inflicted by the mole exert a certain influence on their motility and capability of pushing through the earth. It is not excluded that there are substances in the saliva of the mole that have a paralysing influence on earthworms. Country people believe that the mole is a poisonous animal.

Evans (1948), when investigating wounds inflicted by the mole, placed 10 adult earthworms *Lumbricus terrestris* L. in a large vessel filled with earth. During a period of about 2 months the

earthworms were inactive. When the contents of the vessel were investigated in the month of July, small ramified burrows were found in the soil. The earthworms were alive, in good condition and had laid 22 cocoons. This would prove that when collected and mutilated by the mole their vitality is not impaired. My own observations corroborate this fact, for in warmer spring weather earthworms rapidly disappeared form the collections I investigated. In April 1958 I left till the following day one of the stores found near a nest. On the next day not a single earthworm was to be found. All had disappeared revived by the warm air which had penetrated into the soil moved by a spade. They had not been transported by a mole as there were no traces of digging.

A characteristic feature of autumn findings was the fact that the earthworms were placed, in the majority of nests, in all of the runs, at different depths and even in the molehill covering the nest. I did not find a similar disposition in winter or early spring collections in the same terrain. If the earthworms were located along the runs (Fig. 2, B) they were usually on the same level. I suppose that the mole, as the soil grows colder, transports the earthworms from upper runs into lower regions. I have the impression that both number and location of earthworms met with in the autumn period is characteristic for the initial stages of food storing by the mole.

Autumn findings also indicate the fact that food stores of the mole are a rather universal phenomenon. They were met with in sites where up till now I had not been able to find any. They probably appear in different sizes, in relation to the amount of earthworms found in the terrain. Large stores are used by the mole during the whole winter and in many cases they are not entirely consumed — they can even increase in mild winter weather. Small stores however are exhausted much earlier and that is why I found empty nests in spring. It is apparent that food stores in nests of moles indicate the abundance of soil fauna in a given terrain.

The appearance of small earthworms in collections of that kind was only noted by E v a n s (1948) till the present time. I presume that this was caused by the fact that scientists discovered the stores generally in winter or in early spring. The results of my investigations seem to indicate that small earthworms of which

autumn stores of the mole are partly composed, are eaten at first by the mole. In E v a n s' material small earthworms, as *Lumbricus castaneus* (S a v.) and *Allobophora chlorotica* (S a v.) appeared in very small quantities and were not mutilated. The author supposed that they had penetrated accidentally into the collection when it had been dug out. *Allobophora caliginosa* (S a v.) was second in number after *Lumbricus terrestris* L. and nearly all specimens (with the exception of 2) were mutilated. This relation was similar in the material I had gathered from some nests — but in others, as for instance in one of them, from October 19, *Allobophora caliginosa* appeared in a quantity about twice the number of *Lumbricus terrestris* L.

E v a n s (1948) noted the fact that species composition of earthworms in collections of moles' nests does not correspond to the terrain conditions of that kind. In this author's material *Lumbricus terrestris* L. appeared in 90%, while in the terrain its relation to other species was of more than 25%. It is a well known fact that these relations are strictly dependent on ecological factors in the given terrain. Thus M o s z y ń s k i (1957) publishes results for terrains in Byelorussia when the amount of *Lumbricus terrestris* L. was of 15%. In investigations of J. D. P l i s k o (1959) (and oral information) *Lumbricus terrestris* is a species that is relatively seldom seen, sometimes in 1% only. In my observations on sites investigated by me (Błonie, Jordan's Park, Łęg) this species appeared only in an amount of 3—16%. This same species attained 100% in the collections of mole nests in winter and early spring periods, and 60% in autumn collections on the same terrain. These relations might indicate that moles select their food. As results from the above, the mole feeds usually on small earthworms, preferring them to the large ones which it stores. Observations on captive moles also confirm these facts.

Earthworms from winter and spring collections distinctly demonstrated visible mutilations in 40% of the individuals. The scars on individuals that seemed to have no wounds were difficult to perceive. 100% of the specimens from autumn stores were mutilated. The ascertaining of wounds at a later period can only be undertaken by a skilled expert and to this perhaps must be ascribed the statements of other authors (S c h a e r f f e n b e r g, 1940) about finding completely uninjured earthworms in mole runs.

VII. SUMMARY

Observations carried out on captive moles and some facts observed in nature indicate that the mole collects the food it has not consumed in the vicinity of the nest. The earthworm stores that have been discovered were always connected with winter nests of the mole. These stores can be grouped in a niche specially dug out near the nest or disposed in the walls of the runs or the walls of the nest chamber — or only in the walls of the runs, at a certain distance from the nest. The disposition of earthworms is probably related to ecological factors of the autumn and winter period. The stores are collected successively by the mole beginning with the first autumnal cold days and also during a mild winter. In spring, when the temperature of the soil rises (usually in April) the earthworms leave the stores and disperse.

In all earthworms from autumn stores mutilations of front segments of the head were predominant. Smaller specimens like *Allobophora caliginosa* (S a v.) had in many cases much more considerable injuries (a lack of 1—5 head segments). Mutilations of earthworms from stores found in winter or spring were mostly regenerated and were thus difficult to diagnose. The mole availed itself of food stores during the winter; this was confirmed by half-eaten earthworms or their remnants. The earthworms found during the winter season and in early spring seemed to be in perfect condition.

The stores were found in Łęg, in the winter and spring of every year, on the same site where, under a 30 cm layer of humus, loam of a dough-like consistence was situated. In other parts of the same terrain during the autumn period (October 17—19, 1960) stores of earthworms in different stages were also found. It appears that food storage of the mole is a phenomenon much more frequent than was hitherto supposed. Besides earthworms insect larvae, mostly cockchafer grubs, larvae of *Noctuidae* and *Carabidae* were found in very small quantities. They were not injured and, with the exception of cockchafer grubs, might have been there accidentally.

In stores of the autumn period *Lumbricus terrestris* L, were prevalent (70%). *Allobophora caliginosa* (S a v.) came second (25%) while *Octolasium lacteum* (O e r l e y) appeared in a very small quantity (5%). Autumn collections differ fundamentally as

to the species composition of earthworms from those found in winter and spring. At that time only one species, *Lumbricus terrestris* L. was found in all the collections. This might indicate that the mole consumes first of all the small specimens in the store. The choosing of food by the mole is also stressed by the fact that the percentage of sundry species of earthworms stored by it differs fundamentally from the conditions in the given terrain. In the sites I investigated *Lumbricus terrestris* L. appeared only in 3—15% while in autumn stores its number was of 28 to 98%.

The origin of food stores is related above all to the lowering of temperature in the autumn season. At that time the earthworms living in the soil, especially in its surface layers, become much less active and are therefore easy to attain for the mole. This is the period when moles build their nests and dig runs near the surface for obtaining litter. These runs are mostly situated quite near the nest and, when digging them, the moles collect large quantities of earthworms which they drag in and store. It is not excluded that, besides the low temperature and the wounds inflicted by the mole still other factors incapacitating the earthworms should be considered. Temperature measurements of the soil at different depth and inside the nests of moles and the runs surrounding them showed that although the temperature of mole habitats is higher than that of the soil, the earthworms stored in the nest or the runs around it are less active than the earthworms living in the soil.

The location of earthworms in the runs, apart from their number and species composition, is a characteristic feature of the initial stages of food storing by the mole. They are disposed in all the runs at different depths, while in the winter period the earthworms in the run were mostly found at the same depth. One might presume that the mole transports the earthworms into deeper regions as the temperature lowers.

Acknowledgement :

My sincere thanks are due to Professor dr. Z. Kawecki for introducing me to the study of the mole in Poland, to Professor dr. A. Dehnel for reading of the manuscript and many valuable suggestions and Mgr J. I. Plisko for determining of the material.

This paper is a part of the work „Investigations on the biology and ecology of the mole (*Talpa europaea* L.) in Poland", partly financed by the Commitete for Zoological Sciences of the Polish Academy of Sciences.

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EXPLANATIONS OF PLATES (I — II).

Plate I.

Phots. 1—2. Earthworms mutilated by the captive mole (phot. by L. Sych).

Phot. 3.— Earthworms with a characteristically convex gullet from terrain stores (phot. by J. Starmach).

Plate II.

Phot. 4. Earthworms collected near one of the nests, on March 17, 1960 in Łęg near Kraków (phot. by J. K o t e j a).

Phot. 5. Specimens collected in terrain with characteristically mutilated sectors of the head (phot. by J. S t a r m a c h).

STRESZCZENIE

Obserwacje poczynione nad kretem (*Talpa europaea* L i n n a e u s 1758) w niewoli oraz niektóre fakty stwierdzone w terenie wskazują, że zwierzę to gromadzi zapasy pokarmowe. Zjawisko to jest bardziej powszechne niż dotąd sądzono.

Skupiska dżdżownic znajdywano przede wszystkim w gniazdach zimowych, w specjalnie wykopanej w ich pobliżu niszy, lub rozłożone w ścianach chodników i komory gniazdowej. Obserwowano je też niekiedy w ścianach chodników oddalonych od gniazda.

Powstawanie zapasów pokarmowych kreta związane jest przede wszystkim z obniżeniem się temperatury w okresie jesiennym. Dżdżownice przebywające w tym czasie w powierzchniowej warstwie gleby są o wiele mniej ruchliwe i dlatego łatwiej dostępne dla kretów, które w celu zdobycia ściółki na gniazdo zimowe, kopią liczne chodniki powierzchniowe. Kret może również gromadzić zapasy w ciągu łagodnej zimy. Na wiosnę, wraz ze wzrostem temperatury gleby (zwykle w kwietniu) dżdżownice rozchodzą się z utworzonych skupisk.

W zapasach zimowych kreta, obok dżdżownic, spotykano również niewielkie ilości pędraków, oraz larwy *Noctuidae* i *Carabidae*. Larwy te nie miały żadnych uszkodzeń i być może, z wyjątkiem pędraków, znalazły się w zbiorze przypadkowo. W zbiorach z okresu jesiennego przeważała *Lumbricus terrestris* L. — 70%; drugie miejsce zajmowała *Allobophora caliginosa* (S a v.) — 25%. Inne gatunki jak *Allobophora rosea* (S a v.) i *Octolasium lacteum* (O e r l e y) stanowiły pozostałe 5%. Kret wyjada ze zbiorów najpierw okazy małe. Na wiosnę we wszystkich skupiskach dżdżownic był tylko jeden gatunek — *Lumbricus terrestris* L.

Udział procentowy poszczególnych gatunków dżdżownic w zapasach kreta różni się zasadniczo od stosunków panujących w danym terenie. W moim przypadku stwierdziłem, że *L. terrestris* występuje w terenie w ilości 3—15%, natomiast w zapasach kreta z okresu jesiennego gatunek ten stanowił 28 do 98%.

Wszystkie dżdżownice ze zbiorowisk jesiennych były pokaleczone przeważnie w przednich segmentach głowowych. Okazy mniejsze, jak *Allobophora caliginosa*, wykazywały w wielu wypadkach znaczne uszkodzenia (np. brak 1—5 segmentów głowowych). Dżdżownice znalezione w gniazdach krecich w ciągu zimy lub na wiosnę miały owe pokaleczenia w znacznym stopniu zregenerowane i zdawały się być w pełnej kondycji zdrowotnej.

W początkowych okresach gromadzenia zapasów przez krety dżdżownice są rozmieszczone we wszystkich chodnikach na różnych głębokościach. W okresie zimowym natrafiono na nie przeważnie na jednej głębokości. Prawdopodobnie w miarę ochładzania się gleby, krety przenoszą swoje zapasy w głębsze partie chodników.

Dżdżownice magazynowane przez krety są mniej ruchliwe od żyjących w glebie, mimo że temperatura pomieszczeń krecich jest wyższa. Wydaje się, że poza temperaturą i okaleczeniami mamy tu do czynienia również z inymi czynnikami, mogącymi wpływać na obezwładnienie dżdżownic zgromadzonych w gniazdach kreta.

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Podpisano do druku 20. IV. 1961 r. Druk ukończono 15. V. 1961 r.
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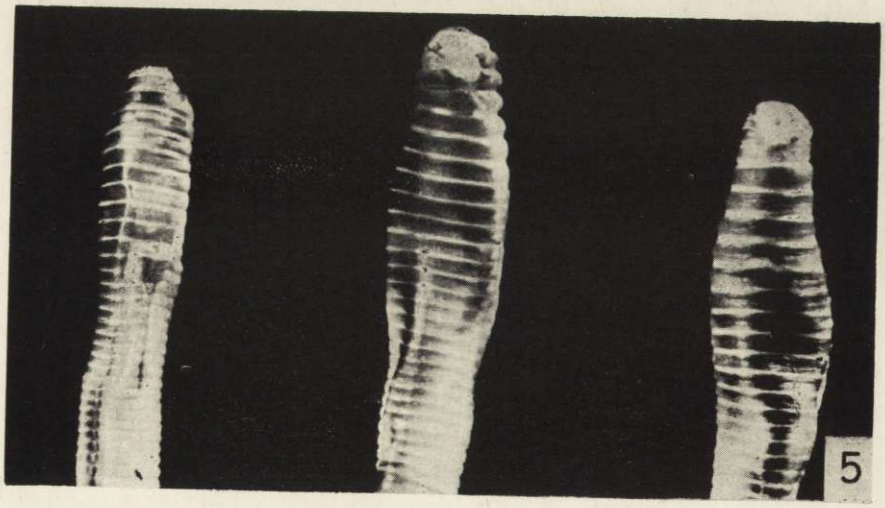

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