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Hunting Methods in Relation to Hunting Situations in Japanese Shrew-mole, *Urotrichus talpoides*

II. Detection of the Earthworm "Head"

With 3 Text-figures

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ABSTRACT The ability of *Urotrichus talpoides* and *Mogera wogura* to detect the "head" of earthworm, which is the main prey of both the species, and the nature of such detection were studied. Both have the tendency to distinguish the "head" sector from other parts of the body of earthworm and to eat from the "head" sector first. *Urotrichus* more strictly distinguished the "head" sector of earthworm than *Mogera*. Movement of an earthworm released bite-and-retreat attack (*Urotrichus*) and repeated bite attack (*Mogera*) to any random part of its body, which made the earthworm immobile. Then, both the species touched the body of the worm along its length anteriorly and delivered an aimed bite to the "head" sector. Thus, both the species showed two patterns of actions, disabling bites and the aimed bite which should be distinctly discriminated. Ingestion of the "head" sector followed the aimed bite and then the rest of the body was also consumed or stored.

It has been said that the European common mole, *Talpa europaea*, eats prey (earthworm) from the anterior end ("head") first (Godfrey and Crowcroft, 1960; Mellanby, 1970). Most of the earthworms found in natural condition which seemed to have been stored by *Talpa* had several anterior segments bitten off (Evans, 1948; Skoczen, 1961, 1970; Mellanby, 1970). It was also described that the *Talpa* in captivity bit off the "head" sector of an earthworm before storing it (Skoczen, 1961; Mellanby, 1970). Similarly, the Japanese shrew-mole, *Urotrichus talpoides*, in captivity was observed to eat an earthworm from the "head" first or to bite off the "head" sector of the prey before storing it (Imaizumi, 1978). These facts suggest that *Talpa* and *Urotrichus* may have ability to distinguish the "head" sector from other parts of the body, especially from the posterior end ("tail"). Herter (1957), Godfrey and Crowcroft (1960) and Ewer (1968) considered that the cue

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controlling this distinction is mobility of the prey: since the anterior end of an earthworm is the part that moves most, *Talpa* bites at the moving part. That is, these authors thought that the "head" itself would not be detected. However, the head-distinguishing ability of *Talpa* has not been analysed quantitatively, nor have cues controlling this distinction been studied experimentally.

During preliminary observations, it was noticed that movement of an earthworm really released the "bite-and-retreat" behavior of *Urotrichus*, but that this behavior was not always directed to the "head" sector and could be directed to any part of the body (Imaizumi, 1978). After the "bite-and-retreat" attack had made the prey almost immobile, *Urotrichus* delivered the aimed bite to the "head" sector and then ate the prey from the "head" sector first, or ate the "head" sector and stored the rest of the body. These facts suggest that detection of the "head" of the earthworm may be controlled by some other factors than mobility.

The aim of this study is to analyse the "head" detecting performance quantitatively in the Japanese shrew-mole, *Urotrichus talpoides* and the Japanese eastern mole, *Mogera wogura* (=*Talpa wogura*), and to examine factors which affect detection of the "head" sector.

Materials and Methods

Experiments were conducted from May through July, 1977 and from August to September, 1978 on 9 *Urotrichus talpoides hondonis* collected at Higashi-Matsuyama City, Saitama Pref. and Subashiri Machi, Shizuoka Pref. and from June through September, 1978 on 5 *Mogera wogura imaizumii* collected at Chichibu City, Saitama Pref. and Subashiri Machi. Only wild caught animals were used in this study.

Each animal was kept singly in a captive cage consisting of two or three glass cages of $60\times36\times30$ cm high sections which were connected by two or three sets of wire mesh tunnel 90 cm in length and 3 cm (*Urotrichus*) and 5 cm (*Mogera*) in diameter (Fig. 2). Animal was able to reach the glass cage floor through a vertical wire mesh tunnel ending in the glass cage 3–7 cm above floor level. Detailed explanation about the captive cage was shown by Imaizumi (1978). The *Urotrichus* and the *Mogera* soon became acclimatized to this captive cage. The animals were fed daily on earthworms, raw chicken meat, mealworms and oatmeal. Water was supplied *ad libitum*.

When the animal was active in the captive cage, earthworms, *Pheretima communissima*, were presented to him either on the floor of the cage, or in the wire mesh tunnel. How the prey was treated was observed and which end of the body of the prey was eaten first and the time spent for eating up the whole prey were recorded. Moreover, the following two experiments were conducted.

I) An earthworm which had been deprived of apparent movement by cold or hot bathing was put on the floor of a glass cage and then the mole was given

access to it.

II) An earthworm was cut into two and both parts were placed on the floor of a cage and then the mole was given access to them.

RESULTS

1) *"Head" detection*

Urotrichus disabled an earthworm with "back-with-grip" attack in a tunnel and with "bite-and-retreat" attack on the ground (see Imaizumi, 1978 for detailed description). On the other hand, *Mogera* pulled an earthworm into a tunnel with brief back-with-grip (at most several centimeters) or scratched the prey out of the soil with the claws of the fore feet before it disabled the prey by pinning it against the substrate with the fore feet or by delivering a series of bites to any part of the prey. On the ground several successive bites without retreat were delivered by *Mogera* to an earthworm to disable it. Neither *Urotrichus* nor *Mogera* shook the prey in the mouth like many other mammalian predators.

In either *Mogera* or *Urotrichus* such disabling bites were directed to no specific part of an earthworm, but any part of it. The bite of *Mogera* was much stronger than that of *Urotrichus* and the part bitten by *Mogera* often became half mutilated. Earthworms, when attacked, sometimes underwent autotomy. Attack of *Mogera* caused autotomies more frequently than that of *Urotrichus*. Twenty-nine percent (N=89) of the earthworms attacked by *Mogera* underwent autotomy, while 15 percent (N=80) of those attacked by *Urotrichus* did so (Table 1).

Table 1
Percentage of occurrence of autotomy of the earthworm as a reaction to attack of *Urotrichus* and *Mogera*.

	No. of worms presented	No. of worms autotomised	%
Urotrichus	80	12	15
Mogera	89	26	29

Then when the movement of earthworm became much slower, either *Urotrichus* or *Mogera* touched the body of the prey along its length toward the anterior end with the lower side of the upper lip. When it reached the "head" sector, it delivered an aimed bite to the "head" sector. The aimed bite directly led to eating the prey from the "head" sector, or to carrying it to an eating place, which was usually followed by eating, or to storing the prey after eating up the "head" sector. However, the animal sometimes touched an earthworm along its length toward the posterior end. In this case either of the following two behaviors followed. i) After the animal had reached and bitten the "tail" a little bit, he turned toward the "head" touching the worm along its length and eventually ate the worm from the "head" sector. ii) When the animal reached the "tail" sector, he consumed

the prey from the "tail". Thus *Mogera* and *Urotrichus* did not always "correctly" detect the "head" of the worm, nor always eat from the "head" sector; they sometimes made "mistakes". As shown in Table 2, these "mistakes" were more frequently made by *Mogera* than *Urotrichus*.

Table 2
The number of the case in which each end of the earthworm (the "head" or the "tail") was eaten first. "Tail" → "head" means that the animal first bit at the "tail", but immediately released it and ate from the "head".

	"Head" first	"Tail" first	"Tail" → "head"	No. of worms presented
Urotrichus				
No. 77–1	11 (100%)	0	0	11
No. 77–2	21 (100%)	0	0	21
No. 77–3	15 (83%)	0	3 (17%)	18
No. 77–4	22 (85%)	0	4 (15%)	26
No. 78–1	30 (81%)	0	7 (19%)	37
No. 78–2	7 (87%)	0	1 (13%)	8
No. 78–3	48 (100%)	0	0	48
No. 78–4	16 (89%)	0	2 (11%)	18
No. 78–5	24 (100%)	0	0	24
total	194 (92%)	0	17 (8%)	211
Mogera				
No. 78–1	27 (60%)	4 (9%)	14 (31)%	45
No. 78–2	7 (64%)	3 (27%)	1 (9%)	11
No. 78–3	30 (63%)	5 (10%)	13 (27%)	48
No. 78–4	63 (85%)	8 (11%)	3 (4%)	74
No. 78–5	93 (85%)	6 (6%)	10 (9%)	109
total	220 (77%)	26 (9%)	41 (14%)	287

These observations suggest that *Urotrichus* and *Mogera* were able to distinguish the "head" of earthworm from other parts though they occasionally made a "mistake". *Urotrichus* in particular was much inclined to distinguish the "head" sector. Since the "head" sector was detected after the worm had been made immobile, movement of the worm may not be directly related to "head" detection, con-

trary to the statements of Herter (1957), Crowcroft and Godfrey (1960) and Ewer (1967).

2) *Experiment with earthworms which were deprived of movement artificially*

If *Urotrichus* and *Mogera* found artificially immobilized earthworms, they did not attempt to bite: neither bite-and-retreat attack nor repeated bite attack was observed. In every case, the animal passed along the length of the worm toward the anterior end by touching the body of the worm with the lower side of the upper lip and when he reached the "head" sector he delivered the aimed bite to it. No "mistake" was made in recognition of antero-posterior direction of the worm in 96 cases (*Urotrichus*) and 55 cases (*Mogera*).

It is noticeable that the "head" sector of an artificially immobilized earthworm was more correctly detected than that of a worm disabled by the animals' attack. Since preliminary disabling attacks, bite-and-retreat (*Urotrichus*) and repeated bite (*Mogera*), were not released by such immobilized earthworms, the factor which released these attacks may probably be movement of the earthworm. On the other hand, touching movement along the body of the worm anteriorly and the aimed-bite were normally released by the immobilized earthworm, that is, the cue controlling these behaviors may not be movement of the earthworm. Thus, the results of this experiment were not consistent with the assumption that movement of the earthworm would be responsible for detection of the anterior end, "head" of the worm, by moles.

3) *Experiment with earthworms cut into two parts in the middle*

Both the anterior and posterior halves of an earthworm were laid about 1–4 cm apart from each other on the ground of the captive cage. Both *Urotrichus* and *Mogera*, when they first found the anterior half of the worm and if it rampayed, immediately delivered bite-and-retreat (*Urotrichus*) or repeated bite (*Mogera*) as they did to an intact earthworm. When movement of the anterior half became much slower, they touched along the body toward the "head", delivered the aimed bite, and then ate from the "head" sector (Table 3). Thus, the anterior half of an

Table 3
The number of the case in which each end of the anterior half of the earthworm (the "head" or the cut end) was eaten first when the animal found the anterior half before it found the posterior half.

	"head" first	cut-end first	No. of worms presented
Urotrichsus	42 (98%)	1 (2%)	43
Mogera	52 93%)	4 7%)	56

earthworm was treated in the same manner as an intact earthworm. However, though *Mogera* sometimes ate an intact worm from the "tail" (Table 2), it was very exceptional that *Mogera* ate the anterior half from the posterior cut end (Table 3).

On the other hand, when *Urotrichus* and *Mogera* found the posterior half of the worm first, they showed definitely different reaction to it from that to an intact worm or to the anterior half.

3-I) *Urotrichus*:— Nine *Urotrichus* found the posterior half of an earthworm 91 times in total before they found the anterior half (Table 4). If the posterior half of the worm moved, *Urotrichus* attacked it with bite-and-retreat attack and after its movement became slow, *Urotrichus* touched the body of the posterior half along its length in postero-anterior direction. However, when he reached the anterior cut end, he abandoned the prey item without delivering the aimed bite (Table 4). Otherwise, touching of the prey from the cut end to the posterior end and that from the posterior end to the cut end were repeated from twice to several times and the prey was eventually abandoned. Then, *Urotrichus* began searching out. When he found the anterior half, he showed bite-and-retreat attack to its movement, touch-

Table 4
Reaction of *Urotrichus* and *Mogera* to the posterior half of the earthworm when they found it before they found the anterior half.

	Abandon after checking	Eat "tail" first	Eat cut-end first	No. of worms presented
Urotrichus	69 (76%)	13 (14%)	9 (10%)	91
Mogera	2 (3%)	38 (60%)	23 (37%)	63

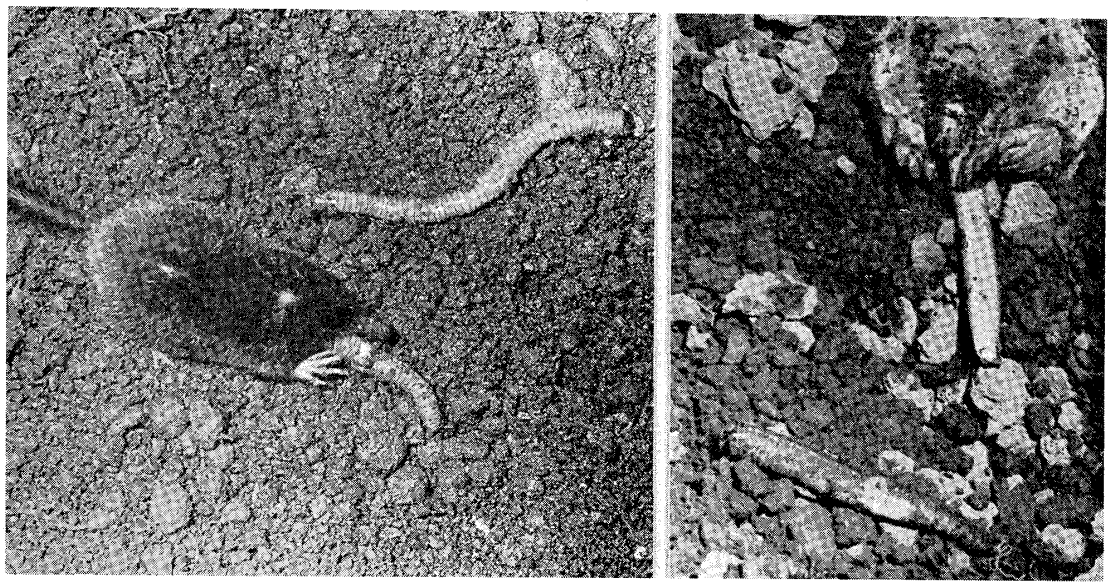


Fig. 1. *Urotrichus* (left) and *Mogera* (right).
The earthworm which had been cut into two was given. *Urotrichus* first found the posterior half, checked it and abandoned it. Then *Urotrichus* found the anterior half and ate it from the "head". *Mogera*, when found the posterior half first, ate it from the anterior cut end.

Table 5
Reaction of *Urotrichus* and *Mogera* to the anterior half of the earthworm which they found after they had abandoned the posterior hlalf.

	"Head" first	Cut-end first	No. of trials
Urotrichus	66 (96%)	3 (4%)	69
Mogera	2 (100%)	0	2

ed it along its length toward the "head" sector, delivered the aimed bite to the "head" sector, and ate from the "head" sector (Table 5 and Fig. 1).

After finishing the anterior half, *Urotrichus* ate the posterior half mostly from the "tail". The fact that *Urotrichus* even abandoned the posterior half if he had not eaten the anterior half from the "head" sector yet, may mean that *Urotrichus* much adhered to the "head" sector of the earthworm as a part to deliver the aimed bite or to eat first. It seemed that *Urotrichus* could get directional information from the skin of the worm but the "head" sector which was essential for the aimed bite or beginning of eating was not meant by a simply anteriormost extremity of the worm's body. Only some feature of the "head" sector itself might release the aimed bite or eating. The following two protocols also suggest such adherence of *Urotrichus* to the "head" sector of the wrom.

Protocol i) *Urotrichus* No. 77-2, 5 July, 1977:— An earthworm 5 g in weight and cut into two in the middle was placed on the floor of the glass cage. The *Urotrichus* came out of the tunnel, found the posterior half of the worm and attacked it (bite-and-retreat). He checked the middle part of the body, the cut end and the "tail" end. Then he abandoned the posterior half and sniffed about. He advanced by 3–4 cm, touched the anterior half, bit it and retreated, followed the body anteriorly with touching, and bit at the part near the "head" end. He released the worm, probably because of violent movement of the worm. Then the animal happened to touch the posterior half again and after checking the cut end and the "tail" end, abandoned it and started searching. He found out the "head" sector of the anterior half again and gripped it, carrying it into the tunnel. There he ate it from the "head" sector first and in 97 seconds finished consuming the whole anterior half. Soon after rubbing off the mucus of the worm from his body, the animal turned to the floor of the glass cage, checked the posterior half from the cut end toward the "tail" end, but soon he abandoned it again, and started searching the tunnel and the glass cage. While he searched these places for more than one minute, he touched the posterior half twice, but he abandoned immediately after checking the cut end and the "tail" end. Since the animal seemed to search for the "head" sector of an worm, an intact earthworm of 2 g was introduced in the cage. The *Urotrichus* instantly came across the worm, disabled it by bite-and-retreat attack, gripped its "head" sector and carried it to the resting place to treat it there.

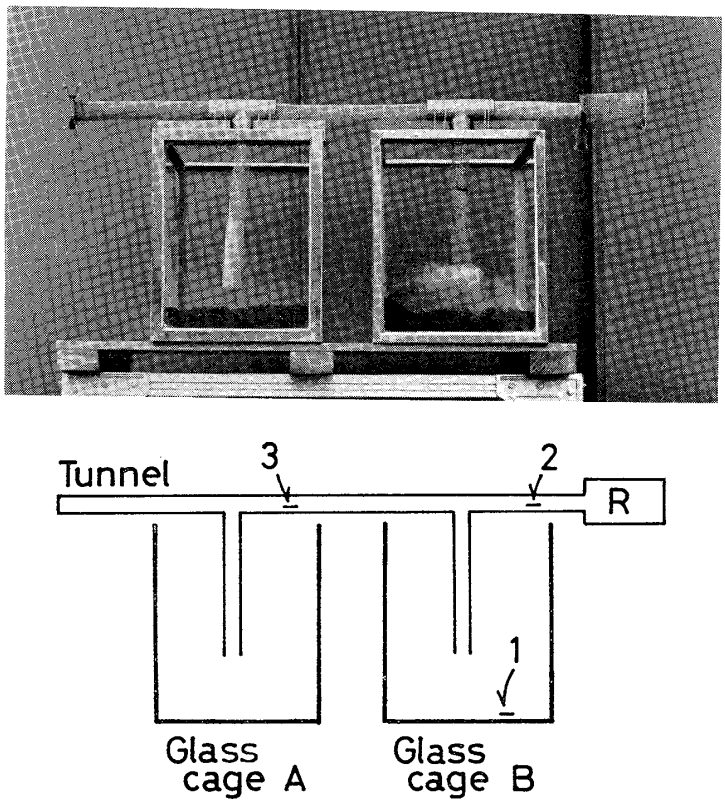


Fig. 2. Side view of an observation cage of *Urotrichus talpoides*. Number 1 indicates the point at which an earthworm was placed by the observer and 2 and 3 the points where the shrew-mole carried and placed the worm. R is a resting place. Explanation in text.

Protocol ii) *Urotrichus* No. 77-1, 6 July, 1977:— An earthworm of 3.8 g was cut into two in the middle and placed on the floor of the glass cage B (at the point 1, Fig. 2). The *Urtrichus* No. 77-1 found and gripped the posterior half of the worm, carrying it into the tunnel. He placed the piece on the floor of the tunnel at the point 2 (Fig. 2), and checked it from the middle part of the body anteriorly to the cut end and abandoned it on the floor. The animal returned to the glass cage B, found the anterior half and carried it up into the tunnel, placing it along with the posterior half at the point 2. He rubbed off the mucus from the fore-feet and the mouth by moving back and forth in the tunnel. He then picked up the posterior half and pulled it backward to the point 3 (Fig. 2). After checking the cut end and the "tail" end two or three times, the *Urotrichus* abandoned the piece. Soon he returned to the glass cage B, searching the floor (he probably "forgot" that he already carried up the anterior half to the point 2 of the tunnel). After a little while, the *Urotrichus* again checked the cut end and the "tail" end of the posterior half of the worm at the point 3 and returned to the glass cage B to search the floor again. Then, he passed through the tunnel, stepping on the posterior half of the worm at the point 3 and went into the other glass cage (A) to search. When he returned to

the tunnel he found out the anterior half at the point 2. Immediately after he had checked the "head", he ate the piece "head" sector first.

3-II) *Mogera*:— When *Mogera* encountered the posterior half of an earthworm first, they reacted to it in a manner much different from *Urotrichus*. *Mogera* touched the body of the posterior half along its length anteriorly and checked the anterior cut end as *Urotrichus*, but he hardly abandoned it (Table 4). Instead, he mostly again passed along the body of the prey in reversed direction toward the "tail" end and on reaching the "tail", immediately ate the prey from the "tail" (Table 4). Sometimes *Mogera* ate from the anterior cut end, immediately he had checked the cut end, or after he had checked the "tail" end, returned to the cut end and checked it (Fig. 1). However, it was only 37 percent of posterior halves of earthworm presented to them that *Mogera* ate from the anterior cut end (Table 4). *Mogera* appeared to prefer to eat from the "tail" rather than to eat from the anterior cut end. Apparently *Mogera* less adhered than *Urotrichus* to the "head" sector of an earthworm as a part to deliver the aimed bite or to eat first.

There were a few exceptions in which *Mogera*, after repeated touching the body of the prey along the body twice, abandoned the posterior half, searched for the anterior half, and ate it from the "head" sector (Tables 4 and 5).

After eating the posterior half, if *Mogera* found the anterior half of the worm, treated it in the same manner as if he would do when finding it before he found the posterior half (Table 6).

Table 6
Reaction of *Urotrichus* and *Mogera* to the anterior half of the earthworm which they found after they had eaten up the posterior half of the worm.

	"Head" first	Cut-end first	No. of trials
Urotrichus	20 (91%)	2 (9%)	22
Mogera	58 (95%)	3 (5%)	61

INGESTION AND STORING

As mentioned earlier, *Mogera* and *Urotrichus* ate earthworms almost always from the "head" antero-posteriorly, but the animal did not consume the prey from the "head" to the "tail" at a stretch. During eating one earthworm, the animal usually made several pauses, in which he scraped the mucus of the worm off the mouth and the fore feet. When the animal resumed eating after the first pause, he ate the worm from the end of the prey opposite to that which had been eaten first; if he had eaten the worm first from its "head" antero-posteriorly, then he began this time with the "tail" postero-anteriorly, and after the second pause he would begin with the anterior bitten end again. Thus, although the animal delivered

the initial aimed bite almost always to the "head", he ate the worm alternatively antero-posteriorly and postero-anteriorly. When the animal held the worm on the ground with the fore feet, gut contents were squeezed out of the worm's body from the bitten end opposite to that which was being eaten and they were hardly eaten.

While eating, *Mogera* showed a characteristic quick upward motion of the head and swallowed bitten flesh almost without chewing. Time spent for eating was very short: the average speed was 4.6 seconds per 1 gram in weight of earthworm (SD=0.25, N=132). On the other hand, *Urotrichus* seldom showed the upward motion of the head and they chewed the prey. The average eating speed was 77.1 seconds per 1 gram of earthworm by *Urotrichus* (SD=22.1, N=59). Thus time spent for eating 1 gram of earthworm by *Urotrichus* was 16.7 times as much as that spent by *Mogera*. Table 7 shows time spent for eating an earthworm in each size (weight class). *Mogera* ate a worm of every size much faster than *Urotrichus*.

Table 7
Time (in second, M±SD) spent for eating an earthworm of each weight class.

Weight of earthworms	Time spent for eating (in second, M±SD)			
	Urotrichus	N	*Mogera*	N
1–1.9 g	89±33	28	3.4±1.9	12
2–2.9	178±53	21	10.2± 4.1	60
3–3.9	291±88	7	16.1± 6.5	39
4–4.9	389	2	22.7±10.9	7
5–5.9	569	1	27.5±18.8	7
6–6.9			79.5	2
7–7.9			92.0	2

After alleviating the first pangs of hunger by eating a total weight of 2–5 g of earthworms (*Urotrichus*) or 8–12 g (*Mogera*), *Urotrichus* and *Mogera* began storing earthworms. After disabling an earthworm, the animal ate a part of the "head" sector, gripped the prey by the "head" in the mouth, carried it to the storing place. *Urotrichus* selected the corner of a glass cage as a storing place, while *Mogera* selected the end of a wire mesh tunnel (Fig. 3). *Urotrichus* even carried the earthworm which was caught in a tunnel to the floor of the corner of a glass cage and stored it there, while *Mogera* carried even the earthworm caught on the floor of a glass cage to a tunnel and stored it in the tunnel. This difference may reflect difference between the two species in degree of specialization for subterranean life.

The earthworm, after being placed on the substrate of the tunnel by *Mogera*, was pushed to the wall of the tunnel several times with the fore feet and the "head" sector was eaten again. If there were fallen leaves or small stones nearby in the tunnel, *Mogera* pushed them into the wall, thus covering the preys with them (Fig. 3). This storing method may correspond to loam-coating of the walls of the runs on which earthworms were stored, observed by Skoczen (1961) in the fields. *Urotri-*

chus, coming to the corner of the glass cage, thrusted his head into the soil with the prey gripped in the mouth, then ate the "head" sector of the prey again (Fig. 3), released it in the soil, and got out of the soil. If a part of the body of the worm was still exposed on the surface of the ground, *Urotrichus* covered soil over it with the fore feet. In both cases of *Mogera* (N=98) and *Urotrichus* (N=189) it was always the "head" sector of the earthworm that was bitten before the prey was stored (Table 8).

Table 8
Ingestion of the "head" sector before storing the earthworm.

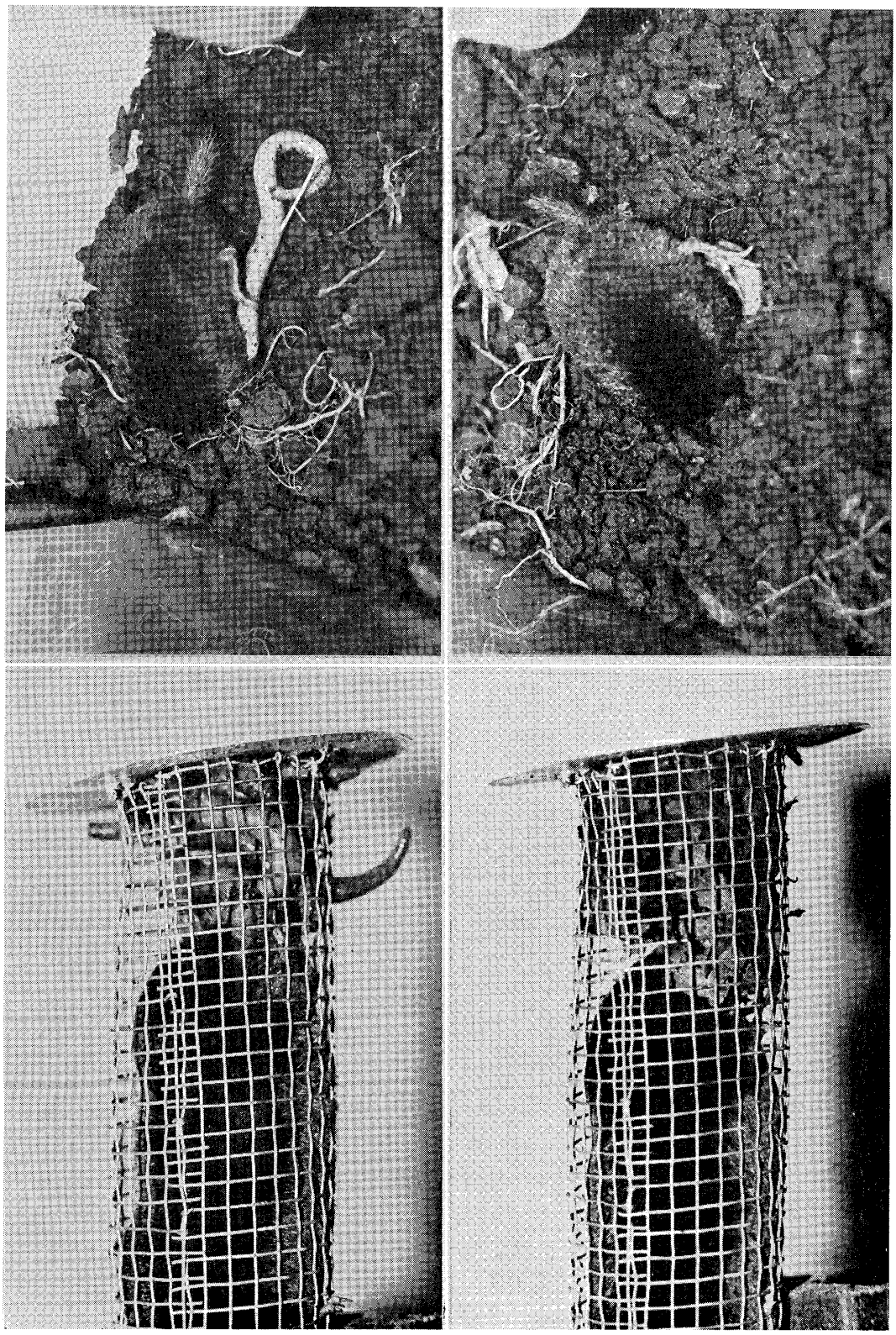
	No. of earthworms stored	Head sector ingested
Urotrichus	189	189 (100%)
Mogera	98	98 (100%)

DISCUSSION

This study reveals quantitatively that *Urotrichus* and *Mogera* distinguish the "head" sector of the earthworm as a specific part. This distinction is not a mere result of bites released by movement of the earthworm as has been stated by many authors (Herter, 1957; Godfrey and Crowcroft, 1960; Ewer, 1968). *Urotrichus* and *Mogera* seem to distinguish the "head" sector by touching the body of the worm along its length anteriorly and deliver the aimed bite to the "head" sector which may be released by some feature of the "head" itself. Movement of the worm releases disabling bites at any random parts of the worm. Thus, *Urotrichus* and *Mogera* have two behavioral patterns, the disabling attack directed to unspecific parts of the prey and the aimed bite directed to the specific part of the prey. As Eisenberg and Leyhausen (1972) stated, these two patterns must be discriminated from each other.

Mogera and *Urotrichus* seem to be specialized earthworm-eating insectivores in that they have the behavioral patterns of delivering the aimed bite to the "head" sector of the earthworm and eating the worm from that part. According to Eisenberg and Leyhausen (1972) who reported earthworm-catching behavior of *Sorex, Echinosorex*, *Hemicentetes*, etc., the characteristic movement of the earth-worm-catching behavior of these insectivores are biting and shaking movements. Neither the aimed-bite oriented toward the "head" nor ingestion from the "head" was reported in these species. On the other hand, neither *Mogera* and *Urotrichus* shows

Fig. 3. Storing earthworms.
Mogera (left) pushed earthworms to the wall of the end of a tunnel one after another (top) and covered them with fallen leaves or small stones (bottom). *Urotrichus* (right) thrusted his head into the soil of the corner of the cage with an earthworm gripped in the mouth, released it in the soil and got out of the soil. Then he covered the exposed part of the worm with soil.



head shaking, probably because they live in tunnels so that that movement is prevented there. Alternatively, *Urotrichus* disables earthworms by dragging them through a tunnel (Imaizumi, 1978).

The reason why *Mogera* less adhered to the "head" of the earthworm as a part to deliver the aimed bite and to eat first was not clearly revealed by this study. However, if one accepts as adherence of *Urotrichus* to the "head" of the earthworm is adaptive to prevent the autotomised anterior part of the earthworm from escaping during eating the posterior part first, that is, to ensure success in obtaining the whole earthworm, then it follows that *Mogera* needs not pay so much attention to the "head" because *Mogera* eats earthworms much more quickly than *Urotrichus* so that *Mogera* does not lose them. Distinction of the "head" of the earthworm by *Mogera* may be more important as processing earthworms to be stored.

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