Art. XV.—*On the Habits of Earth-Worms in New Zealand.*

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The masterly way in which the habits of earth-worms have been treated by Mr. Darwin, in his valuable work on "Vegetable Mould," has not left much room for original research. However, as Professor Hutton informs me that little or nothing is known of the New Zealand earth-worms, a few observations may not be superfluous, especially as their habits differ to some extent from the European species. As these observations were not made with a view to publication, they may not in some instances have been carried out to the extent they deserved, but they may be accepted as fairly accurate. Having mainly followed Mr. Darwin in my experiments, it is unnecessary to give much more than the results.

The New Zealand species of *Lumbricus*, to which these few notes refer—namely, those which burrow into the ground and eject castings more or less on the surface,—are not well known, but they will probably not differ much in number from the Scandinavian species.

In a mild and humid country like this earth-worms work more or less the whole year round, especially in moist and shady situations. During the drier months they retire to a depth of 9–15 inches, a few occasionally as much as 40 inches, into the sub-soil, where they remain, apparently hybernating, either at the bottom of the burrows or coiled up one or more together in the terminal cells, until the rains set in. The dry weather we had in September caused many of them to retire temporarily into their chambers. The burrows run down generally a little obliquely, sometimes perpendicularly, occasionally they turn and run horizontally—in solid ground. Mr. Darwin says: "They are said to sometimes branch, but as far as I have seen this does not occur, except in recently dug ground and near the surface." I have met with instances in which the burrows branched in solid ground, but the branching has merely consisted of two short lateral passages at the termination of the burrow, leading into two distinctly separate chambers. The surface portion of the burrows appears to be generally lined with cement, half a mm. or more thick. This is accomplished by the worms ejecting little pellets of viscid humus on the sides of the walls, then spreading them by gliding up and down. When partially dry this cement not only strengthens the walls of the burrow, but affords a smooth surface to the worm's body, which is a necessary protection, as its movements are often rapid; the interior is kept moist with slime secreted by the worm. When the subsoil is favourable, the walls are occasionally merely smoothed off with light-coloured castings, no defined layer being perceptible. Many

of the burrows, especially the deeper ones, end in a chamber, which is often lined in a similar manner with dark- or light-coloured castings; probably the castings are spread with the aid of its tail. It is not unusual for two separate burrows to terminate in the same chamber.

In Europe earth-worms line their chambers with other materials besides the usual viscid black earth. In reference to this instinct, Mr. Darwin says:—"The sole conjecture which I can form why worms line their winter quarters with little stones and seeds, is to prevent their closely coiled-up bodies from coming in contact with the surrounding cold soil." I have not been able to obtain any information regarding the habits of earth-worms in the colder portions of New Zealand, but as our northern worms do not line their chambers with other materials besides their viscid castings, it is probable his conjecture is correct; our worms are not subjected to the same severe and rapid changes of temperature as those in Europe, consequently do not need the extra protection.

Darwin was the first to point out that the mouths of the burrows were in addition often lined with leaves. This habit does not obtain in our worms, and would not be necessary, for, although they may be often observed lying close to the mouth of their burrows—probably for warmth—the short sharp frost to which they are occasionally subjected does not influence the temperature of the ground to any depth; and the warm sunny day, which almost invariably follows a frosty night, soon raises the temperature of the soil sufficiently to allow of their return to the surface.

It is not improbable that it is our equable climate that renders it unnecessary for earth-worms to plug the mouths of their burrows to the same extent as in Europe. As far as my experience serves, they seem content with occasionally loosely drawing in petioles, portions of leaves, and blades of grass—some are evidently merely meant for food. Mr. Darwin believes that "the use of the plugs is to check the free ingress of the lowest stratum of air, when chilled by radiation at night, from the surrounding ground and herbage." Judging from the loose way his worms plugged the mouths of their burrows when kept in pots in a warm room, and the actions of our own worms in their natural haunts, there is little doubt that the exclusion of cold air is the chief cause of the burrows being plugged. At the season of the year when earth-worms in New Zealand are occasionally subjected to chilled air, the mouths of their burrows are generally protected by their castings.

The habit of closing the mouth of the burrow by heaping-up little pellets of earth and stones, when no castings are being ejected, obtains in the New Zealand worms, and the object is probably to conceal the mouth from their enemies, the greatest of which are, in the vicinity of Auckland,

the mackerel gull (*Larus scopulinus*) and the curlew (*Limosa baueri*). But if Hoffmeister's statement is correct—which is very probable—that the Scolopendra are their bitterest enemies, this instinct must subserve some other purpose as well, as they almost invariably open their burrows at night. As earth-worms habitually lie close to the mouths of their burrows, the stopping may not only tend to give them a sense of safety, but exclude the light.

In loose ground worms rarely void their castings on the surface, using old burrows and cavities. Henson's statement that worms habitually use old burrows—in solid ground—for this purpose, is doubted by Darwin; if he meant that the filling-up of the burrows was entirely due to this cause, he is probably in error, for it is evident, in some soils, that heavy rain causes the walls of the burrows to flow and slide inwards; portions of the sub-soil then collapse, forming alternate streaks of black and light soil. (Mr. Darwin points out that when the soil is not viscous enough to flow inwards, the same end is attained by another agency.) At the same time my own observations lead me to agree with Henson as to the habitual use of the old burrows for the purpose of voiding castings in. During the winter months and wet weather fresh castings retaining their convolutions are to be met with at various depths in the solid ground, and in positions which preclude the idea of their having been washed down; and it appears to me that the amount of black humus used in lining the walls, is inadequate to fill up the burrows and chambers to the extent they often are. Again, fresh castings are to be found in the holes left by decayed roots, and sun-cracks. These holes are generally filled up with fine black earth, most of which is apparently worm-castings. Owing to the nature of the sub-soil, in which my researches have been chiefly carried out, portions of the burrows, and especially the chambers, often retain their form for many months without being filled up with humus. This of course is favourable for observations.

Want of leisure time has prevented my systematically collecting worm-castings off a measured piece of ground, so as to form an estimate of the amount of earth annually thrown out on an acre of land, fairly stocked with worms; but Darwin who has carefully gone into the matter says:—"In many parts of England a weight of more than ten tons of dry earth annually passes through their bodies and is brought to the surface on each acre of land." Compared with the European, worm-castings in New Zealand are light, the larger castings, fresh and well-dried, weigh about ·3 of an ounce; the smaller and most numerous weighing only ·07. Although the worm-castings are light, the amount of earth ejected in favourable ground in the course of years is considerable, apparently equal to some

parts of Britain. This is to be attributed to there being—the conditions being equal—a far greater number of worms in an acre of ground in this country.

Darwin says that the number of worms in old pastures is unknown, but assumes that there may be 26,886 per acre. According to Henson there are 53,767 worms in an acre of garden ground, and about half that number in cornfields; possibly this estimate may be found too low for many parts of Britain. My own estimate of the number of earth-worms (348,480) living in an acre of pasture land, in the vicinity of Auckland—which appeared in an early number of the "N.Z. Journal of Science"—although a low average was given, was so high compared with Henson's, that I went through the work of counting the worms over again this winter; the plan adopted was to take a straight course across several parts of a field, taking out a square foot of soil every twenty paces. The worms have evidently increased since my former observations, so that the results were still more striking. My accurate friend Mr. T. F. Cheeseman, F.L.S., thinking it possible that I might be unconsciously influenced in selecting a spot for examination, suggested the work should be systematically done with the aid of a tape. Accordingly fresh lines were run between some of the former ones, in a portion of a field 17 years in grass. A piece of fair average ground was laid out in squares of 120 feet, a square foot of soil was then taken out at each corner. As the accuracy of my former observations was being put to the test, and at the time (September) most of the worms were in the turf, instead of carrying out my research merely with the aid of a spade, I picked every particle of turf with my fingers; over three hours work gave the following results:—

Number of Earth-worms in each square foot of soil.

6. 3. 10. 27. 56. 19. 5. 10. 0. 12. 12. 20. 25. 17. 9. 11. 36. 17.
12. 3. 20. 14. 48. 22. 24. 27. 40. 14. 12. 10. 15. 18. 18. 26. 13. 19.

Worms hanging to the side-walls were not counted, and the blank hole—only the second in that field—was surrounded with worms.

These figures give an average of 18 worms per square foot, or 784,080 per acre. Although this average is rather striking compared with Henson's, the difference in the actual weight of the worms is not so marked. Von Henson's standard weight of a single worm is 3 grams, accordingly the 53,767 worms would weigh 356 pounds. The greater proportion of the worms met with in our fields are the common *L. campestris*; the larger forms of this species weigh 12 grains—50 averaged 6½ grains; allowing for the few intermixed lighter species, the average of the entire number of worms may be taken at 6 grains, this would give a weight of 612 lbs. 9 ozs. As my former tests in other parts of the farm, where the conditions were

equally favourable, did not differ from those taken in this field at the same time, it may be fairly assumed that if fresh tests had been made with equal care, the results would have been as great. As far as my experience goes, worms seem to be, as a rule, less numerous in worked ground. This does not appear to be the opinion of other observers. In an orchard, originally grass land and favourable for worms, but kept ploughed the last four years, the average was 12 worms per square foot. Several acres in another orchard, light, deep, dry soil, formerly in grass, only averaged 2¼. The number of worms found in garden ground varies considerably; in the drier portions they are often scarce, but in the moist and shady places they are numerous, especially large worms (*L. uliginosus*) weighing 27–30 grains.

From this it appears that worms abound in most cultivated lands in New Zealand; earth-worms are also numerous in moist open spaces beneath high manuka (*Leptospermum*); they affect the edges of swamps in considerable numbers, spreading backwards year by year up the ridges, when the conditions are favourable, largely contributing to form the good soil often found there. Under furze, dense manuka and *Pomaderris*, if the soil is dry, worms are scarce. In fern lands they are rare, except in the damp open spaces, or half-dry swamps covered with dwarf manuka, from whence they spread upon the land being cultivated. I have not had the opportunity of observing native grass lands during the wet season, but from the work done they seem to be fairly represented in some places.

The length of time that land of this class—*i.e.*, fern land—takes to become stocked with worms when laid down in pasture, of course depends upon the extent, moisture, and surroundings. Fields of no great area in the vicinity of older cultivations and swamps appear to get well stocked in about fifteen years. In a portion of a 100-acre field laid down in pasture ten years ago the average of the tests was equal to those given above, but the conditions were extremely favourable. In the remoter portion sown two years later, although increasing, worms are still scarce.

It is unnecessary to enter to any extent into the amount and value of the work done by earth-worms, as the subject has been ably discussed by our illustrious master; but it may be of interest to describe a section I observed when forming an orchard in October, 1875. The vegetation burnt off the newly-cleared land—a raised beach, Manukau Harbour—consisted mostly of manuka and flax, apparently the growth of about thirty years. The trench opened in digging the ground exposed a section consisting of about 4½ inches of black mould, and a horizontal layer, nearly 1 inch thick, of wood-ashes, burnt clay, small stones, and fragments of pumice, lying on a brownish-green arenaceous clay. The black mould was perfectly free from stones, etc., and when a spit was taken up it readily split off from the

coarser layer, which adhered to the sub-soil. A long strip was left intact, and is being preserved for future observations. Similar layers, which consist chiefly of the charred wood, are to be met with in patches, at the same average depth, over several acres of ground.

The section at the present time shows an even depth of 5¾ to 6 inches of black mould. The charred wood, especially where holes have been dug, has decayed considerably the last twelve months, reducing the average width to nearly ½ an inch, but the layer remains horizontal and parallel to the surface, showing that the worms are evenly distributed, and doing an equal amount of work. The regular way in which the embedded objects sink, independently of their specific gravity, as Mr. Darwin points out, "are the striking features of the case." Pieces of burnt clay 1¼ inches in length, weighing over an ounce, small pebbles of jasper rock, fragments of pumice, and the charred wood, have all sunk to the same depth, within the same time, retaining an even thickness that would hardly be expected; the regular depth of the mould, of course, is partially caused by the levelling action of rain.

From this it appears that our earth-worms work with the same regularity as the British species, and eject—their greater number considered—an equal amount of earth. An addition of about 1¼ inches to the superficial surface in eight years, compares favourably with the average cases recorded by Mr. Darwin. Of course the more rapid accumulation of mould the last few years, is owing to the great increase of worms—consequently of worm-castings; although in uncleared lands of this description the annual contribution of decayed vegetable matter is in excess of grass-land, its effect in increasing the thickness of the mould is not equal to the work of the greater number of worms. As the flat is cut off from the higher land by a drain, there is no sedimentary deposit; and the dust blown from desiccated ground is so trifling, that the present increase of mould may be entirely attributed to the work of worms.

It is probable that when a sufficient depth of vegetable—or perhaps more correctly animal—mould is formed for the worms to live in, that the annual increase of thickness decreases; for, as a rule, under those circumstances worms do not penetrate the subsoil to any depth, except when driven down by dry weather. However, in the present case they burrow into the subsoil to a greater depth than worms generally do in the winter months; as it is of a loose nature it probably contains nutritious matter.

It may be worth recording that in May, 1876, I placed an angular block of trachyte—measuring 9 inches in length, 8 in breadth, and 5¾ in thickness—on the same ground; in about four years it had sunk nearly 1 inch; the next two years, it was in the possession of a colony of ants, who no

doubt contributed to undermine it; upon their deserting the stone, the work was again resumed by worms. When measured in August, 1882, the most protuberant point was down 1 inch; in October, 1883, the point was exactly 2 inches below the level of the surface. One end of the ground beneath the stone is considerably excavated; when these burrows collapse, the stone will again sink. In September, 1882, a small stone with a flat base, rounded at the edges, 6½ inches long, 3½ broad, and 3⅝ in thickness, was laid on the turf; on the 15th of last October it had sunk 1 inch, and became sufficiently embedded to require some force to raise it; the same day four fresh stones were placed on the ground, and layers of broken brick and wood-ashes were spread for future observations.

Darwin states that some writers doubt if worms ever swallow earth solely for the purpose of excavating their burrows. Worms effect an entrance into loose soil by inserting the attenuated anterior extremity of their body into any crevice or hole, or forcing aside the particles by alternately withdrawing and driving in the stretched-out body, the pharynx is then pushed forward, and the swollen extremity presses the earth aside; not only would it be impossible—although possessing considerable muscular power—for worms to penetrate into our hard sub-soils by these means, but on three occasions when large worms (*L. uliginosus*) were placed in a pot of very compact earth, they only effected an entrance after about 40, 29, and 32 hours' work, ejecting a considerable amount of castings; again, three small worms were placed in a pot of firm moist siliceous sand, they were only able—in about 30 hours—to bury themselves by swallowing and ejecting the sand; pure sand castings were thrown out for some time afterwards; as the sand had been well washed there could have been no nutriment in it.* Mr. Darwin has shown in a similar experiment, with fine ferruginous sand, that under the circumstances worms are compelled to swallow a large amount of matter unfit for food.

Claparède doubts whether worms swallow any quantity of earth merely for the sake of obtaining nutriment from it; my own observations lead me to agree with Darwin, who has clearly shown that it is not improbable.

Mr. Darwin remarks ("V.M." p. 14) that after heavy rain, succeeding dry weather, an astonishing number of dead worms may sometimes be seen lying on the ground; he further says:—"I believe that they were already sick, and that their deaths were merely hastened by the ground being flooded." As I did not clearly understand whether he meant that when worms, under those circumstances, came to the surface and wandered about during the day, they were necessarily sick, I thought it right to experimentally test whether it was the case, although I had no doubt, as far as our worms were concerned, that a large proportion were healthy.

* These worms have been fed, and are forming a layer of humus on the surface.

On the 10th of last July, 3 worms were picked up at half-past 11 a.m., and placed in a pot of earth; 3 more were treated in the same way on the 18th, but they escaped ten days afterwards. On the 28th there was heavy rain up to nearly 9 a.m., when it cleared there were upwards of 450 large worms crawling about a favourite portion of the garden walk, within a length of 59 yards, all apparently healthy: at 10 the sun shone out; by twenty minutes to 11, most of them had entered some of the old burrows in the turf or beds; a few wandered about, in shady spots, until evening, and, with the exception of a few accidentally crushed, none were seen dead. Six of these worms were placed in a pot of mould, and 6 in a jar of earth and water; the latter were all dead in 58 hours. August 15th, at 9 a.m., 6 worms were placed in two pots, and 6 in a jar of earth and water; in 27 hours 4 of the latter were dead, the remaining 2 in 40 hours. After 30 hours of unusually cold rain, on the morning of the 24th August, there were about 30 worms on the same portion of the walk, some were dead, and many appeared weak and dying. This was an unusual number, although a good many dead worms may occasionally be seen in open drains, apparently drowned; probably the weak worms fall in, and are unable to escape.

What the cause may be that either induces or compels worms to leave their burrows and wander about, under these circumstances, appears not to have been determined; but, as worms do not habitually come to the surface in any great number—especially in the day time—during continued wet weather, but close after rain succeeding dry weather, it is not improbable that they take advantage of the moisture to seek fresh burrows and food; the weak and sickly worms succumbing on the road, especially if it be cold. But whatever the cause may be, it is evident as far as New Zealand earth-worms are concerned, that they are not all sick, for on November 1st when the captured worms were let loose—some of them having been incarcerated for 115 days—they glided away apparently in perfect health.

In regard to worms leaving their burrows at night, Darwin remarks that:—"It has often been said that under ordinary circumstances healthy worms never, or very rarely, completely leave their burrows; but this is an error, as White of Selbourne long ago knew." Like the British worms, our own generally wander about at night after rain, all the year round; probably they leave their burrows in search of animal food; for I have on several occasions seen them, as late as half-past seven, on warm moist winter mornings, gliding with the greatest ease about the trunks of the *Eucalyptus*, evidently searching for animal matter. I have never observed higher than about 12 feet, but as they are occasionally found in gutters on the roofs of houses, probably they ascend to a greater height.

I omitted to test the length of time that earth-worms would live immersed in water during the summer, but Morren found that they endured immersion for 15 or 20 days; like our own, they soon died in winter. Although worms often frequent very wet places, it is probable—except perhaps in the summer months—that those we are concerned with, do not remain completely submerged for any length of time. Some examples of *L. campestris*, that were put into a jar of earth and water, in October, and kept in a room, died in 18½–20 hours; this species appears least able to live for any length of time under water, they desert their burrows when flooded by temporary ponds during the winter months.

Our worms act with the same judgment as the European species, when they drag any object into their burrows; but the amount drawn in, both by worms in confinement and out in the open, appears to be less. The sense of taste is well developed, a preference being shown for special kinds of food; half-decayed onion and cherry leaves being especially relished. The secreted fluid has the usual effect of turning fresh, or half-fresh, leaves a dark brown colour; leaves placed on the surface in pots become in time almost entirely stript of the epidermis and parenchyma, the veins appear not to be eaten, as the skeleton remains entire.

Up to the present time my own experiments have not satisfactorily proved that worms possess a sense of smell; but it seems evident that they are not without it. The effect of light as a rule is not immediate, although in some instances a sudden illumination caused worms to retire rapidly into their burrows; if feeding, a light was either not regarded, or, if they retired, they sometimes soon returned to the surface and continued nibbling at the leaves, taking no further notice of it.

Worms evidently do not possess the sense of hearing and, beyond being affected by light, have no power of vision; the absence of these two senses is compensated for by extreme sensitiveness to currents of air and vibration in any solid matter; which, no doubt, as a rule is advantageous to them.

If, especially, moist loose ground is trodden on sufficiently to cause a slight succussion, it often has the effect of driving out the worms; once on the surface they appear to seek the first opportunity of again retiring below. I would not have alluded to this habit had it not been generally entirely attributed to an instinctive effort of the worms to escape from their enemy the mole; and that some writers, even recently, have drawn erroneous conclusions from the supposed fact. As birds are the chief enemies of worms in this country, and when they are lying near, or on the surface, vibration has the reverse effect of driving them below, it is not improbable that their actions, in this case, are not caused by any definite purpose, but the result of extreme timidity.

In examples of *Lumbricus uliginosus* dissected in the month of March, the calciferous glands were well developed. According to Morren these glands disappear during the winter; and Mr. Darwin has also observed their partial or entire disappearance at the same season. Whether these glands ever shrink sufficiently in New Zealand to be indistinguishable, I cannot say, but in specimens of *L. uliginosus* and *campestris* examined in July–August, although considerably shrunken and empty, the glands were quite perceptible, with the exception of one example of *L. campestris*, in which a lens was required for their satisfactory determination. They commence to swell again during the spring months.

From Charles Darwin's admirable researches it seems probable that such lowly organized forms as earth-worms are not devoid of intelligence; they appear to have a certain amount of social feeling, and their passions are strong: the diversity of their actions when exposed to light or vibration, implies the faculty of attention; from their highly developed sense of touch, they appear to gain some notion of the form of an object; and I hope to show, in a future paper, to what extent they possess the sense of direction.