THE DISTRIBUTION OF LUGWORMS (*ARENICOLA MARINA* L.) OVER THE FLATS AT WHITSTABLE

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(Plate I and Text-figs. 1–2)

Introduction

It has been noted at Whitstable that lugworms (*Arenicola marina* L.) on the Flats are not uniformly scattered (Newell & Chapman, 1948). This is clearly seen in the distribution of castings which tend to be more numerous along straight lines of up to 60 yd. in length. That this effect is not a subjective one is clearly shown by photographs (Pl. I, figs. 1 and 2), by the visibility of the lines to unprejudiced observers as well as by counts of castings in and around the lines, whilst the permanence of the lines (see. p. 630) indicates that they are not due to chance. It also appears that the 'line distribution' is a purely local phenomenon since it occurs only over a restricted area of the Whitstable Flats and has not, apparently, been noticed elsewhere in similar situations. This view has received some confirmation from the late Mr R. Elmhirst and Mr E. M. Venables (private communications).

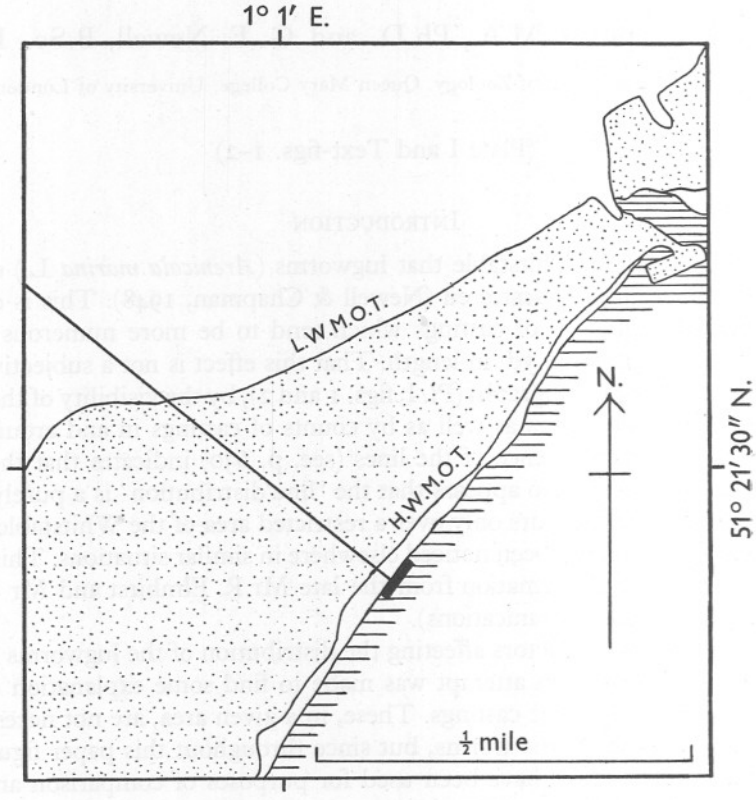
Since a study of the factors affecting the distribution of the lugworms might be of general interest, an attempt was made to find some explanation of the grouping displayed by the castings. These, in a given area, are not necessarily the same in number as the worms, but since throughout this paper figures of the numbers of castings have been used for purposes of comparison and the observations on which the comparisons were made have been done at the same time, it is fair to use the population of castings as an indication of the population of worms.

Experiments carried out on the burrowing of the lugworm (Chapman, 1949) tended to show that the 'hardness' of the marine soil might affect the distribution of these animals, since they seemed to be completely unable to burrow into soil which was made more resistant by the withdrawal of water from it.

It seemed important, therefore, to determine first of all if there were any significant differences in hardness of the soil in different areas of the Flats which might cause patchy distribution. The hardness at different stations was therefore tested by means of the penetrometer used on previous occasions.

Variation in Numbers of Worms from High to Low Water

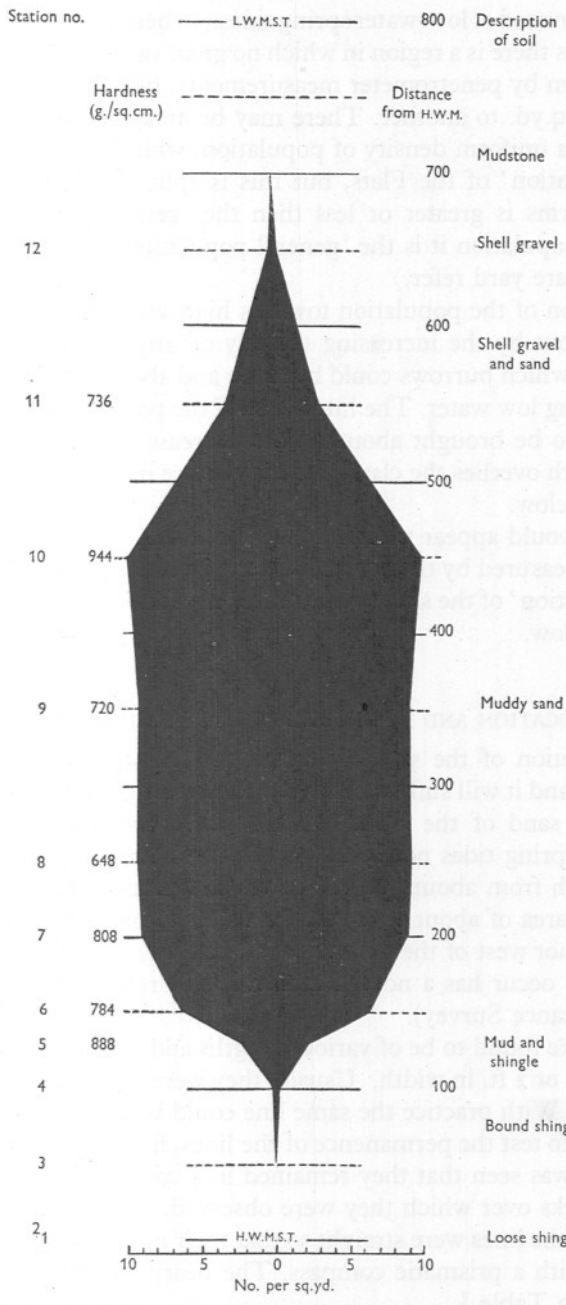
The number of worms per square yard was counted at selected intervals on a transect of the Flats shown in Text-fig. 1. At each station areas of 1 sq.yd. were dug over and examined for lugworms after they had been well broken by the fork. Although the method may be described as 'rough and ready' it is



Text-fig. 1. Transect of intertidal zone at Whitstable along which the lugworm population was determined.

quite adequate for the task involved and capable of yielding consistent results as Newell (1948) has shown. The hardness of the soil in the proximity of the sample was tested with the penetrometer. The results are set out pictorially in Text-fig. 2 in which the hardness of the sand, the mean population of lugworms, and the position on the shore of each station is shown.

It can be seen from Text-fig. 2 that the lugworms are most numerous in the region of the Flats that can be described as muddy sand and that they fall off rapidly in numbers in the shingle bank towards high water and towards the



Text-fig. 2. Diagram showing the numbers of lugworms per sq.yd. in intertidal zone at Whitstable. The hardness, in g./sq.cm., is the mean of twenty readings at each station. The numbers of worms per sq.yd. is a mean of not less than three samples. H.W.M.S.T., high-water mark spring tides; L.W.M.S.T., low-water mark spring tides.

clay that is uncovered at low-water spring tides. In between these two less thickly populated zones there is a region in which no great variation in hardness occurs, at least as shown by penetrometer measurements, but in which the population varies from 1 sq.yd. to another. There may be areas of many square yards in which there is a uniform density of population, which can be described as the 'general population' of the Flats, but this is split up by areas in which the number of worms is greater or less than the 'general population'. (In this survey of the population it is the 'general population' to which the figures of worms per square yard refer.)

The limitation of the population towards high-water mark would appear to be brought about by the increasing scarcity of any soil of sufficiently small particle size in which burrows could be made and also, probably, by the drying of the soil during low water. The limitation of the population towards low-tide mark appears to be brought about by the decrease in depth of the sand and fine gravel which overlies the clay. Other evidence in favour of this hypothesis will be given below.

In short, it would appear that there is insufficient variation in the hardness of the soil, as measured by the penetrometer, to cause any great variation in the 'general population' of the shore. The cause of such local variations as do occur is discussed below.

The Location and Distribution of the Lines of Castings

A brief description of the shore zonation at Whitstable has been given by Newell (1948), and it will suffice to mention here that the lines of castings occur on the muddy sand of the Flats which stretches from within about 100 yd. of high-water spring tides nearly down to low-water mark, the lugworm belt varying in width from about 400 to 800 yd. The lines of lugworm casting are confined to an area of about 0·5 square mile, none being found east of Whitstable harbour nor west of the clay cliffs at Seasalter. The centre of the area in which the lines occur has a normal national grid reference of 097662 (sheet 173, 1 in. Ordnance Survey).

The lines were found to be of various lengths and widths but rarely exceeded 60 yd. in length or 2 ft. in width. Usually they were about 40 yd. in length and 18 in. in width. With practice the same line could be recognized on successive occasions, but, to test the permanence of the lines, five of them were marked by stakes when it was seen that they remained in a constant position during the period of 5 weeks over which they were observed.

Almost all of the lines were straight so that their magnetic bearings were easy to determine with a prismatic compass. The bearings of 50 lines were taken and are given in Table I.

Unaided observation gave the impression that the lines run at random in all directions, but it can be seen from the compass bearings recorded that there is

not an *equal* number of lines in all directions. More, in fact, occur with bearings of about 45° and about 165° than in other directions. The predominating direction of the lines of castings seems to be roughly parallel with the coastline.

TABLE I. BEARINGS OF LUGWORM LINES

Number of lines recorded in each 5° of arc, magnetic bearings.
Number of lines recorded in each 20° of arc is also indicated.

Bearing	No. of lines		Bearing	No. of lines		Bearing	No. of lines	
0	1		60	2		120	0	
5	2		65	0		125	1	
10	1		70	1		130	1	
15	3	7	75	1	4	135	0	2
20	3		80	0		140	3	
25	0		85	0		145	1	
30	2		90	1		150	2	
35	0	5	95	1	2	155	1	7
40	4		100	1		160	3	
45	5		105	0		165	2	
50	1		110	0		170	0	
55	4	14	115	0	1	175	3	8

POPULATION DENSITY OF THE LINES AND ADJACENT AREAS

The number of castings in the lines is greater than the number per square yard forming the general population of the shore. For example, castings on the shore which are not in lines vary in numbers from minima of 1 or 2 to maxima of 30 to 40 per sq.yd. The population of the lines may rise above 40 per sq.yd., whereas the areas adjacent the lines generally contain about 5 or 6 casts per sq.yd. To obtain these results areas of $\frac{1}{2}$ by 2 yd. were marked off, one on either side and one along the lines and the number of castings in each area was counted. The results are shown in Table II.

TABLE II. POPULATION OF LINES AND ADJACENT AREAS

Worms per sq.yd. flanking line	Worms per sq.yd. in line	Worms per sq.yd. flanking line
0	42	4
3	45	5
6	46	8
6	28	4
3	38	10
0	45	1
0	43	6
3	29	6
2	36	9
14	43	8

VARIATIONS IN SOIL DEPTH AND TYPE

As has been mentioned in previous papers, the soil of the Flats consists of muddy sand underlain by impervious clay. This stratum is almost certainly London clay (Dr J. F. Kirkaldy and Mr C. D. Ovey, private communications), and is found at different depths on different parts of the shore, being exposed near

low-water mark but being elsewhere overlain by a thickness of sand which varies from about 1 to 12 in. It has been noted that lugworms, which appear to be able to burrow and live in gravelly soil seem unable to penetrate the clay (Wells, 1945), or at least are not normally found living in it. Accordingly, the depth of the sand (or topsoil as it may well be called) was measured along the lines of casting by means of an auger and was compared with that in the less densely populated areas.

In each of four prominent lines a series of borings was made in order to record the depth of the topsoil (*a*) along the middle of the line, (*b*) at distances of 6 in. from the middle of the line, (*c*) at distances of 12 in. from the middle of the line, and (*d*) at distances of 18 in. from the middle of the line. A selection of these results is given in Table III, from which it can be seen that the topsoil is much deeper along the line than at its flanks.

TABLE III. DEPTH OF SAND IN AND NEAR LUGWORM LINES

Depth of sand in inches.

18 in. from centre	12 in. from centre	6 in. from centre	Centre of line	6 in. from centre	12 in. from centre	18 in. from centre
8	9	10	12	9·5	6	8·5
7·5	8	12	12	10·5	7·5	6
4·5	7	11	12	5·5	3·5	3·5
5	10·5	15	12	11	10	4·5

THE GENERAL EFFECT OF THE DEPTH OF TOPSOIL ON THE NUMBERS OF WORMS

A close correlation between the dense population of lugworms and the depth of the topsoil along the lines of castings having been established it seemed of interest to find out if this principle were of wider application. Fortunately, a small area was found which showed patchy distribution of a different kind from that previously examined. In 1942 a large bomb fell on the Flats just seaward of the *Fucus* and shingle zone and, its crater subsequently filling with muddy sand, its presence was no longer detectable except for the extreme density of the lugworm population. The centre of the former crater had a great depth of topsoil, but was surrounded by a rim of clay covered merely by a few inches of sand. Within the margins of the crater the lugworm population had a density of 42 per sq.yd., that of the marginal zone being only 4 per sq.yd., whilst the undisturbed area outside the crater rim had a density of 28 per sq.yd. So sharp was the separation of an area rich in worms from an area practically devoid of castings that the counts from which the figures were quoted were made only a yard or so apart.

The evidence from the bomb crater and from a study of the lines of castings is strongly in favour of the view that one of the main factors influencing the density of the lugworm population is the depth of the topsoil overlying the clay rather than the admixture with the topsoil of even a large proportion of shingle or shell gravel.

Migrations of the Lugworm Population

There is some evidence in favour of the view that lugworms can change their burrows and that the population of a given area is not determined solely by the original settlement of the larvae. There are reasons for believing that movement to new burrows takes place through the water, that is by swimming. To test this view two pits, each a square yard in area, were excavated in the clay forming the rim of the former bomb crater, the clay being removed to a depth of 10 in. The pits were filled with topsoil from which an attempt had been made to remove all lugworms and were then examined occasionally for the

Table IV. Repopulation of an Isolated Area of Deep Soil

Date	No. of casts in marked square yard 1	No. of casts in marked square yard 2
18 Aug. 1948	Pits dug in clay and filled with fine sand	
20 Aug. 1948	0	2
24 Aug. 1948	0	3
24 Sept. 1948	1	4
24 Oct. 1948	0	3
21 Nov. 1948	0	4
5 Dec. 1948	0	5
16 Jan. 1949	4	6
18 Feb. 1949	4	9
16 Apr. 1949	15	12
24 Apr. 1949	16 13 headshafts	13 11 headshafts

presence of worm castings. The number of castings found on visits made from the beginning of the experiment in August 1948 to April 1949 are shown in Table IV, from which it can be seen that the pits became repopulated gradually until the spring when there was a rapid immigration of worms. It is inconceivable that the worms could have burrowed through the very dense clay forming the walls of the pits. Neither were there, in fact, any worms to be found in the soil immediately adjacent to the pits, so that it must be concluded that they had repopulated the areas by swimming and burrowing from the surface.

From this it would seem that the patchy distribution of the worms, whether in lines or in other areas is due to the dynamic effect of a shifting population, the worms tending to aggregate in areas of deep topsoil most suitable to their burrowing and feeding activities. The explanation of the trenching in the clay, however, which allows of a deeper layer of topsoil is far from clear, but its solution must probably be sought in the geological history of the Flats. It is, nevertheless, interesting to find that the lugworm is a fairly reliable indicator of the depth of soil suitable to its (and probably to other animals') way of life, and that its discontinuity of distribution shows up, quite clearly, unsuspected discontinuities in what at first sight appears to be a very uniform habitat.

Summary

It has been shown that the main factor which influences the local distribution of the lugworm at Whitstable is the depth of the muddy sand overlying the clay stratum below.

In places this clay is furrowed by straight channels which are revealed only by the arrangement of the lugworm castings. These are more numerous along the channels.

Migration of adult lugworms has been shown to occur, most freely in the spring.

REFERENCES

Chapman, G., 1949. The thixotropy and dilatancy of a marine soil. *Journ. Mar. Biol. Assoc.*, Vol. xxviii, pp. 123–40.

Newell, G. E., 1948. A contribution to our knowledge of the life history of *Arenicola marina* L. *Journ. Mar. Biol. Assoc.*, Vol. xxvii, pp. 554–80.

Newell, G. E. & Chapman, G., 1948. Distribution of lugworms. *Nature*, Vol. clxii, p. 75.

Wells, G. P., 1945. The mode of life of *Arenicola marina* L. *Journ. Mar. Biol. Assoc.*, Vol. xxvi, pp. 170–207.

EXPLANATION OF PLATE 1

Figs. 1 and 2. Photographs of the muddy Flats at Whitstable showing lines of lugworm castings.

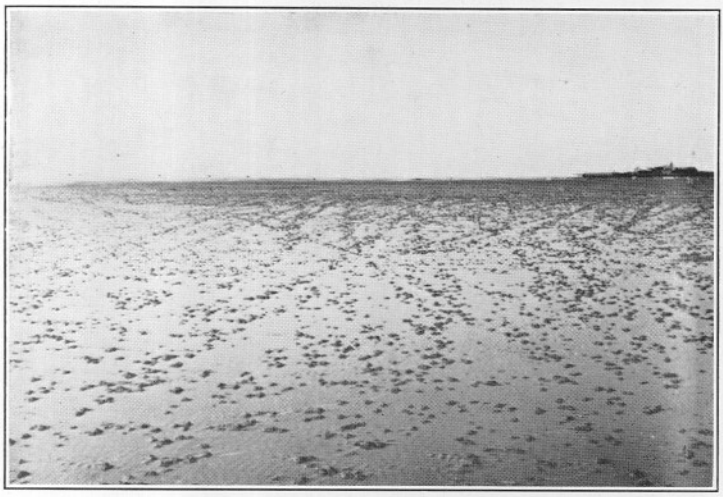


Fig. 1.

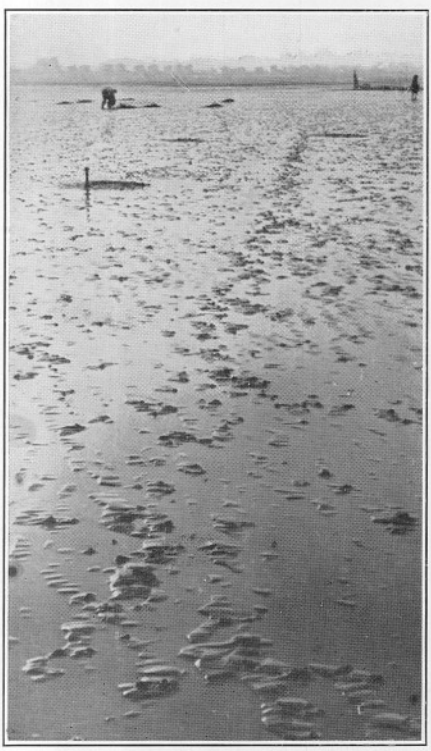


Fig. 2.