

The Foraminifera of the Exe Estuary.

By

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SAMPLES of sand were taken, either from the shore immediately above low water of spring tides, or from the bottom in a few inches of water.

With one exception no samples were dredged. The localities were few: Polesands; the north or estuarine shore of the Warren west of Salthouse Lake; the banks of the Salthouse Lake; a low-water stream on the Warren; near Lympstone; and (the dredged sample) within Exmouth Docks.

To appreciate the results it is necessary to consider shortly the physical conditions at the mouth of the Exe estuary.

The low-water channel of the Exe, which would naturally enter the sea in a southerly direction, is diverted by a spit of land known as the Warren and a sand bank known as the Polesands, turned through a right angle to the eastward, and only after passing some little distance parallel to the coast discharges into the sea.

That portion of the Polesands which uncovers at low water is chiefly, if not entirely, pure sand; the surface is in no way compacted, but is unstable and ridges, furrows, and travels with every tide.

The Warren consists of sands, gravels, and shingles, with patches of fair-sized pebbles, and to the westward compact clays.

From the presence of these clays it may be surmised that the western end of the Warren is a genuine spit of land; the eastern end and the Polesands are alike due to littoral drift.

The mouth of the Exe is more exposed to southerly than to easterly gales, and breakers from the southward drift the beach across the estuary, and drift it in greater quantity than the tidal current of the ebb, setting out from the estuary, can remove in the intervals between successive gales.

Easterly gales, which are rare, and are to some extent fended off by the coast-line, have been unable to drive the sand and shingle back to their original position westward and southward of the harbour mouth.

In course of time the limit has been reached at which the tidal scour of the ebb, and the breakers from the eastward, suffice to check the further easterly advance of the bar.

The channel between the Polesands and the land has adjusted itself

to that width and depth through which the waters of the ebb will flow with sufficient velocity to maintain a fairly constant cross-section.

The surface of the Polesands, turned over by wave and current action even in calm weather, contains little or no organic matter, and any Foraminifera attempting to establish themselves thereon are liable on each tide to be buried at a considerable depth below the surface.

The average least diameter of the largest sand grains on the seaward slopes of the Polesands is 0·7 mm., the average least diameter of the largest sand grains on the estuarine slope of those sands is 0·4 mm.; in each case the average greatest diameter would be about 50 per cent. more. The figures were obtained by ranging a number of grains between parallel plates. The average least diameter of the largest sand grains at low-water mark on the north shore of the Warren is 0·25 mm.

To move a grain of quartz sand of 1 mm. diameter requires a current of velocity 0·5 feet per second, or, say, one-third of a knot; while to move a grain of 0·25 mm. requires a velocity of 0·25 feet per second, or, say, one-sixth of a knot.

If the sand is once allowed to compact thoroughly with a reasonable admixture of silt, a much higher velocity is required to move it, say, up to ten times the figures above given.

To anyone familiar with the actual tidal currents at Exmouth the unstable nature of the surface of many of the sand banks, especially below half-tide level, will be at once apparent.

According to King's *Channel Pilot* :—

“When the banks at the entrance (of the estuary) are covered, both flood and ebb streams set fairly over them, about $2\frac{1}{2}$ knots; but when uncovered, these streams run strong through the channel, and their strength increases at Ferry Point to 5 knots.”

The channel followed by the ebb across the Polesands at the end of the Warren, until these sands are uncovered, can be clearly seen on the chart of the harbour.

It is to be noted that the grains on the inner side of the Polesands are much better polished and rounded than those on the outer. The former travel some little distance to and fro with each ebb and flood, the latter are chiefly subject to wave-action.

The Warren sand is richer in organic matter as it rises in level from low-water toward high-water level, but it is not to be understood that the increase in organic matter is directly proportioned to level.

Near Lymptone a very fine sand occurs, the average least diameter of the largest grains being only 0·12 mm.

The conditions being so unfavourable, it is not surprising that Foraminifera are scarce.

On the Polesands, above and immediately below low water, there are practically no living Foraminifera.

Stranded on the outer or seaward slopes of these sands the following dead shells were found; no attempt has been made to estimate the relative numbers.

Miliolina seminulum.
Truncatulina lobatula.
Rotalia beccarii.
Nonionina depressula.
Polystomella crispa.
Polystomella striato-punctata.

On the northern or estuarine slope of these sands even dead shells are absent.

The method of investigation adopted consisted in spreading 13 c.gms. of each sand on a glass slip and counting and identifying the Foraminifera.

This process is not exhaustive, as small specimens and species may be overlooked, no matter how carefully the sand may be spread. Also the less common species cannot be expected to be represented in each 13 c.gms. Accordingly fifty times this quantity (6.5 gms.) is taken, and the Foraminifera floated from same as far as may be. Invariably additional species are thus found. The drawback to this proceeding lies in the fact that the numerical results are no longer absolute. No doubt the direct count gives results in themselves too low, but at least fairly comparable as between the species identified. In floating, however, only a small proportion of the Foraminifera of any species are obtained, and the relative numbers of the different forms depend largely on the weight per unit displacement of the individual species. Thus *Rotalia beccarii* floats extremely ill, and *Polystomella striato-punctata* fairly well. The effect from actual averages is as follows: Assume a case in which 1,000 of each of the following species are counted in a sample, then on floating we should obtain the following numbers only:—*

	For each 1,000 found by actual count.
<i>Polystomella striato-punctata</i> . . .	170 or 17 per cent.
<i>Biloculina ringens</i> . . .	167 „ 16.7 „
<i>Planorbulina mediterraneanensis</i> . . .	73 „ 7.3 „
<i>Nonionina depressula</i> . . .	36 „ 3.6 „
<i>Bulimina pupoides</i> . . .	30 „ 3 „
<i>Miliolina seminulum</i> . . .	13 „ 1.3 „

* It should be noted that the figures given are the average of a large number of observations; but when, as at Exmouth, a great proportion of each species is represented by small individuals, the actual percentages which float will be much greater than given in the table, the relative percentages remaining constant.

	For each 1,000 found by actual count.
<i>Discorbina rosacea</i> . . .	12 or 1.2 per cent.
<i>Truncatulina lobatula</i> . . .	10 „ 1 „
<i>Textularia gramen</i> . . .	6 „ 0.6 „
<i>Rotalia beccarii</i> . . .	1½ „ 0.15 „

It would therefore appear as though *Polystomella striato-punctata* were 113 times more numerous than *Rotalia beccarii*, although both would really be present in equal numbers.

Undoubtedly some of the *Lagena*, *Nodcosaria*, and *Bolivina* float better than *Polystomella*, but exact figures have not been ascertained; the above table is itself somewhat tentative. Meanwhile, numerical results from floating are still of value as giving the relative abundance of any one species in different samples.

SAMPLE taken just above low-water mark, on the north shore of the Warren, about 150 yards west of Salthouse Lake stream.

FORAMINIFERA COUNTED IN 13 GMS.		No.	Per cent.
<i>Nonionina depressula</i> . . .	.	4	50
<i>Polystomella striato-punctata</i>	2	25
<i>Miliolina seminulum</i>	1	12½
<i>Rotalia beccarii</i>	1	12½

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FORAMINIFERA FLOATED FROM 6.5 GMS.		No.
<i>Nonionina depressula</i>	90
<i>Polystomella striato-punctata</i>	52
<i>Lagena orbignyana</i> . . .	.	6
<i>Miliolina seminulum</i> . . .	.	5
<i>Rotalia beccarii</i> . . .	.	5
<i>Polymorphina</i> (?) * . . .	.	3
<i>Trochammina inflata</i> . . .	.	3
<i>Polystomella arctica</i> . . .	.	3
<i>Polystomella crispa</i> . . .	.	2
<i>Nonionina stelligera</i>	2
<i>Bulimina pupoides</i>	1
<i>Bolivina</i>	1
<i>Spirillina</i> (?)	1
Undetermined	2

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A SAMPLE taken at the same place but under low-water mark contained but few Foraminifera, and the results would only be possibly misleading.

* Provisionally attributed to *Polymorphina*. This species will form the subject of further inquiry.

ANOTHER SAMPLE taken from inside an old kettle resting on sand at same point below low water yielded the following:—

FORAMINIFERA COUNTED IN 13 C.GMS.		No.	Per cent.
<i>Nonionina depressula</i>	.	5	45½
<i>Polystomella striato-punctata</i>	.	4	36½
<i>Polystomella arctica</i>	.	1	9
<i>Rotalia beccarii</i>	.	1	9
		11	100

The comparative shelter of the kettle probably accounts for the presence of these as against the practical absence of all Foraminifera from the sand on which the kettle rested.

A SAMPLE taken immediately above low water on the bank of the Salthouse Lake stream, about 100 yards from the low-water channel of the Exe.

FORAMINIFERA COUNTED IN 13 C.GMS.

This method was not applied in the present instance.

FORAMINIFERA FLOATED FROM 6·5 GMS.

	No.
<i>Polystomella striato-punctata</i>	91
<i>Nonionina (chiefly) depressula</i>	49
<i>Rotalia beccarii</i>	3
<i>Polymorphina</i> (?) *	2
<i>Miliolina seminulum</i>	2
<i>Trochammia inflata</i>	1
<i>Haplophragmium canariense</i>	1
<i>Lagena hexagona</i>	1
<i>Lagena orbignyana</i>	1
<i>Bulimina pupoides</i>	1
<i>Bolivina dilatata</i>	1
<i>Biloculina ringens</i> (?)	1
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SAMPLE received labelled—"Lympstone mussel-bed, sand between weeds." This is a singularly fine sand and very free from silt.

FORAMINIFERA COUNTED IN 13 C.GMS.		No.	Per cent.
<i>Rotalia beccarii</i>	.	6	60
<i>Nonionina depressula</i>	.	3	30
<i>Polystomella striato-punctata</i>	.	1	10
		10	100

* See previous footnote.

FORAMINIFERA FLOATED FROM 6·5 GMS.		No.
<i>Nonionina depressula</i>	.	30
<i>Polystomella striato-punctata</i>	.	27
<i>Lagena orbignyana</i>	.	18
<i>Rotalia beccarii</i>	.	9
<i>Miliolina seminulum</i>	.	8
<i>Polystomella arctica</i>	.	2
<i>Verneuilina polystropha</i>	.	2
Undetermined	.	4

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SAMPLE dredged from bottom of Exmouth Docks: consists of a fine sand mixed with much silt and organic matter; general appearance a somewhat sticky mud. In this case there is an entire absence of tidal scour or wind wash, and a constant depth of water. On the other hand, the water of the dock is by no means so clear or pure as in the channel outside the gates.

FORAMINIFERA COUNTED IN 13 C.GMS.

It was impossible to take a satisfactory census in this manner.

FORAMINIFERA FLOATED FROM 6·5 GMS.		No.
<i>Nonionina depressula</i>	.	178
<i>Polystomella striato-punctata</i>	.	33
<i>Rotalia beccarii</i>	.	31
<i>Lagena orbignyana</i>	.	11
<i>Miliolina seminulum</i>	.	10
<i>Bulinina pupoides</i>	.	5
<i>Verneuilina polystropha</i>	.	2
<i>Polymorphina compressa</i>	.	2
<i>Bolivina textilaroides</i>	.	1
<i>Bolivina dilatata</i>	.	1
<i>Cornuspira foliacea</i> (?)	.	1
Undetermined	.	11

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From the relative floating capacity of the species it is obvious that *Rotalia beccarii* greatly predominates, and is followed by *Nonionina depressula*.

LIST OF SPECIES TAKEN.

[Nomenclature: BRADY, *Challenger Report*, ix.]

BILOCULINA RINGENS (*Lamarck*). One individual somewhat doubtfully identified, from Salthouse Lake.

MILIOLINA SEMINULUM (*Linn.*). Dead shells from the southern slope of the Polesands. One of the four or five commoner species from the Warren, Salthouse Lake, and Lympstone; and decidedly one of the more prominent on the bed of Exmouth Docks. Nowhere really plentiful, and no large, well-grown specimens obtained except from the south slope of the Polesands.

HAPLOPHRAGMIUM CANARIENSE (*d'Orbigny*). A single individual from Salthouse Lake.

TROCHAMMINA INFLATA (*Montagu*). At low-water mark on Warren and from Salthouse Lake. Well-grown specimens.

VERNEULINA POLYSTROPHA (*Reuss*). Found at Lympstone and in Exmouth Docks. Appears in this estuary to replace the *Textularia*, no specimen of either *Textularia gramen*, *agglutinans*, or *saggitula* having been found.

BULIMINA PUPOIDES, *d'Orbigny*. Single individuals from Warren and Salthouse Lake; five times as plentiful in Exmouth Docks, which is not a typical ground for this species. Probably, however, *Bulimina*, in common with all the more elongate Foraminifera, suffers more than the lenticular forms from the tidal scour. The actual number present in the sample from the docks does not compare with the representation of this species on grounds where it is really at home.

BOLIVINA DILATATA, *Reuss*. Found at Warren, Salthouse Lake, and Exmouth Docks; in neither case more than barely represented. From some results not numerically stated above, is probably more plentiful in the docks than elsewhere.

BOLIVINA TEXTILAROIDES, *Reuss*. Exmouth Docks.

LAGENA HEXAGONA (*Williamson*). Salthouse Lake only, but may occur elsewhere; distinctly rare however.

LAGENA ORBIGNYANA (*Seguenza*). Six floated from 6.5 gms., Warren; one from 6.5 gms., Salthouse Lake; eighteen from similar quantity, Lympstone; and eleven from Exmouth Docks. A light shell of small size which succeeds here in establishing itself in comparatively quiet situations. Compared with its occasional numbers, it is poorly represented at all the stations mentioned above.

POLYMORPHINA COMPRESSA, *d'Orbigny*. Infrequent.

SPIRILLINA. One of doubtful species, from Warren.

CORNUSPIRA FOLIACEA (*Philippi*). A single individual somewhat doubtfully identified, from Exmouth Docks.

TRUNCATULINA LOBATULA (*Walker and Jacob*). Dead shells from south slope of Polesands; absent elsewhere. An adherent species; its absence is probably largely if not entirely due to the want of suitable hosts.

It may be noted that *Planorbulina mediterraneensis*, another adherent species, is also absent.

ROTALIA BECCARII (*Linn.*). In all samples. Where the numbers are so small percentages are apt to be misleading. At the Warren and Salthouse Lake this species is third in point of number, *Nonionina* and *Polystomella* being distinctly more numerous.

In the sample from Lympstone *Rotalia beccarii* is distinctly the dominant species, as also in the dredging from Exmouth Docks.

NONIONINA DEPRESSULA (*Walker and Jacob*). All samples. The dominant species at Warren and the second at Lympstone, probably the second in Exmouth Docks. Distinctly an estuarine species, but is still fairly prominent in some localities at twenty fathoms off this coast.

NONIONINA STELLIGERA, *d'Orbigny*. Probably occurs in all samples; in much less number, however, than *depressula*.

POLYSTOMELLA CRISPA (*Linn.*) and

POLYSTOMELLA STRIATO-PUNCTATA (*Fichtel and Moll.*). These forms have been treated as separate species to this extent, that the individuals have been assigned to one or the other denomination according to a purely arbitrary judgment that the specimen more nearly approached the recognised type of *crispa* or *striato-punctata*.

Var. *striato-punctata* is distinctly the more prominent, and is second in order at the Warren, probably third in order at Salthouse Lake, third at Lympstone, and third in Exmouth Docks.

Well-charactered forms of var. *crispa* are rare, and extreme types absent.

POLYSTOMELLA ARCTICA, *Parker and Jones*. This seems another ill-defined species, which may apparently be regarded as of merely varietal significance.

The above list of species gives all the commoner forms, and some at least which are present in but small numbers; it cannot, however, be regarded as actually exhaustive.

Generally speaking, it indicates that the conditions are very distinctly more estuarine than at Salcombe.

A few dredgings from the low-water channels would have given a greater value to the results.