TIDAL STREAMS AND LARVAL DISPERAL AT WHITSTABLE.

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INTRODUCTION.

The results of Carruthers and his co-workers have made it clear that in some sea areas around the British Isles the ebb and flood tides are not of equal magnitude. In other words there is sometimes a residual current which, although it may vary with a particular tidal phase and with the wind, is, over a period of time, important and may average several miles per day. Carruthers et al. made use of the “vertical log” (Carruthers, 1947) an apparatus which makes continuous records of the movements of a thick layer of water equivalent to the draft of an oceangoing ship. The “vertical log” was used to trace the water movements past the Varne, Mouse and East Goodwin lightships and in each of these positions residual currents were recorded.

It is worthwhile noting that at least in one instance, viz., past the East Goodwin lightship (Carruthers, Lawford and Veley, 1951), the residual current is rather local since it is in a S.W. direction whereas through the Straits of Dover in general the residual current is N.N.E. in direction. The explanation of this apparent anomaly is that about opposite the Gull there is a small anticyclonic eddy set up by the interposition of the Goodwin Sands between the main N.E.-going current and the E.-going current along the north Kent coast.

Carruthers and Lawford (1950) showed that there is an average E.-going residual of 6·8 miles a day at the more northerly position of the Mouse lightship and one of 1·0 miles a day at its southerly position about five miles N.N.E. of Warden Point on Sheppey near the entrance of the Ooze Deep. The very striking decline in the residual for the southerly position when, indeed, it may on occasions be reversed, makes it by no means impossible that there is a west-going residual close to the north coast of Sheppey. No explanation of this residual current was offered by Carruthers and Lawford but possibly it is due to the circumstance that both positions of the lightship were close to the Thames Estuary (E.-going) ebb channel delineated by Robinson (1956).

The present paper deals with residual currents a short way offshore from Whitstable in a region which, although technically a part of the Thames Estuary, is not in its main stream and, from the charts, would be expected to be affected more by the water entering and issuing from the Swale. Our interest in measuring the currents was mainly a biological one and the experiments were designed chiefly to throw some light on the dispersal of larvae spawned in the Whitstable area and on the way in which the area may be colonised from districts to the east.

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METHODS.

For various reasons, such as time and expense, no elaborate or extended observations were possible and our results must be regarded as tentative. Nevertheless, they are of interest in relation to the marine fauna of Whitstable, an account of which has been given (Newell, 1954). We are indebted to Dr. Carruthers for much valuable advice and for the suggestion that the simplest method of obtaining fairly accurate estimations of any residual currents would be to follow the movements of a floating object throughout a series of complete semidiurnal tidal periods each day for a suitable week, say from neaps to springs.

In 1955 as a floating marker or "logship" we used a broomstick so weighted at one end that it floated upright in the water. This had the advantage that it was practically unaffected by wind and gave the movement of a layer of water approximately three feet in depth. Its disadvantage lay in the difficulty of keeping it in view, particularly when the sea was choppy. Unfortunately, we could not carry out our complete programme. On one day the weather was too rough for the boat to leave its moorings and on another the water was too shallow. Indeed, the shallowness of the water made work at low water very difficult. The boat, which drew five feet, often went aground and on some occasions we had to take to the dinghy to keep our marker in sight.

Indeed, as is obvious from the 1 inch Ordnance Survey map and the Admiralty chart for the area, the Pollard Spit off Seasalter, the Street at Tankerton and Long Rock off Swalecliffe formed obstructions to our boat for most of the time except for the period between three hours before and three hours after high water. But, in addition to these obstacles there are other banks not marked on charts. In 1955 we considered it advisable to begin all observations at slack water and this meant that on some days it was impossible to follow the marker through a complete tidal period owing to darkness.

To overcome the difficulty of following such a small object as a vertically floating broomstick, an open-ended canvas-covered drogue 4 ft. 6 in. by
2 ft. 6 in. by 2 ft. 6 in., ballasted and suspended from a small buoy (Russell and Macmillan, 1952) was used in the 1956 observations as a logship. Experience by one of us off the Northumberland coast suggested that there is virtually no windage effect on a marker of this pattern and this is confirmed by the strong residual current found on August 22nd in the face of a force 5 E.N.E. wind. In 1955 the position of the logship was determined at hourly intervals by means of horizontal and vertical sextant angles, at least three marks on shore being used for each determination. These marks are shown on the sketch maps (figs. 3, 4, 5). In 1956 fixes were made at intervals of three-quarters of an hour. Another difference from the 1955 experiments was that the markers were put overboard at about the same time each day and therefore at a variable state of tide. Here again, previous experience showed that a good estimation of the position which would have been reached by the logship could be made by noting its position after an interval of half the tidal period and then doubling the distance it had traversed.

**RESULTS.**

The results are set out in figs. 1 and 2 and in a series of sketch maps (fig. 6). Figs. 3, 4 and 5 show the course followed by the logship on a neap, average and near spring tide respectively in more detail. The direction of the flood tide around the Isle of Sheppey is shown in fig. 7.

**DISCUSSION.**

It will be seen from the figures that at one neap tide there was a small (probably negligible) S.S.W. residual current and a considerable period of slack water. At average and at spring tides there is only a short
Sketch map to show the course followed by the logship on a neap tide.
period of slack water and there is an appreciable E.E. residual current which becomes increasingly apparent as spring tides are approached, the maximum recorded for any one tide being of the order of four miles.

It is a matter of common knowledge among the sea-going folk at Whitstable that the ebb tide is stronger than the flood but it was a surprise to find that the residual diminishes to zero at neaps. Nevertheless, it remains true to say that there is an east-going residual for most tides not only immediately off Whitstable but also in the eastern Swale and that the smaller the tide, the smaller is the residual. At and near springs this E.N.E. residual is of the same order as that recorded by Carruthers and Lawford at the northerly position of the Mouse lightship.

The explanation of this residual current is not at all obvious but it is clear that there must be water in addition to that entering the Swale from the east on the flood tide or else the Swale Estuary would soon run dry! It seemed unthinkable that this extra water could be provided by the outflow of fresh water from the River Medway alone and indeed this is not so. Some observations carried out in September 1955 and also in August 1956 throw some light on this matter. It was found by means of throwing in pieces of wood at selected places on the Swale that the flood tide at Kingsferry Bridge is from west to east, that is, it arrives around the north and west coast of Sheppey past Sheerness and Queenborough (fig. 7). The tidal stream continues in the same direction for about two hours after high water after which it reverses and the ebb runs to its finality from east to west. Yet at a point roughly opposite Ridham Dock or slightly to the east, about a mile away from Kingsferry Bridge, there is no tidal stream on the flood tide whilst still farther to the east, at Elmley Ferry the flood tide is up-Swale from east to west. Thus the Swale derives its water from two opposite directions which meet near Ridham Dock. It was found that there is also a separation and reversal of the streams during the ebb in the Swale to the eastwards of Kingsferry Bridge and that the place of separation varies with the state of the tide, gradually working eastward with increasing time after full tide.

Time did not permit of as extensive observations as could have been desired but it was observed that at Elmley Ferry although the flood tide is always up-Swale, i.e. from east to west, the ebb begins from west to east and continues in this direction for about three hours after which it reverses and runs in this new direction until slack water. Yet from observations made near the eastern entrance to the Swale and off Whitstable, it was clear that there must be a place where the ebb tide is always from west to east. This was found to be near Fowley Island, just outside the entrance to Conyer Creek. Thus the fact that for a time the ebb stream is east-going throughout the whole length of the Swale even in that region in which the flood tide stream is also from west to east must mean that more water leaves the Swale by its eastern entrance than entered it. This will, in part at any rate, account for the east-going residual noticed at Whitstable. In addition, the region includes an ebb channel, the E. Swale exit, known locally as “the River” which is
an ebb channel of the Thames Estuary as mentioned by Robinson (1956) and implies an east-going residual. The above remarks apply only to average and spring tides.

As might be expected from the findings that there is a small east-going residual or no residual at all at Whitstable on neap tides they do not hold good to the same degree for neap tides in the West Swale. When these occur it was found that the flood tide stream around the north of Sheppey barely reaches Ridham Dock and reverses at one hour after full tide at Kingsferry Bridge so that little or perhaps no extra water is added to the east-going ebb tidal stream which peters out about one-quarter mile west of Conyer Creek. Such conditions occur for two or three days only in each fortnightly tidal cycle and do not affect the main conclusions.

Shortly after making these observations on the currents in the Swale, we came across the account given in the Pilot’s Guide to the Thames Estuary and Norfolk Broads (Wilson and Branson, 1949). This is an accurate summary of information given in the North Sea Pilot, vol. 3, 1948, and tells the same general story as has been outlined above but there are important differences in detail. Thus these accounts state that the two flood streams in the Swale meet near Fowley Island. But several observations on both spring and neap tides in August and September 1955 and August 1956 showed that this is not so. The tidal streams then as stated, met just east of Ridham Dock at spring tides and just west of Ridham Dock at neap tides. On five occasions it was confirmed that the flood tide stream at Elmley Ferry, which is situated about one and a half miles east of Ridham Dock, was from east to west and on each occasion the weather conditions were in no way unusual, the strongest wind being of force 4 from the S.W.

It is difficult to account for this difference between our findings and the information given in the North Sea Pilot and it may be that more extended observations would indicate that over a longer period of time the tidal streams vary a good deal. However, this difference in detail does not detract from the view that the tidal streams in the Swale run for longer in an easterly than in a westerly direction. Indeed, the North Sea Pilot states that between Faversham Creek and the eastern entrance to the Swale the stream runs inwards from the Thames Estuary between −0.525 and +0.005 hours and that the outgoing (ebb) tide in the eastern Swale runs between +0.005 and −0.555 hours relative to the time of high water at Sheerness. That is, the duration of the east-going ebb stream exceeds that of the west-going flood by half an hour.

Inspection of the shores in the West Swale re-inforce the idea that the extra water flowing eastwards during the ebb is mainly sea-water (in contrast to mainly fresh water derived from the Medway). There is an abundance of the brown algae, *Fucus spiralis* and *Ascophyllum nodosum* and of the barnacles, *Balanus balanoides*, all of which tolerate only small drops in salinity. Partially euryhaline animals such as *Mya arenaria*, *Scrobicularia plana*, *Cardium edule*, *Carcinus maenas*, *Elminius modestus* and *Balanus improvisus* are also plentiful but do not provide very reliable
Sketch map to show the course followed by the logship on an average tide.
Sketch map to show the course followed by the logship on a tide approaching springs.
evidence of fully marine conditions, yet it is reported that typically marine fishes like the bass, *Labrax lupus*, are common. Obviously a good indication of the source of the water in the West Swale is given by salinity determinations. Accordingly samples were taken at or near high water of spring tides at Kingsferry Bridge and at Elmley Ferry. They show that the former locality the salinity was 31.46 a mille as compared with 30.93 parts a mille at Elmley Ferry whilst the corresponding figures for Whitstable were 34.0 parts a mille. These figures indicate that some less saline water from the Medway enters the Swale.

The experiments with floating markers, as has been seen, showed that the tidal stream on the flood enters the eastern entrance of the Swale in a roughly S.W. direction but, as is well known, the flood tide runs roughly N.W. along the north coast of Sheppey. From this it is obvious that at some point near the eastern end of Sheppey there must be a separation of the flood streams. This was found to be opposite a point about one mile N.W. of Shellness. N.W. of this point the flood stream sets along the north coast of Sheppey and S.E. of it, it runs in a S.E. direction into the Swale. Before it reaches the eastern end of Sheppey the main flood tide has traversed the Kentish Flats but there is, so far as we could find, no information as to the relative strengths of the flood and ebb tides close in to the north Sheppey shore. It is possible that here there is a west-going residual as is suggested by biological evidence.

From all this it seems that Whitstable derives its water largely from seaward or from the areas to the east, but in a very indirect manner, much of the water having circulated around the north coast of Sheppey, and also receives a contribution from the Medway Estuary. The existence of the Thames and Swale ebb channels to the north and south of Sheppey, respectively, lend strength to this idea. Ebb and flood tides tend to avoid each other and whilst the last of the ebb is draining down the ebb channels the young flood could make its way between them, running close to the north Sheppey shore.

The occurrence of an east-going residual, which may be of the order of 20 miles a week, means that larvae spawned at Whitstable would be carried many miles to the east by the time they are ready to metamorphose and settle on the bottom were there no compensating currents in the opposite direction. An example that springs to the mind is the oyster which has for long been associated with the name of Whitstable. Its larvae have a pelagic life of from eleven to fourteen days and it might appear unlikely, therefore, that the oyster beds at Whitstable could ever be directly re-populated to any extent by larvae spawned in the area. Some of the few numbers of spat that do settle there may have been released up-Swale, possibly near Milton Creek which is about 14 miles from the Whitstable Flats but only a few breeding oysters now remain in the Swale whereas at one time they were plentiful, and to this circumstance may be attributed in part the decline in the oyster fishery at Whitstable. The reasons for the virtual absence of oysters in the Swale are not certain but among them may be overfishing, neglect of the beds and pollution.
Sketch maps to summarise the courses followed by the logships. Broken lines indicate estimations. H.W.—high water, L.W.—low water, S.W.—slack water.
Nevertheless, in most years there is a small but by no means negligible spatfall on the Flats and sometimes on the oyster beds themselves and this would seem to indicate that some oyster larvae, after having been carried eastwards, are returned to the Whitstable area by currents which circulate around the Isle of Sheppey at a stage when they are ready for settlement.

Whilst this idea must be regarded as very tentative, it is made more plausible by considering some of the other marine animals which have pelagic larvae and which are found in the Whitstable area. The common limpet, *Patella vulgata*, for example, is not uncommon on the chalk platform in Minnis Bay and occurs in much smaller numbers on the stones around midtide level at Whitstable, a situation which must be regarded as unusual since the limpet is typically an inhabitant of rocky shores.

Bearing in mind the east-going residual current it would seem impossible that limpet larvae could have worked up the shore from east to west and their precarious colonisation of the Whitstable beaches suggests a compensating current around Sheppey. The finding of the youngest postmegalopa stages of the shore crab in the Swale near Kingsferry Bridge also is indicative of a colonisation from the west.

It might be argued that water entering the west Swale could have come across from the Essex side but there are important dissimilarities between the fauna of the Whitstable and Essex shores (Mistakidis, 1952; Newell, 1954) so that a regular exchange of this kind seems unlikely. It is clear, however, that if there is a circulation of water from the Kentish Flats around Sheppey, polluted Swale water could make its effects felt in two
ways—directly, by reducing local populations and indirectly by damaging larval during their return passage in an eastward direction. Much more needs to be known before it will be possible to assess the effects of the east-going residual current on the variety and density of marine life at Whitstable but there can be little doubt that there is a continual drain of pelagic larvae away from the area which in this respect resembles the Carmel Head area of Anglesey (Crisp and Knight-Jones, 1954) and colonisation from the east must be more difficult than if the main current was absent or in the reverse direction.

Not all of the bottom-dwelling invertebrate animals have pelagic larvae. Some are viviparous while others have yolky eggs from which hatch young forms which from the first live on the bottom. In the intertidal zone these, as well as the adults, are subjected to the action of beach drift which, along the North Kent Coast, is from east to west. Beach drifting thus provides a means whereby many animals can be passively shifted into the Whitstable area from the east and there can be little doubt that it has played an important part in building up the fauna. Evidently the conditions at Whitstable are very different from those in an estuary such as the Crouch where there is a relatively simple piston-like action of the tides (Knight-Jones, 1952) which does not cause a continual drain of planktonic larvae away from the area.

SUMMARY.

1. By following the movements of a logship some idea has been gained of the residual currents at Whitstable.

2. As found by Carruthers and Lawford (1950) north of Sheppey, the tidal streams are west-going on the flood and east-going on the ebb. At neap tides there is no residual but at normal and at spring tides there is an east-going residual which may reach as much as eight miles a day. Further observations may show that it exceeds this figure.

3. It is suggested that the explanation of the residual current may lie partly in the peculiar tidal streams in the West Swale where the flood tide is from west to east and the ebb continues for some time in the same direction thus adding water to that derived from the flood tide which has entered the east Swale through its eastern entrance. The ebb-channel of the E. Swale (Robinson, 1956) also implies an east-going residual.

4. The east-going residual current must carry many pelagic larvae away from the Whitstable area, but some may be returned after circulating around Sheppey. The difficulty of re-colonisation is to some extent offset by the east to west beach drift which occurs all along the north Kent Coast.

REFERENCES.


