THE HYDROLOGY OF THE FLEET

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INTRODUCTION

Whereas the literature on the origin and evolution of Chesil Beach and the associated area is considerable (see Bird, 1972; Carr & Blackley, 1974, for a review), published information on the Fleet waterbody and its hydrology was until a decade ago, virtually non-existent.

The present paper is a shortened version of a more comprehensive publication (Whittaker, 1980). It is the result of my original survey (Whittaker, 1972), further work undertaken by the Fleet Study Group since 1975, and information gleaned from the important Central Electricity Generating Board's (CEGB) hydrographic survey (1968), recently released.

BATHYMETRY

Although the Fleet is about 13 km long, the widest part, across Butterstreet Cove is only 900 m, while in the Narrows it is less than 65 m across. For the most part it is very shallow.

The connection with the sea, via Portland Harbour, is at Smallmouth (Fig 4D). Here the roadbridge (Ferrybridge) restricts the channel to 75 m wide, and the depth falls to -5.2 m O.D., the deepest point in the Fleet. Because of the poor condition of the present bridge a completely new structure is to be built a short distance nearer to Portland for which a completely new channel of similar contour to the present one, will be cut. The present entrance to the Fleet will then be filled in. Above Ferrybridge the channel swings sharply towards Chesil Beach and then runs adjacent to it until at Pirates' Cove it quickly shallows to -1 m O.D. (Fig. 4D) over a shingle bar and swings landwards round outcropping Corallian rocks, before entering the Narrows. In the Narrows, the Fleet is greatly restricted in width for about 1 km and scouring from the strong tidal flow has resulted in depths of up to -3 m O.D.

Above the Narrows the Fleet opens out into Lynch Cove Tidmoor Cove and Butterstreet Cove, known collectively as Littlesea where there are extensive 'mudflats' around datum level colonised by Zostera and a deep channel runs adjacent to Chesil Beach, but gradually decreases in width and depth, until by Butterstreet Cove it is no longer clearly defined. A series of deep sinuous channels also traverse Littlesea, the deepest being 'Big Lake' (max. depth -3.1 m O.D.) (Fig. 4C) which takes the main part of the tidal flow in and out of Butterstreet Cove and West Fleet. The other channels are formed by drainage of the mudflats and are relatively narrow, deep (max. depth -2.4 m O.D.) and steepsided in contrast to the more gradual slopes of Big Lake. A further channel between Chickerell Hive Point and Chesil Beach directly opposite, is man-made for the passage of boats at low water. On the mudflats of Littlesea water depths vary between 0.5 and 1.5 m on spring tides, whilst in periods of neaps the water barely covers them and at low water they are dry.

West Fleet, from above Butterstreet Cove to Abbotsbury (Figs 4A,B), is very shallow, the bed being generally around datum level, slightly above O.D. or no more than -0.5 m O.D., except opposite Herbury (down to -1 m O.D.) and a larger area in the Abbotsbury Embayment where depths of -0.6 m and over are achieved. In West Fleet, the water, even at high water, is usually no more than 1-1.5 m deep and often less.

TIDES AND CURRENTS

Extensive work on the tides and currents was undertaken by the CEGB in 1967, and more recently by the Department of Oceanography, University of Southampton. These findings are discussed in detail by Robinson elsewhere in this volume. For the sake of completeness a brief description of these factors is given here, mainly from the results of my own survey (Whittaker, 1972).

Tidal readings were taken over 12 hr periods on both spring and neap tides at several times of the year (1969) at a number of stations on the Fleet, using temporary tide-boards surveyed into Ordnance Datum. Two such readings of the tidal range are given in Table 1 below and show the maximum and minimum ranges

TABLE 1

Station	Tidal range	
	Spring tide (29th Aug., 1969)	Neap tide (5th Sept., 1969)
Portland Harbour	1.91 m	0.63 m
RE Bridging Point	1.52 m	0.46 m
Chickerell Hive Point	1.12 m	0.36 m
Langton Hive Point	0.18 m	0.03 m
Top Ferry (Morkhams Lake)	0.15 m	0.03 m

that can be expected under optimum conditions.

Locally, near the Abbotsbury end and opposite Chickerell, percolation of sea-water through Chesil Beach has been seen by the author. This is not surprising on account of the time lag of the tides between the Fleet and West Bay (on the other side of Chesil Beach), the water in the sea being as much as 1.2 m, on springs, and 0.6 m, on neaps, higher than in the Fleet at certain states of the tide. In West Fleet, particularly during neap tides, when this inequality of water levels is maintained the longest, percolating water can modify the salinity regime to some extent (see Fig. 5C), though its effects are by no means as important as Bird (1972) would suppose. The cans or seepage

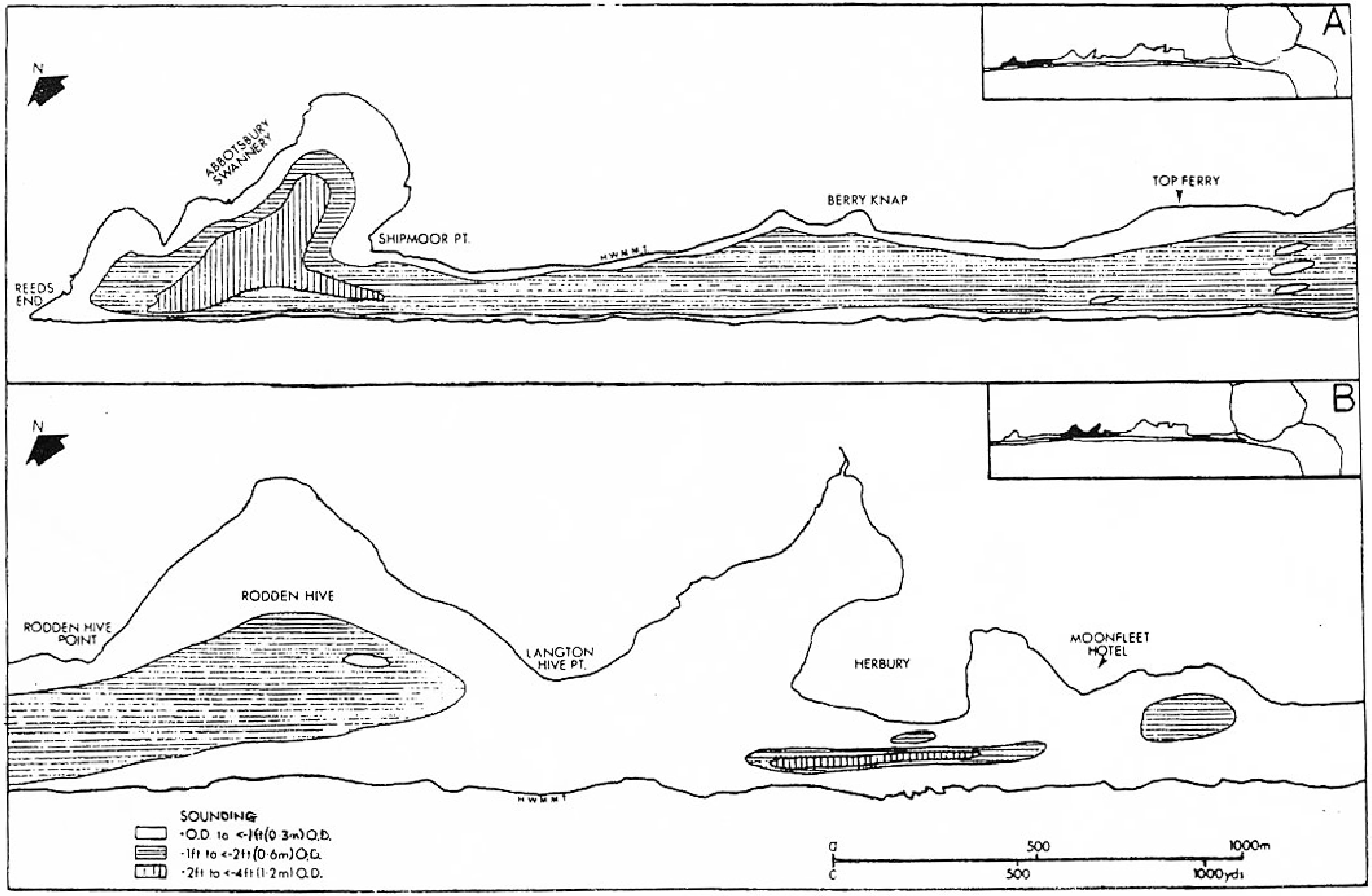
A
N
ABBOTSBURY SWANNERY
SHIPMOOR PT.
BERRY KNAP
TOP FERRY
REEDS END
HWNMT
B
N
RODDEN HIVE
RODDEN HIVE POINT
LANGTON HIVE PT.
HERBURY
MOONFLEET HOTEL
HWNMT
SOUNDING
+O.D. to <-1ft (0·3m) O.D.
-1ft to <-2ft (0·6m) O.D.
-2ft to <-4ft (1·2m) O.D.
0 500 1000m
0 500 1000yds

Fig 4A & B

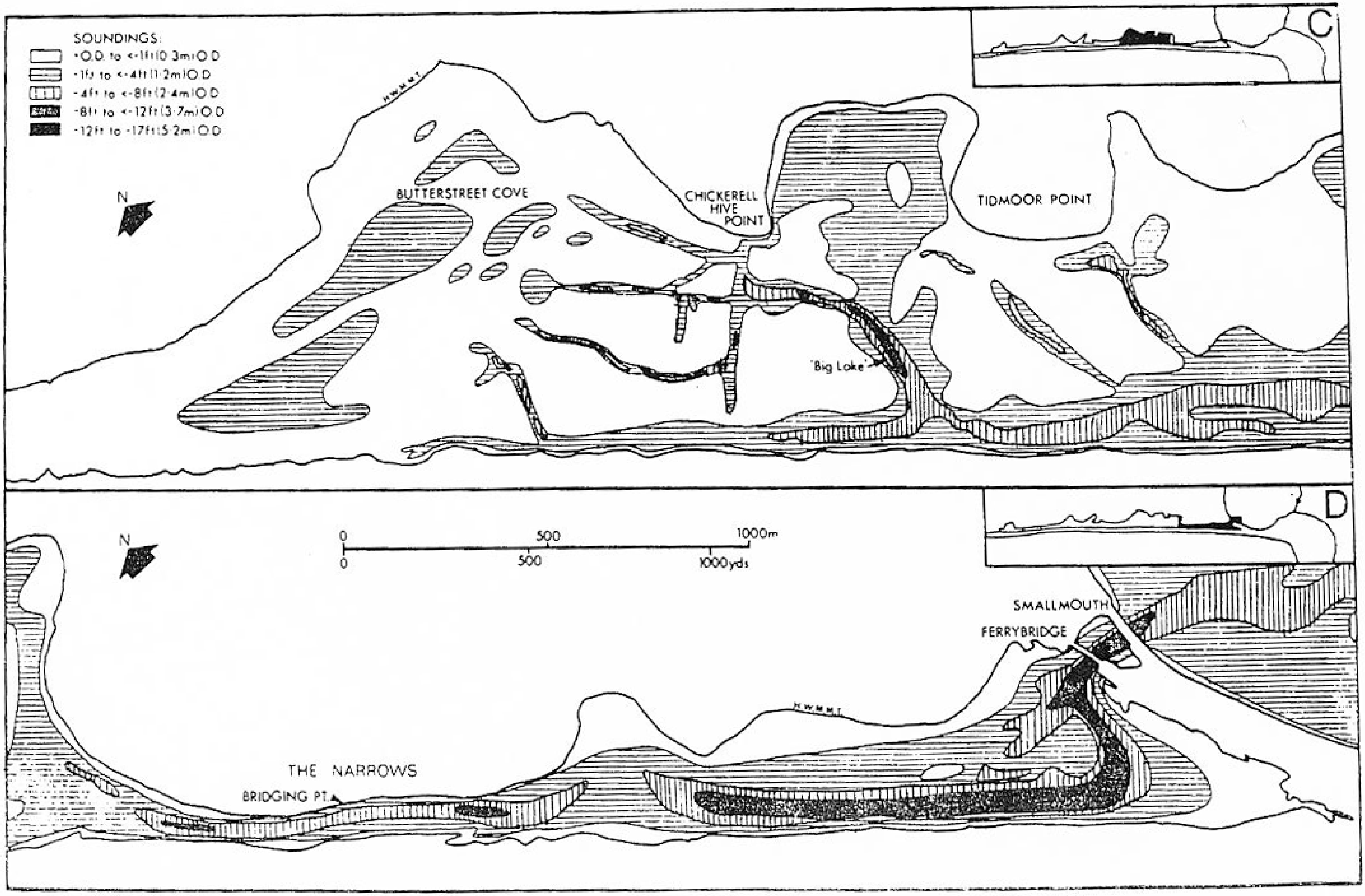
SOUNDINGS:
+O.D. to <-1ft (0.3m) O.D
-1ft to <-4ft (1.2m) O.D
-4ft to <-8ft (2.4m) O.D
-8ft to <-12ft (3.7m) O.D
-12ft to -17ft (5.2m) O.D
C
N
H.W.M.M.T.
BUTTERSTREET COVE
CHICKERELL HIVE POINT
TIDMOOR POINT
'Big Lake'
D
N
0
500
1000m
0
500
1000yds
SMALLMOUTH
FERRYBRIDGE
H.W.M.M.T.
THE NARROWS
BRIDGING PT.

FIG 4C & D

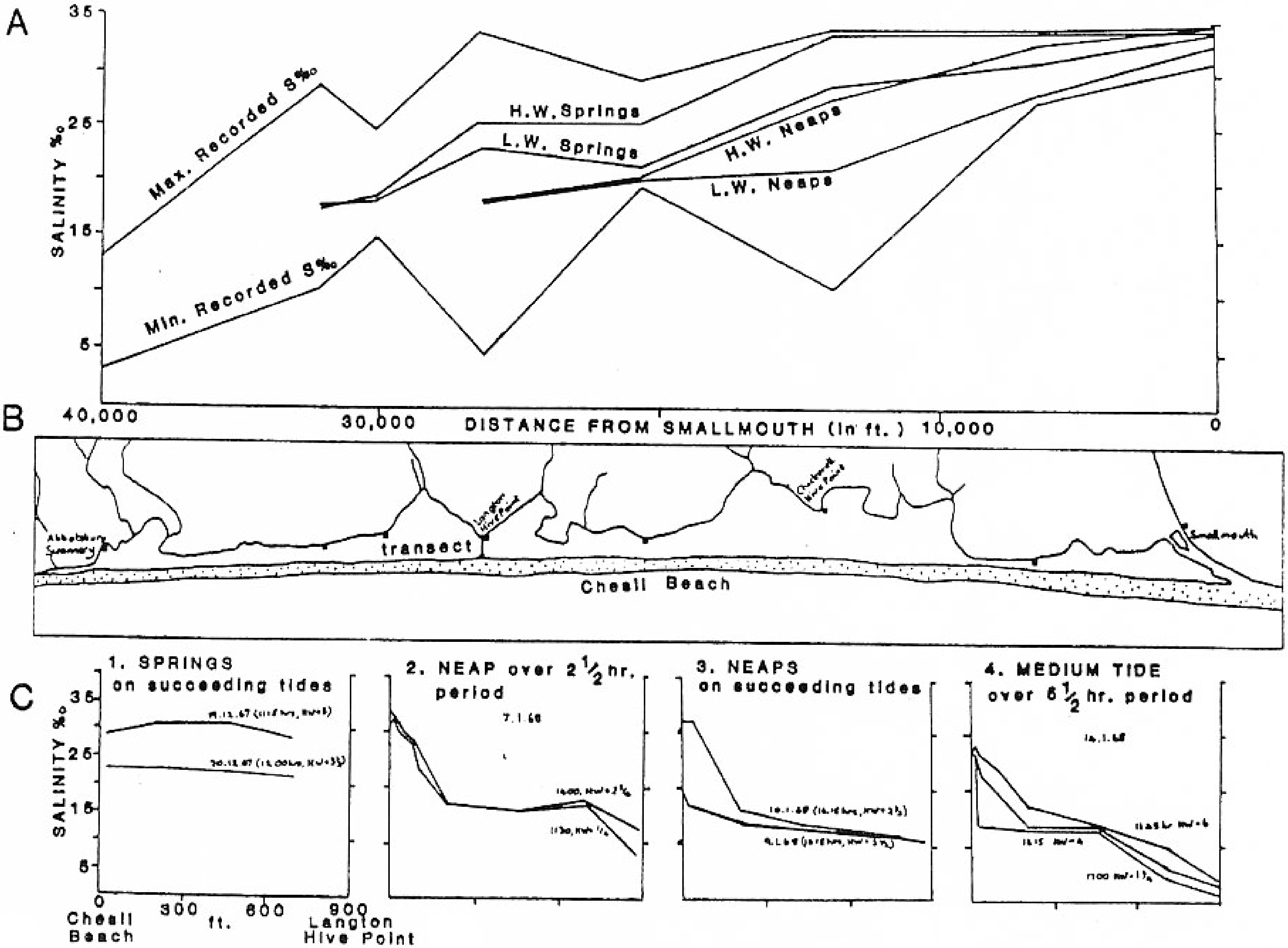
A
SALINITY ‰
35
25
15
5
Max. Recorded S‰
Min. Recorded S‰
H.W. Springs
L.W. Springs
H.W. Neaps
L.W. Neaps
40,000
30,000
DISTANCE FROM SMALLMOUTH (in ft.)
10,000
0
B
transect
Chesil Beach
Smallmouth
C
1. SPRINGS on succeeding tides
2. NEAP over 2 1/2 hr. period
3. NEAPS on succeeding tides
4. MEDIUM TIDE over 6 1/2 hr. period
SALINITY ‰
35
25
15
5
0
300
600
900
ft.
Chesil Beach
Langton Hive Point

Fig 5

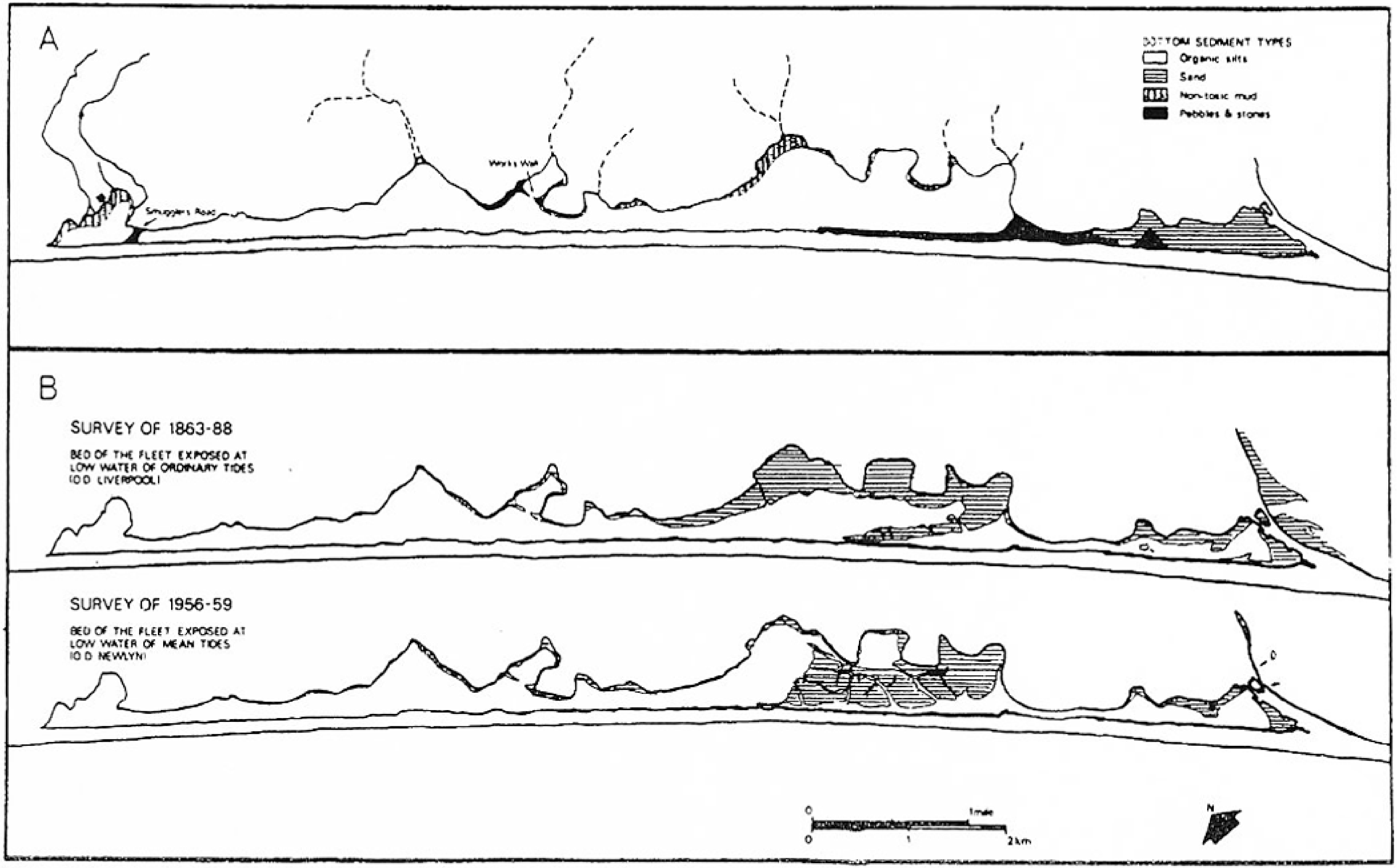
A
BOTTOM SEDIMENT TYPES
Organic silts
Sand
Non-toxic mud
Pebbles & stones
Smugglers Road
B
SURVEY OF 1863-88
BED OF THE FLEET EXPOSED AT
LOW WATER OF ORDINARY TIDES
(O.D. LIVERPOOL)
SURVEY OF 1956-59
BED OF THE FLEET EXPOSED AT
LOW WATER OF MEAN TIDES
(O.D. NEWLYN)
0
1 mile
0
1
2 km
N

Fig 6

hollows, which are a marked feature of the Fleet side of Chesil Beach are not connected with seepage caused by the time-lag of the tides, rather they are catastrophically formed and regulated under exceptional southwesterly storm conditions when the waves in West Bay are driven above a certain critical level in the Beach. At this time its porosity is enough to allow large amounts of water to pour through, but normally the cans are dry. The CEGB survey was of the opinion that seepage of any form was insignificant compared with the tidal discharges, and even under storm conditions water entering the Fleet through the cans was likely to produce nothing more than a local effect.

Within the Fleet the time-lag of the tides is itself an interesting phenomenon. Highwater at RE Bridging Point is usually up to 45 minutes later than at Portland, at Chickerell Hive Point it is over 1½ hrs later and at Langton Hive Point and Top Ferry 3 and 4 hrs later respectively. The Zostera-flats of Littlesea are tidal and begin to emerge about 3 to 4 hrs after local highwater, becoming finally dry a further 1 to 2 hrs later.

The strongest currents in the Fleet, between 3 and 4 knots occur in the Narrows on a spring floodtide, while the current under Ferrybridge also exceeds 2 knots, this time on an ebbtide. Above the Narrows velocities of more than 1 knot, even on springs are unknown. On neap tides the maximum velocity is about 2 knots, again in the Narrows.

The picture is therefore one of a tidal influence rapidly diminishing in a northwesterly direction, with little penetration of the tide and low current velocities beyond Butterstreet Cove, the narrow inlet at Smallmouth and the small tidal range of the English Southcoast (max. of c. 1.8 m) being such as to inhibit tidal flow. The lack of tidal influences in West Fleet also means that the water there is rarely replaced, this has important repercussions on the flora and fauna.

SUBSTRATUM

The bed of the Fleet above the Narrows is made up of organic silt, formed from the decay of the Zostera (Fig. 6A). There is little in the way of other sediment entering the lagoon because of the small size of the streams and the lack of erosion of the landward cliffs. These silts (with some peats) rest on bedrock, mainly Oxford or Kimmeridge Clay, which varies in depth between a metre or so near the shore to over 20 m in the Littlesea area and in places under Chesil Beach. Pollen evidence (Carr & Blackley, 1974) suggests that most of the infilling was very rapid after the inception of the lagoon and was mainly completed by 5,000 years ago. Nevertheless some silting appears to be continuing today. A comparison of the First edition of the Ordnance Survey 6"/1 mile map, with the latest edition (Fig. 6B,) shows more extensive areas of the Fleet bed exposed in the Littlesea embayment today at low water than a century ago. This may be a phenomenon accentuated by a more restricted tidal flow since the building of Portland Harbour, but there is very little historical evidence to substantiate it, let alone give us a detailed picture of what the Fleet was like prior to the 19th century.

The present distribution of Zostera dates from the last few decades as in the late 1930's it was virtually wiped out by the widespread "Zostera-disease" of the time. It now covers an area greater than at any time since its recolonisation and is practically ubiquitous from Littlesea right to Abbotsbury. Because Zostera growth is seasonal, the substratum here is mostly rotting vegetation and strongly reducing silts during the winter months until, in late spring, the new green shoots appear. Only in the Abbotsbury Embayment are there perennial streams and these have built out small mud deltas colonised by Phragmites reeds. Elsewhere, although small streams enter the Fleet after heavy rainfall (Fig. 6A), little is added in the way of sediment. Around Herbury and the shore of Butterstreet Cove, a small amount of sediment has been winnowed out of the low cliffs, but wave erosion is minimal due to the restricted fetch. In the cove below Langton Hive Point (at 'Works Wall') and just to the southeast of Shipmoor Point ('Smugglers' Road') areas of stones in very shallow water occur, the ruins, so it is said of early 19th century (unsuccessful) attempts to drain parts of the Fleet. The shore in the vicinity of Langton Hive Point is pebbly, the pebbles having been brought there by fishermen to assist in the beaching of boats.

For the remainder of the Fleet the substratum is rather different. Between the R.E. Bridging Point and Smallmouth fine sand is the dominant substratum (Fig. 6A), it having been brought into the Fleet in suspension by the tide. In the Narrows the bed of the Fleet is pebbly, the pebbles having been washed over Chesil Beach in storms, also in part added by human activity, while the strong currents serve to wash out all the finer sediment.

SALINITY

The Fleet, unlike a normal estuary is long and narrow, it has a relatively small discharge from rivers, a large volume of 'estuarine' water at low tide, and a tidal flow greatly retarded by the small marine inlet. A salinity gradient is well developed from Smallmouth to Abbotsbury, though the degree of dilution and hence the steepness of this gradient varies from season to season and with the cycles of the tide (Fig. 5A).

Autumn 1968 (samples taken on 19th and 20th November) showed a gradient from 34°/oo at Smallmouth (normal marine salinity) falling to 17°/oo at Abbotsbury. The penetration of marine salinities as far as Butterstreet Cove is significant as this marks the limit of effective tidal flow. The wet winter of 1968-69 (sampled 1st-5th March 1969) showed a marked dilution of the water, particularly in the shallow West Fleet, where salinities varied between 3 and 25°/oo. Although the Fleet has few permanent streams, dilution after heavy rain, at least in shore stations, can be rapid; this is well shown in the spring survey (28th-30th May 1969) when very low readings in the coves of Rodden Hive, Butterstreet and Tidmoor, compared to stations further offshore, were recorded after heavy downpours. Elsewhere the high spring tides at the time of the survey were responsible for the deep penetration of marine water as far as Herbury. Further to the northwest the salinity gradient was steep, reducing to 3°/oo at Abbotsbury. In summer 1969 (2nd-4th August) marine salinities were similar and extended as far as Langton, though in West Fleet they had fallen, by Abbotsbury, to around 15°/oo. By September, following a long period of sunny weather conditions had reached almost drought proportions and the Fleet was affected accordingly, marine conditions reaching almost to Abbotsbury (even higher salinities were recorded in the 1976 drought).

Salinity values, particularly in West Fleet tend to be higher for stations towards Chesil Beach than close to the landward shore. This is due partly to seepage of freshwater from the land and partly to percolation of marine water through Chesil Beach at certain states of the tides and weather conditions. The results of a salinity transect from Langton Hive Point across to the Chesil on several tides are shown in Fig. 5C, but the role of these modifying factors is discussed in detail elsewhere (see Robinson, ibid.).

The wide diel* fluctuations in salinity (20-30°/oo over a tide) observed by Murray (1966) in nearby Christchurch Harbour, Dorset, and probably quite typical of estuaries as a whole, do not occur in the Fleet. Under dry weather conditions salinities in East Fleet appear to vary only about 2°/oo at any one station over a tide, or by perhaps as much as 10°/oo in shore stations after heavy rain. In West Fleet, where the salinity gradient is steep, diel variations probably never exceed 5°/oo at any one place, but close to the Chesil and landward shores seepage and heavy rainfall may increase this figure to 10°/oo or more.

The Fleet can now be divided into three parts based on salinity:-

(1) A marine to near-marine part, extending from Smallmouth to Butterstreet Cove, only extending further northwards during high tides in summer months, and over periods of exceptionally fine weather.

(2) A high-salinity brackish part, covering most of West Fleet, with values of between 12 and 30°/oo in winter and spring, and a little higher generally in summer (24-30°/oo).

(3) A low-salinity brackish part, found in the Abbotsbury Embayment, with values

*diel - over a 24 hour day.

frequently below 10°/oo; rising to 20°/oo or even higher in periods of low discharge of the Abbotsbury Millstream.

The chief factor influencing the salinity of the Fleet, as with water levels, is the tidal effect. This is in spite of the low tidal range and the restricted marine inlet. This is then modified to some extent by both freshwater run-off and marine percolation through Chesil Beach. Though only bottom-water was collected as a rule in the present survey, a number of surface-water samples taken in various parts of the Fleet, failed to indicate a vertical salinity gradient, thus underlining the minor role of these modifying factors. These general findings conflict with the 'estuarine lagoon system', governed by high percolation in both directions through the enclosing shingle barrier, proposed as a model for the Fleet by Bird (1972). Certainly he considered this factor to be of far greater importance than it appears to be in reality.

pH.

Apart from during the autumn the Fleet water is much more alkaline than the normal pH of the sea (average seawater has a pH of around 8.0) (see Table 2, below). The high values are produced by photosynthesis of the vegetation in the largely shallow water, thus the lowest readings are for the autumn survey when most of the Zostera was dying back and photosynthesis reduced. In the hot September of 1969 the water of West Fleet became dark brown in colour with a low pH and there was considerable fish mortality. The cause was thought to have been a bloom of phytoplankton possibly triggered off by pollution from farm fertilisers, as the water here is rarely flushed out. A similar occurrence took place in the severe drought of 1976

TABLE 2

Season (Month)	No. of samples	pH Max.	pH Min.	pH Mean
Autumn, 1968 (November)	19	8.2	6.9	7.8
Winter, 1968-69 (March)	23	8.8	8.1	8.5
Spring, 1969 (May)	30	9.5	7.7	8.9
Summer, 1969 (August)	36	8.8	7.8	8.4

Winter pH figures are somewhat higher because the colder water can take up more oxygen and the pH and oxygen values tend to be linked. During spring and summer months when sunlight is most intense and plant growth at its optimum pH values often exceed 9.0. As a rule the highest values occur on the Zostera-flats of East and West Fleet in late spring and in summer, the lowest around Abbotsbury in summer and autumn where the water stagnates and fouling by the large bird population may also contribute to the lowering of the pH.

Diel changes in the pH of the water are also significant, rising from a neutral figure (around 8.0) at night to over 9.0 in the afternoon at times of strong photosynthetic activity. Although such a phenomenon has been observed in rockpools, diel changes of 1-1.5 units are probably the first record of such a marked effect of photosynthesis in a waterbody as large as the Fleet. It is clear that in spring and summer the lagoon behaves like a gigantic rockpool.

In my original survey only the bottom water was measured, no readings were taken within the organic silt because of the difficulty of taking the pH of sediment in situ; it is, however, presumed to be very acid. Contamination of the pH of the water by this silt during churning by storms is probably minimal, owing to the thick carpet of vegetation that covers the substratum for most of the year.

DISSOLVED OXYGEN CONTENT

Over the period November, 1968 to August, 1969, all records of dissolved oxygen content of the Fleet water showed supersaturation (i.e. above 100% saturation) and a number were in excess of 200% in the spring (see Table 3, below).

TABLE 3

		Dissolved oxygen (% saturation)		
Season (Month)	No. of stations	Max.	Min.	Mean
Autumn, 1968 (November)	15	182%	106%	146%
Winter, 1968-69 (March)	16	174%	112%	142%
Spring, 1969 (May)	23	258%	118%	168%
Summer, 1969 (August)	19	177%	123%	147%

Similar conditions, with strong diel fluctuations, had been described as early as 1935 by Broekhuysen on Zostera-flats in the Netherlands, and can be by no means unusual in such an environment. Even the winter samples showed constant readings over 150% when there was no Zostera in the Fleet, it is thought the colder water would be able to take up more oxygen.

CALCIUM AND MAGNESIUM VALUES

Murray (1966) had found a strong calcium deficiency in the bottom water of the shallow Christchurch Harbour, Dorset, in the summer months. In the Fleet, however, the calcium and magnesium values show a perfectly linear relationship with the salinity in both the winter and spring surveys, in summer the calcium values show a deficiency as against the mean winter line. Whereas, in Christchurch Harbour there was a virtual total and rapid calcium removal when the marine water spread out over the mudflats, water entering the Fleet is low in calcium in the first place. As the water moves up the lagoon the lowering of values merely reflects dilution of saline water. No calcium is lost through precipitation or organic activity in the Fleet because of the unsuitable nature of the Zostera-covered substratum. The summer calcium deficiency appears to have originated in the shallow waters of Weymouth Bay and Portland Harbour.

TEMPERATURE AND CLIMATE

The Fleet lagoon has much warmer water in summer and cooler water in winter than the surrounding sea. The highest water temperature recorded (26°C or 80°F) is as warm as on the Bahama Banks, whilst in winter it is little above freezing and indeed can freeze over in severe winters. Water temperatures recorded over the survey period 1968-69 are given in Table 4, below.

TABLE 4

Season (Month)	No. of stations	Water temperatures in °C Max.	Min.	Mean
Autumn, 1968 (November)	21	10.0	5.5	7.5
Winter, 1968-69 (March)	29	6.1	1.7	4.2
Spring, 1969 (May)	36	23.9	12.9	16.1
Summer, 1969 (August)	39	26.0	17.5	20.0

The climate on the south coast of England usually gives long, warm and calm summers with low precipitation. Winds can influence the tidal cycles in the Fleet particularly in West Fleet where ponding from southeasterlies occurs in early spring and autumn. Chesil Beach is also one of the most exposed sites along the English Channel coast for southwesterlies. Carr & Blackley (1974) show that the prevailing offshore wind direction for strengths of over 17 knots is in this quadrant. Generally speaking, however, the Chesil does offer some degree of protection to the shallow waterbody and the fetch is not enough to produce much in the way of erosion of the landward cliffs.

Diel variation in the water temperature is pronounced in sunny weather, with fluctuations of over 5°C (10°F) between early morning and afternoon being commonplace in the shallow water.

ACKNOWLEDGEMENTS

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