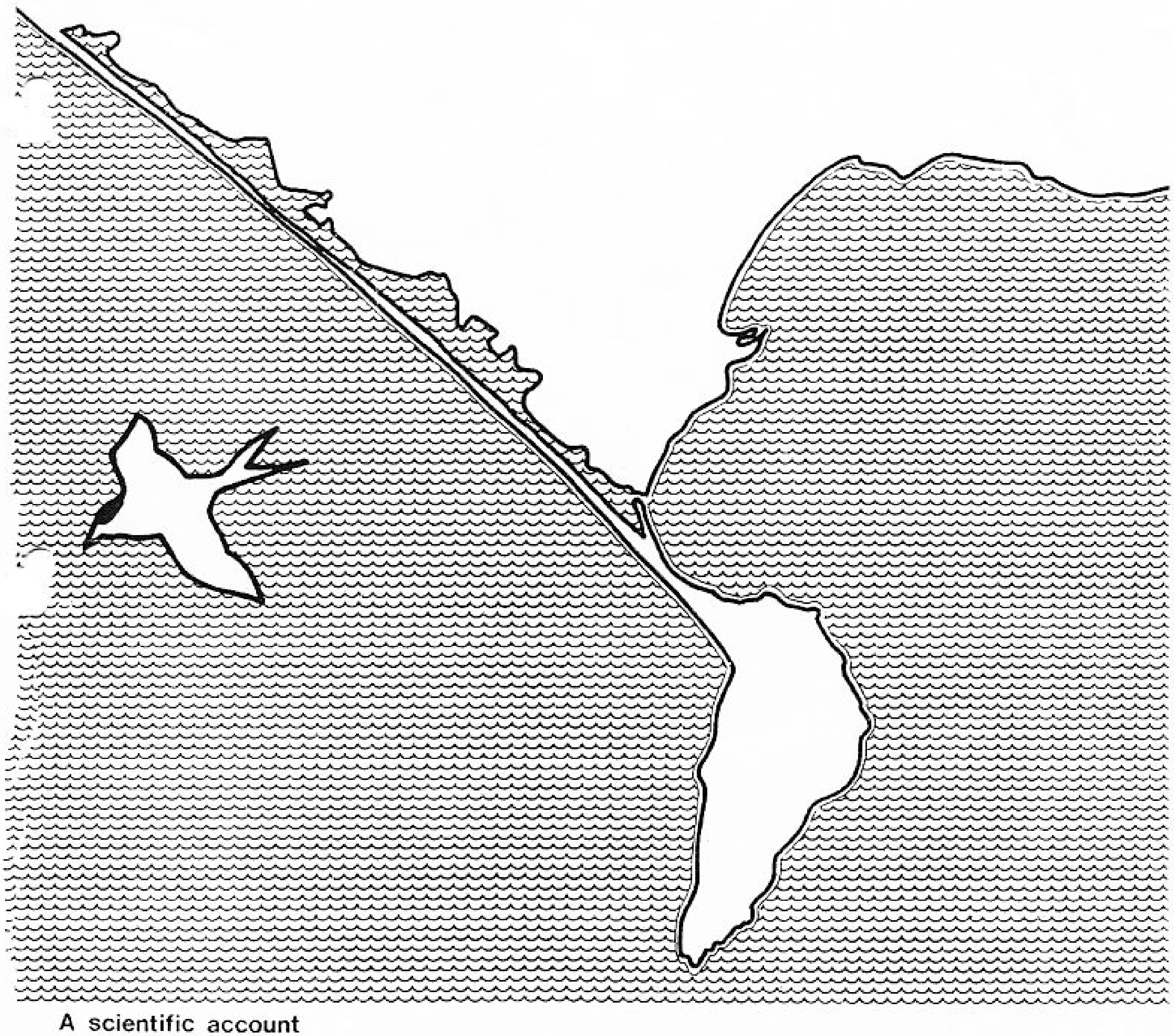
THE FLEET AND CHESIL BEACH

STRUCTURE AND BIOLOGY OF A UNIQUE COASTAL FEATURE



A scientific account
compiled by the Fleet Study Group

editor Dr. M. Ladle

PREFACE

These papers about the Fleet and Chesil Beach derive from a one day seminar held at the Dorset County Museum.

The County Planning Department supported a student studying the two features in 1972, is party to the nature reserve and the Fleet Study Group, and is assisting the publication of this factual document in order to encourage a wider understanding of the geophysical and ecological nature of the Fleet and Chesil Beach. It is intended to be an objective statement of existing knowledge and, as such, brings together information not otherwise easily available which will be of value to the many people interested in this important area. The document has not been adopted by the County Council and the scientific opinions expressed are those of the individual authors.

In addition to thanking the individual authors for all their efforts over a long period, I thank Jeanne FitzPatrick for co-ordinating the work of the Fleet Study Group, Dr Ladle for his editorial expertise, and Richard Burden for preparing the document for publication.

A T Swindall, DipTP, FRTPI, ARICS
County Planning Officer
County Hall
Dorchester
Dorset

ISBN No. 0 85216 288X
Printed by Dorset County Council. August 1981

CONTENTS

INTRODUCTION

M Ladle
The River Laboratory
East Stoke
Wareham
Dorset

The Fleet is a 13 Km tidal lagoon on the coast of Dorset. It is separated from the open sea of West Bay by the Chesil Beach and opens into Portland Harbour and, ultimately, Weymouth Bay through a narrow entrance at Smallmouth (N.G.R. S.Y.6667762). The long narrow lagoon extends west to Abbotsbury (SY 575840) and beyond this the Chesil Beach continues to West Bexington (SY 544868).

In 1971 the Natural Environment Research Council set up a working party on estuarine research to bring all users of estuaries together for the overall management of these resources. The Fleet is not an "industrial estuary", but is a unique, brackish water lagoon of high scientific value, having many estuarine characteristics.

The inaugural meeting of the"Fleet Study Group" in April 1975 was held at Weymouth College of Education with the principal of the College, Miss O'Sullivan, in the Chair. Dr P Head of N.E.R.C. was present at the meeting in an advisory capacity as were representatives of the Strangways Estate, Dorset Naturalists' Trust, Wessex Water Authority, Nature Conservancy Council, Dorset County Council and Freshwater Biological Association. Subsequently a small Committee met three times a year.

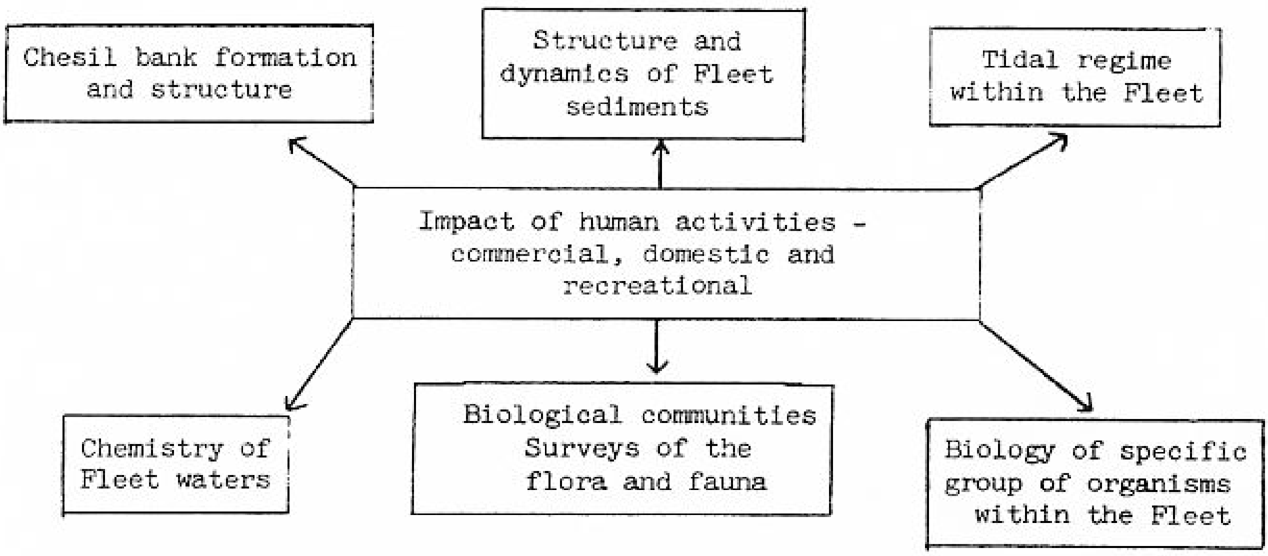
The activities of the Fleet Study Group are strictly scientific with the main aims being to review and evaluate the state of knowledge on the Fleet and the associated Chesil Beach. Additional, associated objectives are the identification of "gaps" in the available information and listing of priorities for future work. Remoteness from centres of marine research has led to neglect of the Fleet as a subject of study. In addition the region is, both literally and metaphorically, overshadowed by the presence of the Chesil Beach.

Much of the Fleet area is controlled by the Strangways Estate and under the auspices of the estate is used by multiple interests. In particular, there are activities related to education, ornithology, boating, angling and bait digging, commercial fishing, military training and general recreation.

The Fleet is designated by the Nature Conservancy Council as a grade one Site of Special Scientific Interest. Much of this interest has, up to the present time, lain in the structure and development of the Chesil Beach, hydrological mapping, complex tidal changes within the Fleet, and the presence of populations of swans, terns, widgeon and other birds which colonise the area. A good deal of information is also available on the flora of the margins of the Fleet and on the phytoplankton, benthic algae, Ostracoda, Mollusca and Foraminifera which inhabit the intertidal and sublittoral regions. Much of the British work on the vegetation of "shingle" has been carried out on the Chesil Beach. Watson (1922) records many lichens and a few mosses from the beach.

In May 1976 a list of scientific organisations and individual scientists was drawn up and "circulated" with a view to stimulating interest in the pursuit of studies on geomorphology, hydrology, chemistry and biology, these having been, tentatively, assigned priorities with regard to "sequential desirability" in terms of the progression of data collection. The highest priority was given to a proposal for examination of the tidal regime within the Fleet although it was realised that this should not preclude the initiation of any other work which might contribute to knowledge.

In general, research requirements can be divided into two interrelated groups as follows,



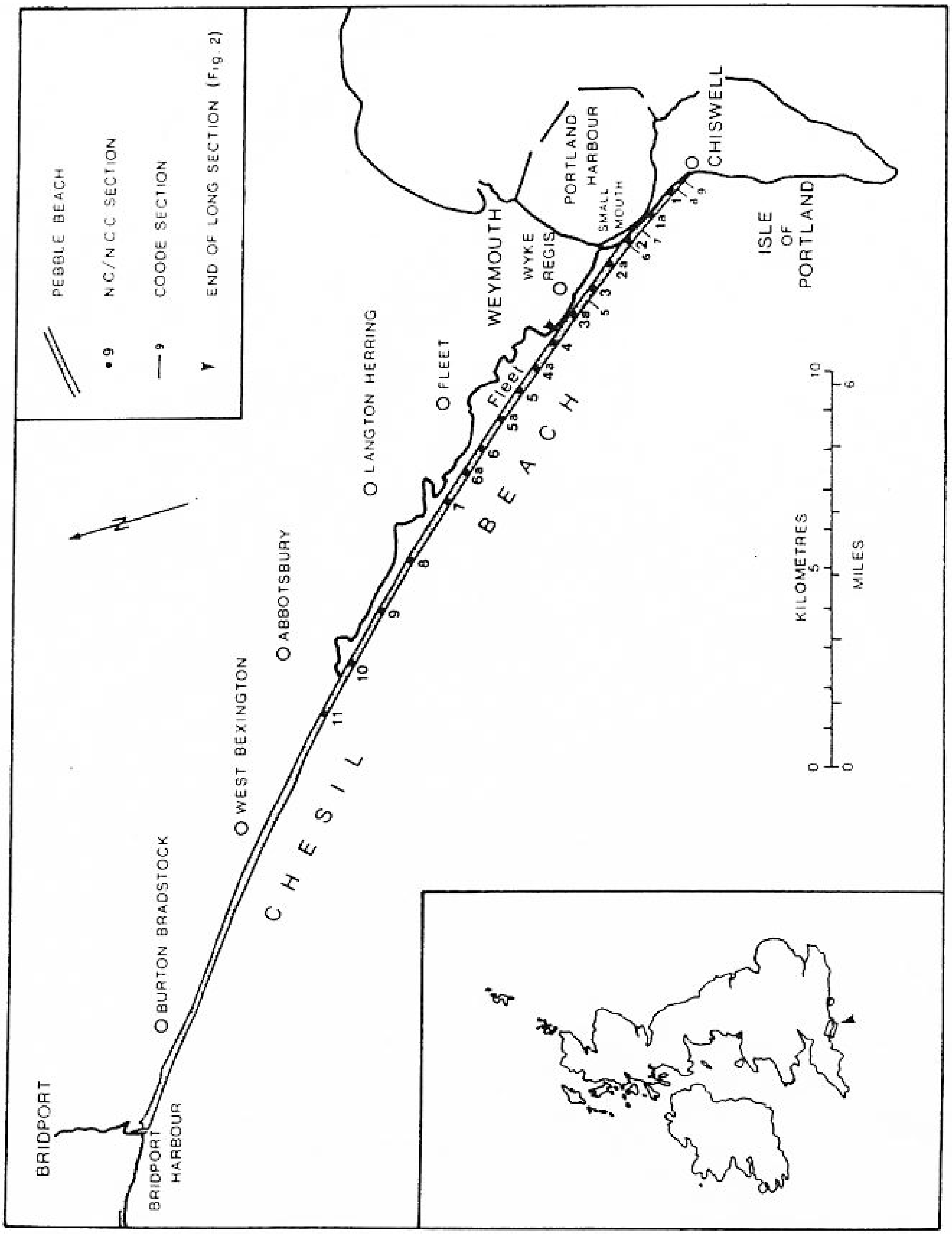
Some of the conservational and recreational issues affecting the Fleet and its surroundings are discussed by Sturdy in a report dated 1972. Although it is not within the objectives of the Fleet Study Group to judge on contentious or political issues, clearly information of this kind must be considered when assigning relative priority or desirability to particular aspects of research. In addition it is necessary to give due attention to the preservation of rare or localised species or, perhaps of greater relevance, to the maintenance of unique or scarce habitats. All of these factors should be borne in mind, in the assessment of existing "gaps" in knowledge which usually stem from the way in which science singles out subjects or biological taxa for detailed attention.

The aesthetic qualities of any region should always be considered but, from the ecological point of view, it should not be emphasised to the detriment of "smelly" mud flats or "inaccessible" salt marsh.

The Fleet area has been described as a naturalists' paradise by W C Cook and there can be no doubt of the importance of such a unique feature to research.

The present publication is a compilation of the work of authors having widely different interests. Understandably, their individual contributions may differ somewhat in style. In addition the content of the various chapters will vary according to the information, at present, available. Hopefully in the not too distant future some of the very obvious gaps in our knowledge of the Fleet will be filled in and the ecological patterns represented within this unique coastal feature will be more clearly defined to the advantage of all.

Fig 1



PEBBLE BEACH
N C / N C C SECTION
CODDE SECTION
END OF LONG SECTION (Fig. 2)
N
BRIDPORT
BRIDPORT HARBOUR
BURTON BRADSTOCK
WEST BEXINGTON
ABBOTSBURY
LANGTON HERRING
FLEET
Fleet
WEYMOUTH
WYKE REGIS
PORTLAND HARBOUR
SMALL MOUTH
CHISWELL
ISLE OF PORTLAND
CHESIL BEACH
KILOMETRES
MILES
0
5
10
6

THE FLEET AND CHESIL BEACH

E W S Green
Strangways Estates Office,
Evershot
Dorchester
Dorset
DT2 OJY

There is much to be said about the Fleet and Chesil Beach, and even more to be found out, but one fact that tends to be forgotten in the discussions about their origins and their flora and fauna is that the ownership of the Fleet and a substantial part of Chesil Bank has remained with one family since the Reformation and the Dissolution of the Monasteries.

The protection given by this continuity of interest has preserved the area in the past and, in more recent years, contributed to the increased scientific interest in many of its unique features.

The Fox-Strangways family acquired the Abbotsbury Estate and consequently the rights to the Fleet and part of the Bank when the Abbey of St Peter was dissolved in 1539.

The establishment of a Monastery at Abbotsbury in the time of King Canute has meant that there are records for the area stretching back nearly a millenium, although many of the Abbey records were destroyed as a result of the seige of the old monastic buildings by Cromwellian troops during the Civil War. However other commentators have been drawn to the area, John Leland in 1546, Camden: Coker in 1635 remarked "Abbotsbury towne is but poore, the chiefest trade consists in fishing . . .". Indeed fishing has always attracted comment; Defoe on his tour of England wrote in 1724 that he saw "all the way on the seashore . . . shops fishing for mackerel" and that the catches were "so much that the men could hardly draw them on shore . . . the mackerel the finest and largest I ever saw were sold at the seaside for a hundred for a penny".

A feature of the Bank is still the 'crews' of local men fishing off the beach with seine nets at Langton and Abbotsbury, although, perhaps, things have improved since 1752 when the London Journal maintained that "all the people of Abbotsbury, including the vicar, are thieves, smugglers and plunderers of wrecks".

It is doubtful whether anything can ever have such an impact on the area as the creation of Portland Harbour, but it is certain that since the middle of the last century the pressure from development has grown with every year. In 1980 alone there have been proposals for a nuclear power station at Langton Herring, a new roadbridge connecting Weymouth and Portland, and a new caravan site at Chickerell. The advent of the harbour works, the railway line to Portland and the roadbridge closing the narrows at Smallmouth completely altered the natural features of the East Fleet whilst the spreading urban sprawl through Wyke Regis and Chickerell, reaching out towards Langton Herring has altered the former rural communities causing social friction and further social pressure on the area.

It is therefore pleasurable to report that at the western end of the Fleet the creation of a nature reserve based around the Swannery at Abbotsbury has enabled the Swanherd to perform many of the same tasks about which the monks reported in 1393.

It is undoubtedly, only this continuity and the joint commitment of the owners and those interested, both local and distant, professional, scientific or laymen, which will continue to protect the many fascinating features of the Fleet and Chesil Beach.

CHESIL BEACH: ASPECTS OF ITS STRUCTURE, STABILITY AND THE PROCESSES ACTING UPON IT

A P Carr
Institute of Oceanographic Sciences
Grossway, Taunton, Somerset

INTRODUCTION

Much of the geological, geomorphological and historical data concerning Chesil Beach and the Fleet lagoon (Fig 1) have been summarised in Carr and Blackley (1974). The purpose of the present Chapter is to briefly state some of the salient conclusions concerning the beach derived from that paper without further discussion, and then to concentrate in slightly more detail on three aspects where more information has become available.

Chesil is essentially a simple, linear, shingle storm beach which, because it links the so-called Isle of Portland with land much further west, is frequently quoted as an example of a tombolo. Although the pebble and cobble feature is joined to the mainland at Abbotsbury and Chiswell, over the intervening 13 km it is backed by the shallow, tidal, Fleet. Opposite the Fleet, Chesil Beach is between 150 and 200 m wide, but it is narrower both adjacent to the cliffs in the west and at its extreme eastern end. The crest is intermittent at the western end but becomes continuous from midway between West Bexington and Abbotsbury, to Chiswell. The general picture is of a progressively increasing ridge height from W to E with the maximum some 14 m above mean sea level. The pebble size above low water mark coarsens in the same direction with the most rapid rate of change at the Chiswell end. Mean long diameter at Chiswell (Section 1) is of the order of 5 cm, falling to 3.5 cm by Section 2 and rather under 2.5 cm by Section 7 (Carr 1969). Offshore the beach drops at a broadly similar gradient to that of the seaward face above low water mark before shelving gradually to about -18 m some 270 m offshore of Wyke Regis and -11 m at a similar distance off West Bexington.

On the basis of records extending over a 2 year period Hardcastle and King (1972) showed that the most frequent wave period was between 10.00 and 10.50 seconds and that 50 per cent of the significant waves (H_s) exceeded 0.26 m at Wyke and 0.23 m at West Bexington. At the latter site 2.7 per cent exceeded 2m, with maximum wave height (H_{max}) calculated as approximately 8 m at some time during the observation period.

SOME FIRMLY BASED VIEWS

Although argument remains as to other aspects of investigation and to detail, research prior to 1974 indicates that:

(a) The western limit of the beach is arbitrary, depending upon the criteria used to define it (eg consistency in the longshore size grading of the beach material or the continuity of the crest line). It has been drawn variously at Abbotsbury, West Bexington (on the basis of longshore sediment size grading), Burton Cliff, and West Bay, and may be changing with time. Thus, as the beach advances very gradually towards its hinterland the various segments between Abbotsbury and West Bay become more isolated one to another and to the main stretch of Chesil Beach further E. The evidence indicates that there have been various potential sources of material, including fluvial as well as marine deposits, and the relative significance of these sources is likely to have varied with time over the long-term. Although the bulk of the material, some 98 per cent, is chert and flint which could have been derived from a number of primary (and secondary) sources the diagnostic rocks, eg Triassic quartzites, are all derived from the SW. In general, there appears to be little appropriate material now available to nourish the beach from offshore.

Borehole samples show that pebbles become more angular with depth and at these lower levels they are then derived from more local, less resistant, geological strata. This implies that attrition is of some importance as a cause of loss of volume of the beach, at any rate in the long-term. The boreholes also indicate that the massive pebble and cobble deposits are concentrated in the exposed, ie sub-aerial, part of Chesil Beach. Although shingle is present below low water mark it is as limited, discontinuous, horizons. (This explains why estimates for shingle volume range between about 25 and 100 million tonnes; the volume of deposits below mean sea level is not adequately known from existing borehole coverage.)

(b) There is evidence to suggest that there have been various changes in the crest height of Chesil Beach over the last 300-400 years and that at one time the crest may have been lower over most of the length between Abbotsbury and Portland. Although the total volume of beach material appeared to change very little between Sir John Coode's survey of 1852 and one in 1968-9 the crest height between Abbotsbury and Wyke Regis showed a substantial increase. This was of the order of 2 m at Langton Herring. Between Langton Herring and E of Wyke Regis there was a rise, typically of 1.5 m, but near Chiswell a drop of 0.5 m, reaching an extreme fall of 3.5 m at one point, was recorded. New data is available on this aspect and is discussed below.

(c) There has been considerable disagreement about the nature and cause of longshore grading of beach pebbles and cobbles. However, recent work at Chesil confirms that, providing wave energy is high enough to move coarse material, the largest fraction on the exposed beach will move faster. Longshore transport is also dependent upon the angle of wave approach relative to the shoreline.

Grading alongshore is restricted to the zone above low water mark. It is not true that the direction of grading is reversed below low water; rather that there is no grading there (Neate, 1967).

In tracer experiments near Wyke Regis, approximately Section 4 in Figure 1, longshore movement was predominantly towards the SE, ie in the direction of coarsening of particle size of the natural beach material, although coarsening of tracer pebbles towards the NW was recorded at one time. At Portland, where waves approach approximately normal to the beach, lateral transport was much more random in its nature (Carr, 1971).

RECENT DATA ON BEACH PROCESSES

Longshore transport:

Some experiments on longshore transport of pebbles have also been undertaken along the length of beach between West Bexington and West Bay. In March 1973 the (then) Unit of Coastal Sedimentation, now part of the Institute of Oceanographic Sciences, carried out trials at Freshwater Beach (approximately 1 km SE of Burton Bradstock in Figure 1). These proved inconclusive.

Jolliffe (1979) describes qualitative experiments extending over 18 months using simulated pebbles incorporating fluorescent particles at West Bay. The results suggest that while labelled material travels from E to W, ie the opposite direction to that shown as the general trend in the Wyke Regis area, it does not move in the reverse direction. The Hydraulics Research Station (1969; 1979) also expressed this view in part because shingle extended further seaward along the E jetty of the West Bay harbour approach than along the W jetty. It had been formulated in the 1955 and 1966 Public Inquiries.

The data from investigations at Wyke Regis, Portland and West Bay thus give totally different results. It is suggested here that the Portland ones are a fair representation of the processes occurring but the Wyke results may be slightly biased by the grades of pebbles and cobbles employed. Jolliffe's West Bay tracer programme may have been complicated by the unrepresentativeness of the labelled material; the lack of beach material to the W of the jetties; the tendency of pebbles to infill extraction sites, and the localised hydraulic conditions at the harbour entrance. However, if the evidence provided by longshore grading of the indigenous beach material is accepted then the

Freshwater and West Bay locations are outside the limits of the present-day Chesil Beach sediment transport system. This is the conclusion that would also be drawn from the suite of tracer experiments if taken at their face value.

Changes in the height of the beach crest:

It has been observed above that there were variations in the crest height of Chesil Beach between 1852 and 1968-9. Nevertheless data suggest that, apart from the uneasy junction between the rigid sea wall at Chiswell and the flexible natural defence of Chesil Beach itself, the beach crest remained remarkably stable for a long period prior to the 1978-79 winter. However, in the course of that winter there were two flooding events the second of which, in particular, was accompanied by substantial modification of the beach crest. That in December was attributable to short-period storm waves and the other, in February, due to long-period swell.

during a fairly typical year (1965-66) a series of sections were taken at various times and locations along Chesil Beach. These showed that some of the short-term changes on the seaward face of the beach were of the same order as those which occurred between Coode's surveys of 1852 and that date. While during 1965-66 it was possible for the swash from waves to reach the beach crest it did so without any residual energy and the crest-line remained virtually unaltered. This situation appears to be quite common, thus wrack is deposited at or near the crest on perhaps one occasion in most years. Nevertheless, as Figure (2) shows various other surveys confirm that the crest-line itself in the apparently most susceptible area remained unaffected during the whole period between October 1955 and September 1978. Throughout this time even detailed topographic forms were retained except adjacent to the sea wall junction. Figure (3) comprises a number of cross-sections surveyed in 1965 and 1977. Apart from small changes at the crest on Section 6 the only real differences relate to the seaward slope. Nevertheless, as indicated above, substantial changes have taken place over the longer term. In their 1972 paper the present writer and Ray Gleason found difficulty in explaining this phenomenon although it helped give credence to early 19th century reports that the beach used to be over-topped more frequently. A comparison of the 1968/9 profile and associated data with that of March 1979 shows that the single winter 1978/9 was capable of producing the same order of change at the SE end of Chesil Beach as that indicated between 1852 and 1968/9. Thus at one location there was a maximum fall of 2.7 m in crest height between September 1978 and March 1979, making a total lowering of 3.4 m between 1852 and 1979. Coupled with the known stability of the crest between 1955 and September 1978 it suggests that one event would be enough to produce the scale of change observed over the period 1852 to 1968/9. Such an event appears to have occurred in 1904 under similar long period swell conditions to those recorded on

13 February 1979. In both instances there was no local storm but a depression in mid North Atlantic travelling at such a speed that it generated high waves of unusually long period and large wavelength. These were directed up the English Channel and, at least in the case of February 1979, coincided with spring tides and a relatively large surge.

A possible mechanism to account for these height changes is that where a typically large swell wave arrives at right angles to the beach, the crest is overtopped, lowered, and pushed inshore (ie towards Portland Harbour). Further W, towards Abbotsbury, swell would arrive more obliquely so that instead of moving pebbles from low water mark, over the crest, and down the backslope the material would simply be transferred from the face to the crest by which time the wave energy became expended. In the course of this operation the crest would become higher than before and there would be some net longshore transport of pebbles towards the E.

Between the 1850's data of the Admiralty and Sir John Coode, and that of 1968/9, Carr and Gleason could only find one stretch of the beach where landward recession, of some 17 m, was greater than the possible plotting errors for the scales of the respective surveys. This was close to the narrowest beach width opposite Portland Harbour and roughly coincides with the site of Coode's Sections 6 and 7 shown in Figures (1) and (2). Some of the recession there can be attributed to the relatively frequent storm waves. These had already resulted in the restoration of a near-natural backslope to Chesil Beach between the laying of a water main in 1942 and the 1978/9 winter. Nevertheless the localised retreat of the crest SE of this location as far as Chiswell during the February 1979 event was of the same magnitude as the long-term recession opposite Portland Harbour. It is interesting, too, to note the way in which only certain parts of the crest were modified during 1979 as shown in Figure (2). These presumably coincide with the main focus of the waves for that storm. Elsewhere even under the extreme conditions prevailing on 13 February, the net change to the crest line remained minimal. Thus different stretches of the beach respond preferentially to different events.

Attempts have been made to assess the frequency of events such as that of February 1979 using oceanographic data, and the results have given a return period of between 50 and 70 years. However, this event was due to a high swell of quite exceptionally long period (nearly 20 seconds), combined with a meteorological surge of over 0.5 m, and spring tides. It is not certain what other combinations of conditions might produce similar results, so the frequency estimate has to be regarded as subject to considerable uncertainty. The historical data base is inadequate since the only unequivocal records of such events are for those of 1904 and 1979.

In the geological column it is frequently the atypical event which is recorded. More normally, erosion and accretion tend to cancel each other out. The situation is more acute along much of the British coastline where present-day conditions appear to be biased towards long-term net erosion. Thus a major occurrence such as the increase in crest height along much of Chesil Beach between 1852 and 1968/9 is of special interest. So, too, is the dramatic erosion and flooding of the 1978/9 winter. They emphasise the difficulty of applying suitable time scales to site investigations for civil engineering works and the scale of resources, which would need to be devoted to protection against remote, largely unquantifiable, contingencies.

Short-term versus longer term changes in beach volume

Sir John Coode (Coode 1853) calculated that the temporary loss of material from the beach to the zone immediately offshore following a gale in February 1852 was 3.82 M tonnes. This compares with an apparent loss of 3.05 M tonnes, between the 1965 and 1977 surveys. This drawdown represents a substantial proportion of the beach above mean sea level and appreciably more of that in front of the beach rest.

'Pebble-picking' of selected grades of beach material took place in the Chiswell area from at least the late 1940's until 1973. Although quantities removed were relatively small, typically 350 tonnes per year, they are likely to have had a marginal effect on the stability of the beach there as well as an influence on the local longshore beach grading. However, by far the greater extraction of pebbles has occurred from W of Abbotsbury to as far as West Bay, Bridport. Records show (Jolliffe 1979; Carr 1980) that between the mid-1930's and 1977 some 1.1 M tonnes were known to have been extracted for commercial purposes. If we take the quantity of pebbles and cobbles in Chesil Beach as 50 M tonnes then the losses due to human agency since the mid-1930's are somewhat over 2 per cent taking the beach as a whole; the proportion would be far greater if the western portion alone were considered. No-one knows how this compares with the natural rate of attrition of the pebbles and cobbles which comprise Chesil Beach.

ACKNOWLEDGEMENTS

I would like to thank Dorset County Council, Nature Conservancy Council and Weymouth and Portland Borough Council for the use of data incorporated in Figures 2 and 3.

Note: Comprehensive references to Chesil Beach are given in Carr and Blackley (1974). Those specifically referred to in the present Chapter are incorporated in the consolidated list at the rear of the volume. So, too, are a few additional published references located since 1974.

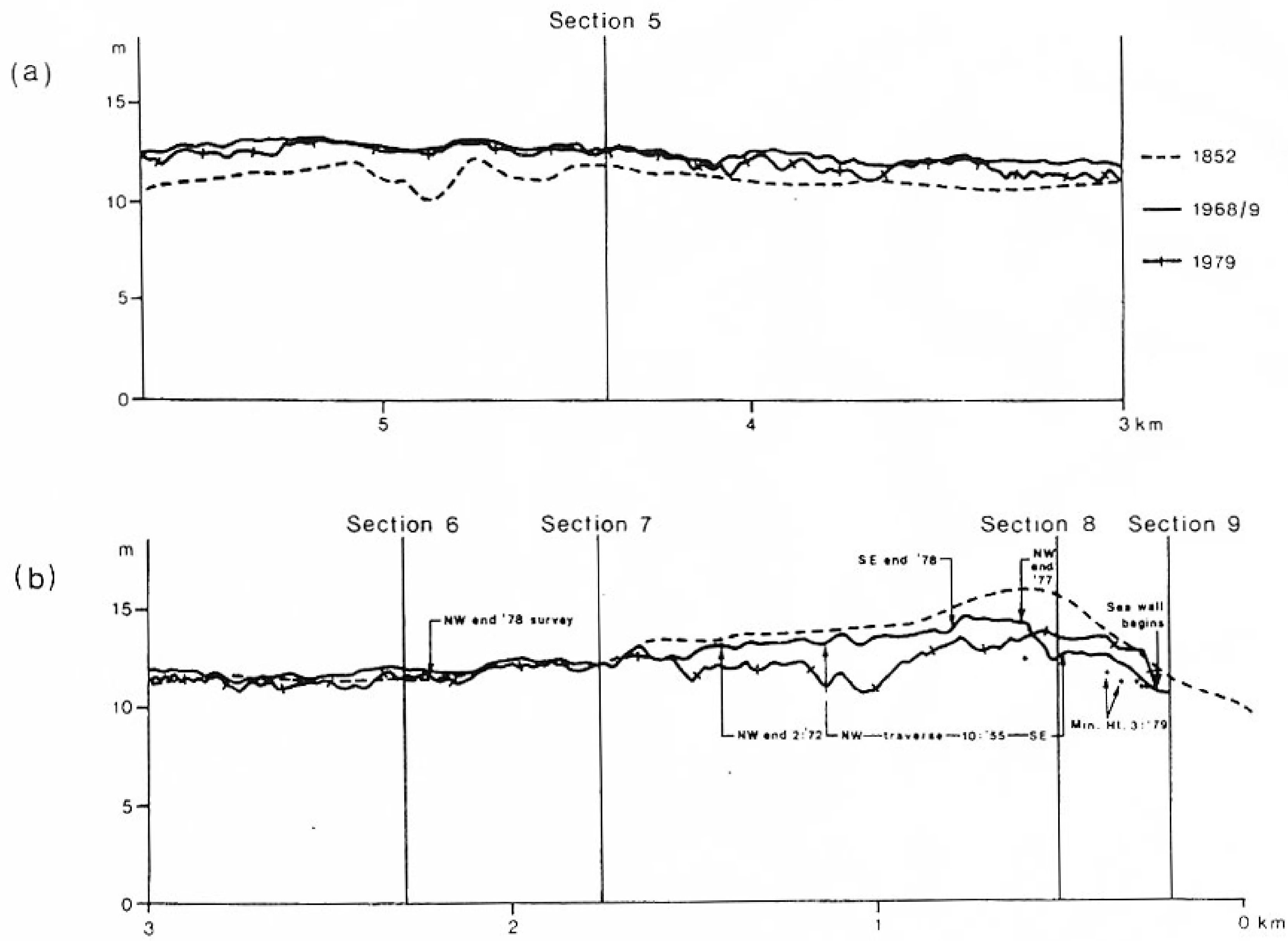
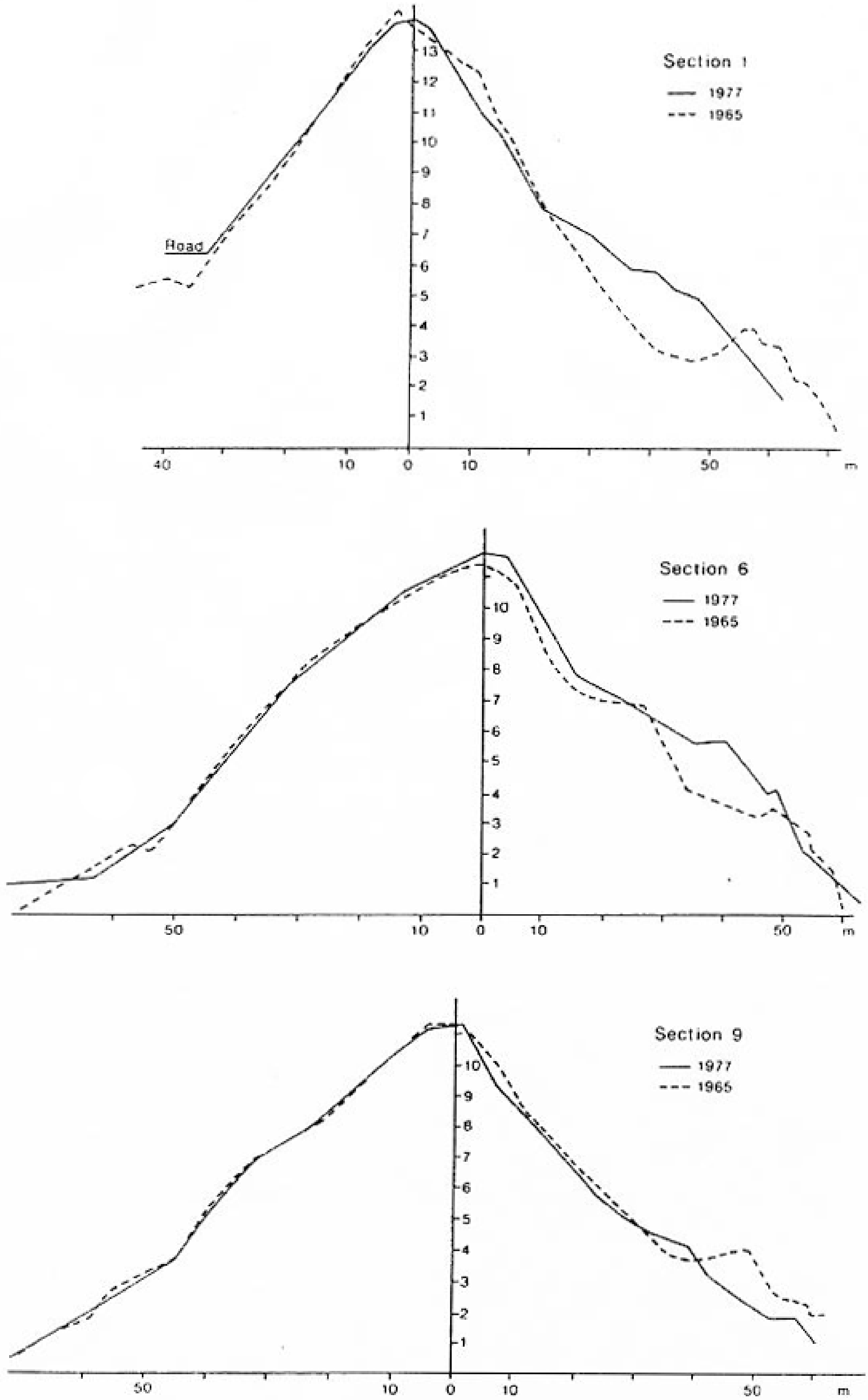

Section 5
(a)
m
15
10
5
0
5
4
3 km
1852
1968/9
1979
Section 6
Section 7
Section 8
Section 9
(b)
m
15
10
5
0
3
2
1
0 km
NW end '78 survey
SE end '78
NW end '77
Sea wall begins
NW end 2:'72
NW—traverse—10:'55—SE
Min. Ht. 3:'79

Fig 2

Fig 3


Section 1
1977
1965
Road
1 2 3 4 5 6 7 8 9 10 11 12 13
40 10 0 10 50 m
Section 6
1977
1965
1 2 3 4 5 6 7 8 9 10
50 10 0 10 50 m
Section 9
1977
1965
1 2 3 4 5 6 7 8 9 10
50 10 0 10 50 m

THE HYDROLOGY OF THE FLEET

John E Whittaker
Department of Palaeontology
British Museum (Natural History)
Cromwell Road
London
SW7 5BD

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

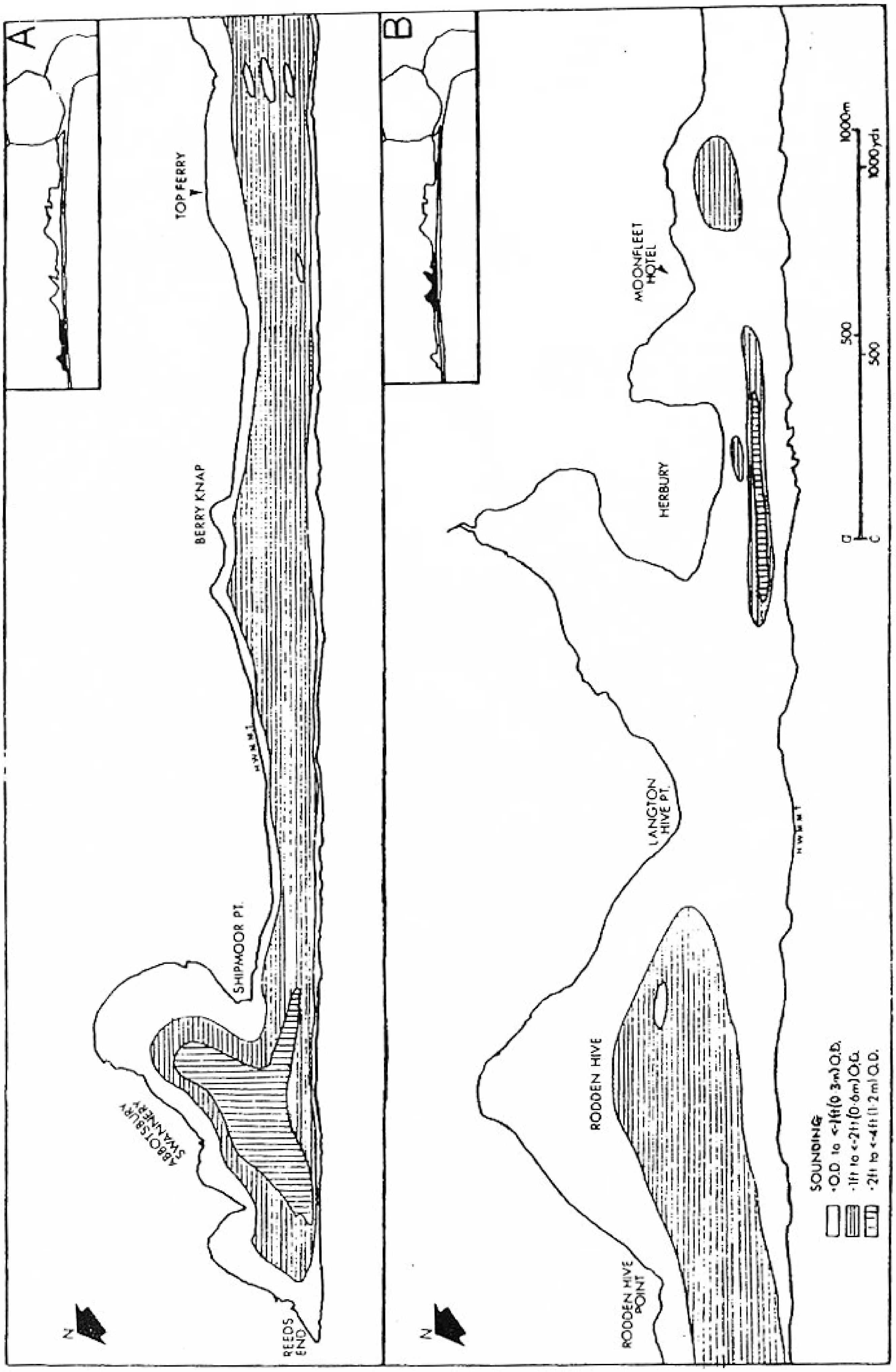
TABLE 1

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

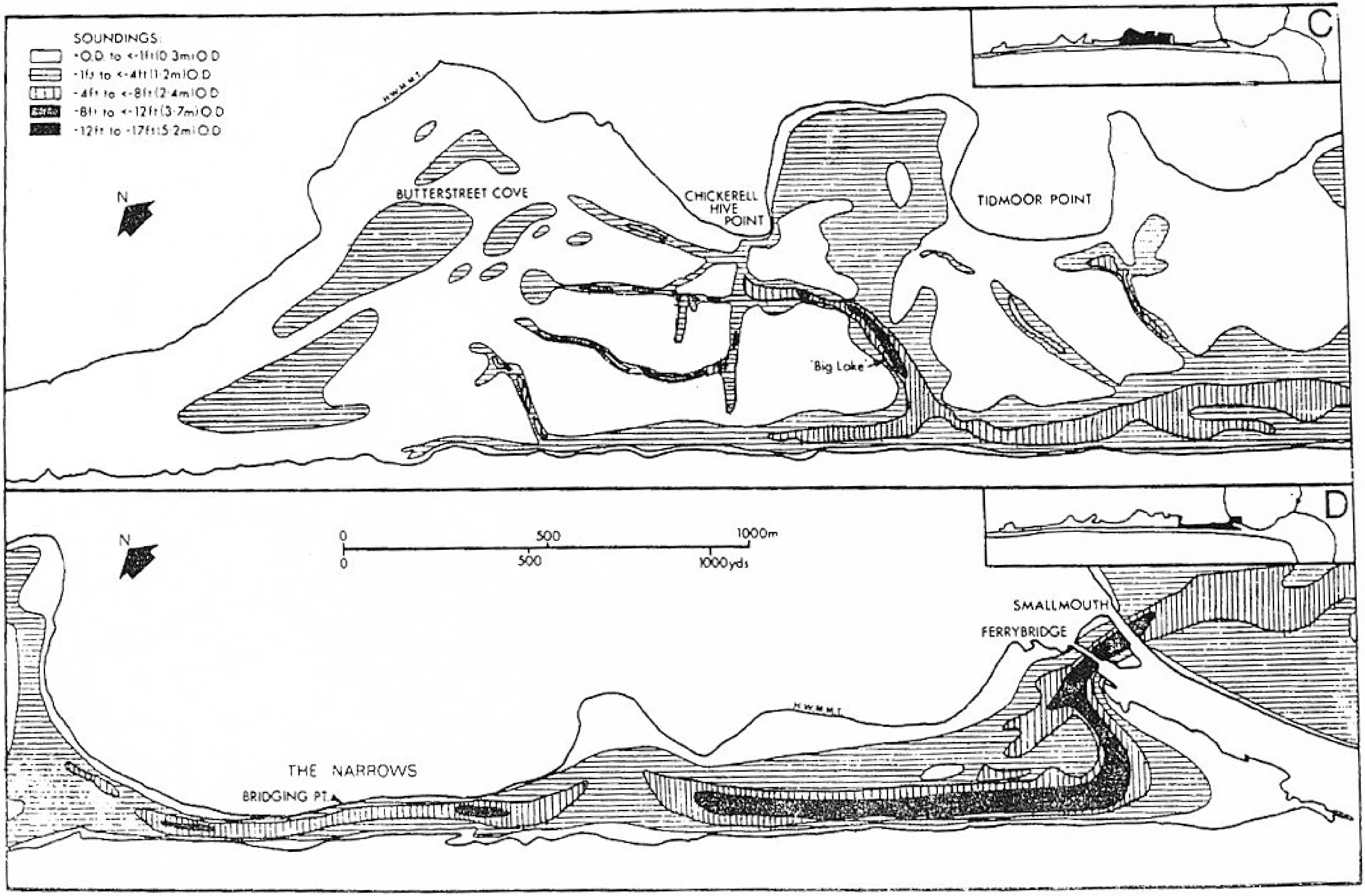
that can be expected under optimum conditions.

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

Fig 4A & B



A
B
TOP FERRY
BERRY KNAP
SHIPMOOR PT.
ABBOTSBURY SWANNERY
REEDS END
H.W.M.T.
N
MOONFLEET HOTEL
HERBURY
LANGTON HIVE PT.
RODDEN HIVE
RODDEN HIVE POINT
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
1000yds


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.

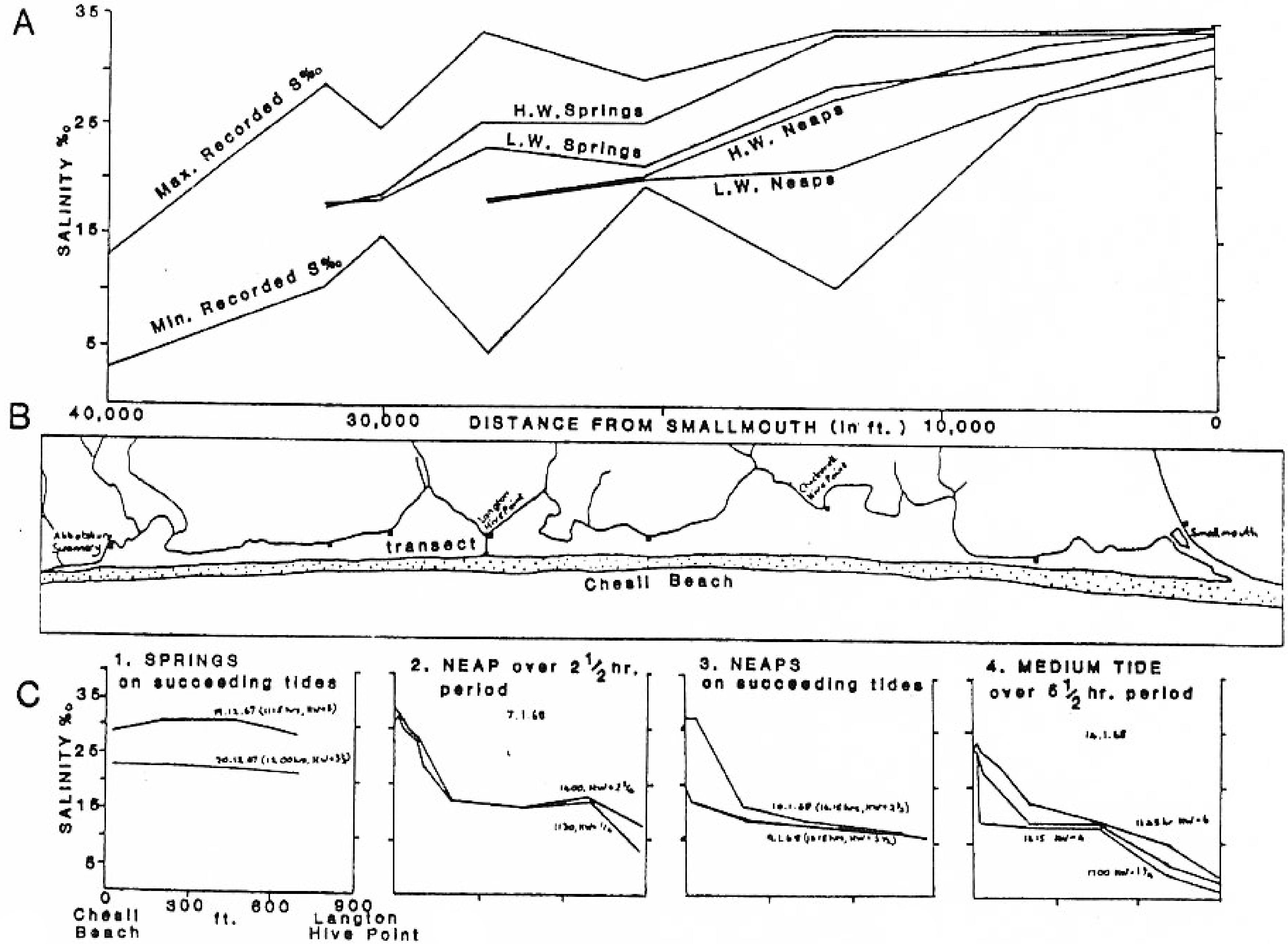

A
B
C
SALINITY ‰
35
25
15
5
Max. Recorded S‰
Min. Recorded S‰
H.W.Springs
L.W. Springs
H.W. Neaps
L.W. Neaps
40,000
30,000
DISTANCE FROM SMALLMOUTH (in ft.)
10,000
0
Abbotsbury Swannery
transect
Langton Hive Point
Smallmouth
Chesil Beach
1. SPRINGS on succeeding tides
2. NEAP over 2 1/2 hr. period
7.1.68
3. NEAPS on succeeding tides
4. MEDIUM TIDE over 6 1/2 hr. period
16.1.68
0
300
600
900
ft.
Chesil Beach
Langton Hive Point

Fig 5

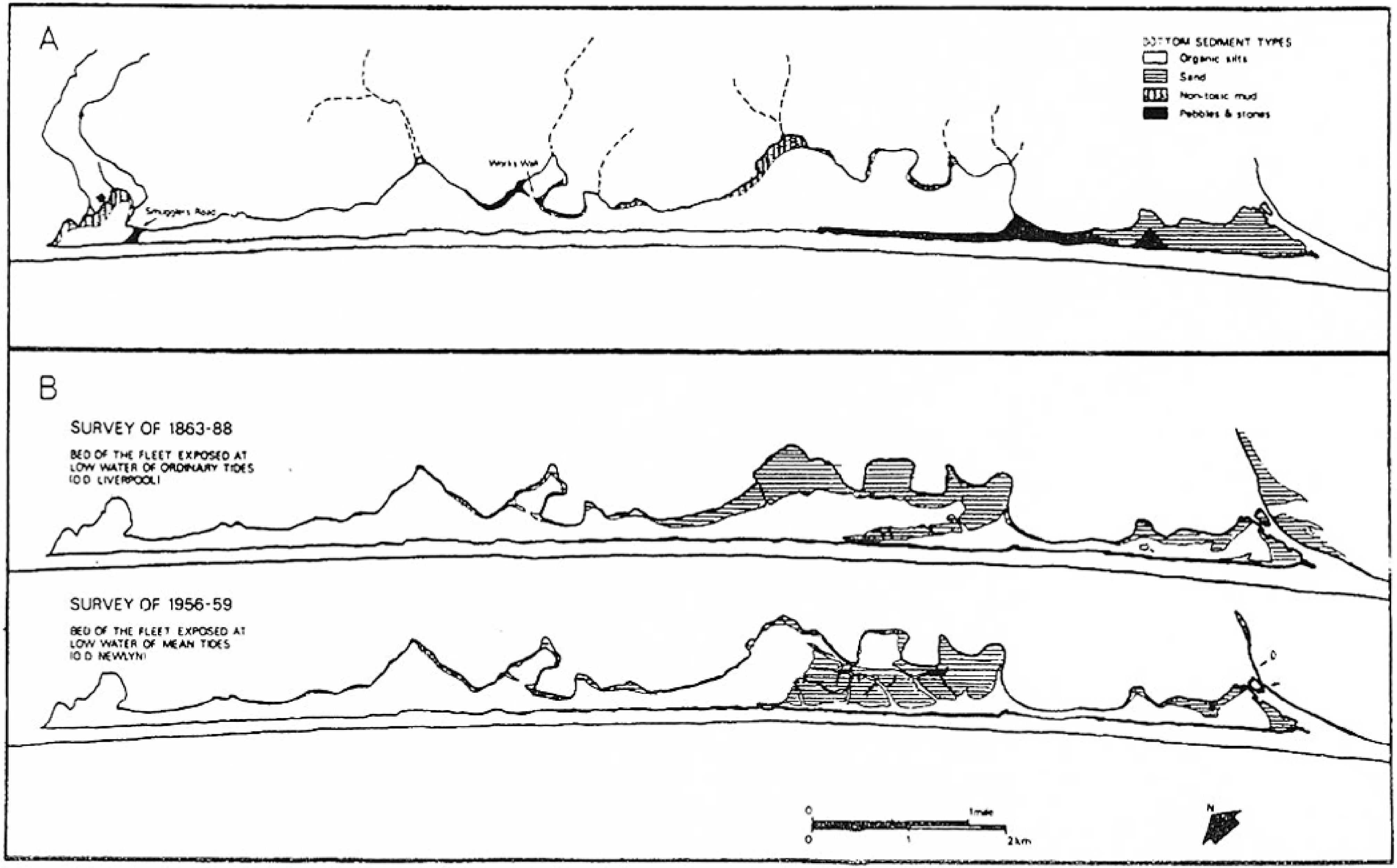

A
BOTTOM SEDIMENT TYPES
Organic silts
Sand
Non-toxic mud
Pebbles & stones
Smugglers Road
B
SURVEY OF 1863-88
BED OF THE FLEET EXPOSED AT
LOW WATER OF ORDINARY TIDES
(O.D. LIVERPOOL)
SURVEY OF 1956-59
BED OF THE FLEET EXPOSED AT
LOW WATER OF MEAN TIDES
(O.D. NEWLYN)
0
1 mile
0
1
2 km
N

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 $10^{o}/oo$; rising to $20^{o}/oo$ 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

Season (Month)	No. of stations	Dissolved oxygen (% saturation) 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

My original survey of the Fleet was greatly facilitated by the cooperation and kindnesses of a large number of Dorset people and former colleagues of the University College of Wales, Aberystwyth; supervision was by Dr R.C. Whatley and funding by the Natural Environmental Research Council. Subsequently, further work has been undertaken thanks to the help given by members of the Fleet Study Group. The cooperation of the Strangways Estates throughout, is much appreciated. Mr G.E. Tuck (Central Electricity Generating Board) gave permission for the release of information from the confidential CEGB Fleet Hydrographic Survey.

TIDES AND WATER LEVELS IN THE FLEET

Dr I S Robinson
Department of Oceanography
The University
Southampton SO9 5NH

INTRODUCTION

Although the Fleet is effectively isolated from the English Channel along the whole of its length by Chesil Beach, it is open to Weymouth Bay and the influence of the open sea through the narrow entrance at Smallmouth. This not only permits the inflow of salt water to produce the marine/brackish character of the Fleet, but enables tidal fluctuations of the sea level to penetrate into the Lagoon, sometimes as far as Abbotsbury. The periodic rise and fall of water level is itself an important factor in the ecology of the Fleet, whilst the association flood and ebb streams are the dominant water motion, contributing to the distribution of saline water, the flushing out of fresh water and pollutants, and the control of sedimentation.

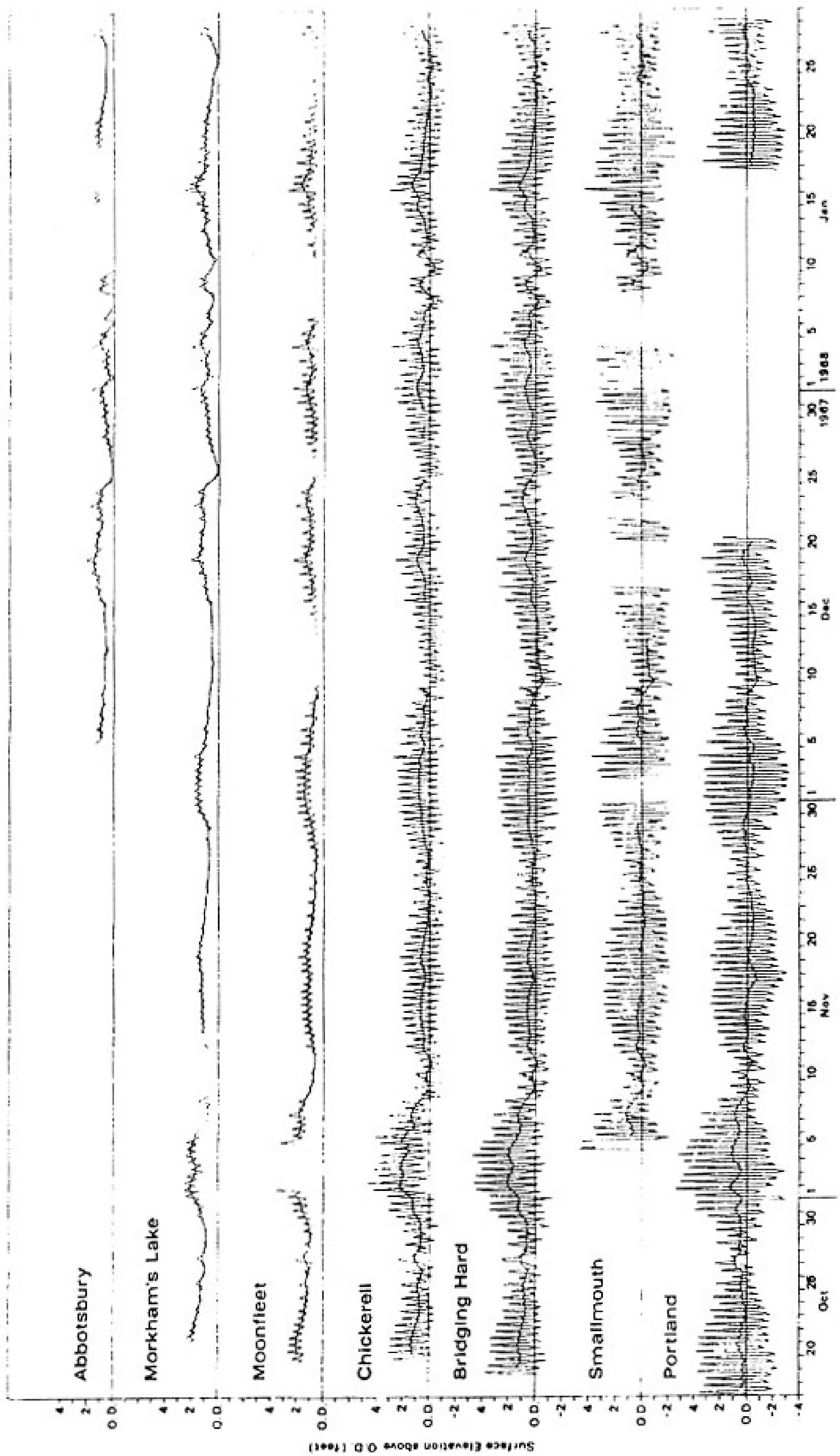
Tidal fluctuations at a typical U.K. coastal location are relatively easy to comprehend, with the dominant period between successive high waters being 12 hours 25 minutes, and the tidal range (the height between a successive high and low water level) fluctuating from large values (Spring tides) to small values (neap tides) and back to large values in a fourteen day cycle. Although the tides never exactly repeat themselves, they are related to the astronomical variables linking the orbits of the moon, earth and sun, and can therefore be predicted with a fair degree of confidence. Weymouth and Portland are no exceptions, and accurate predictions of tidal heights are available for the mouth of the Fleet. However, inside the Fleet itself such regularity of the sea level fluctuations is not immediately apparent, particularly in the West Fleet. Local naturalists, having observed on one occasion the time lag between low tide at Weymouth and the exposure of some mud flats in the Fleet, have applied the same time lag a few days later only to find the flats under two feet of water! Under different circumstances, heavy equipment has been stranded on Chesil Beach because the water level has fallen unexpectedly below the draught of the pontoons used to ferry it across the Narrows. Such first-hand experiences have led some authors (eg Bird 1972) to conclude that the water level fluctuations are due more to wind effects than the regular astronomical tides, and may even be strongly influenced by seepage through Chesil Beach. However, a recent study of several months of tidal data for the Fleet (Robinson, Warren and Longbottom, 1981) has been able to demonstrate that the astronomical tides are the dominant cause of the rise and fall of the Fleet water level, but are distorted by the shallowness of the water.

TIDAL FLUCTUATIONS

In the winter of 1967/68, a thorough hydrographic survey of the Fleet was performed by Messrs G. Wimpey and Co. Ltd. on behalf of the Central Electricity Generating Board. Some years later, the data collected in the survey were made available by the CEGB for scientific analysis (see Whittaker 1980). Amongst the data were tide gauge records collected at Smallmouth, Bridging Camp, Chickerell Hive, Moonfleet Hotel, Morkham's Lake and Abbotsbury (Figure 4). These consist of readings of water height every half hour, for periods of between one and three months, and provide a basis for objective analysis of the tidal regime.

Time series of these tidal data are plotted in figure 7, along with the observed tides at Portland Dockyard. Gaps in the record occur where instruments malfunctioned, and in certain cases this occurred when sea level fell so far below what was expected that the tide gauge "dried out". Plotted in this way, the records show that the tidal fluctuations at Smallmouth, Bridging Hard and Chickerell are very similar to the "normal" record of Portland, for which predictions are available.

Fig 7



Abbotsbury
Morkham's Lake
Moonfleet
Chickerell
Bridging Hard
Smallmouth
Portland
Surface Elevation above O.D. (feet)
Oct
Nov
Dec
1967
1968
Jan

Moonfleet shows tidal fluctuations corresponding to those further east, although the shape of the tidal profile is distorted. Morkham's Lake and Abbotsbury records reveal an intermittent operation of the tide, but when sea level fluctuations of a $12\frac{1}{2}$ hours period do penetrate to the west end of the Fleet, they can be directly related to the tidally driven oscillations entering through Smallmouth. Occasionally there are particular peaks of water level (e.g. 16th/17th January 1968) which appear to stand out from the regular tidal pattern, but in general the astronomical tides appear to be the dominant cause of sea level fluctuations.

The shape of the tide curve for a particular spring tide and a particular neap tide is shown expanded in figures 8a and b. Once again the correlation of the tide from place to place along the Fleet is apparent, but certain features in which the tide curve differs from a normal coastal record demand explanation. Firstly the time of high water becomes later the further westward the tide gauge is located. The time of low water becomes later still, and the delay times also differ between spring and neap conditions. Table 1 summarises the delay times of high and low water after high and low water at Portland, and insofar as these two days are typical of spring and neap conditions, table 1 can be used as an approximate guide to predict times of high and low water relative to Portland predictions. The height cannot be so easily predicted.

The shape of the tidal curve also changes markedly from the profile at Smallmouth, where a double low water occurs, to Moonfleet and the West Fleet where a sawtooth shape is a more appropriate description, the double low water having disappeared. The tidal range also decreases rapidly on moving North Westward to the head of the Fleet. Interestingly enough, these features are to be found occurring over a much larger length scale in estuaries such as the St. Lawrence in Canada, and the Severn in the U.K. An explanation is demanded as to why they should occur over such a short distance in the Fleet.

A final feature of figure 7 which must be explained is the appearance of fluctuations of sea level of periods larger than a day. These are shown by the curve drawn through the centre of the tidal curve. This is calculated from a 25 hour running mean and effectively represents the height of mean water level on a given day. It is seen to vary particularly over a fortnightly cycle, and to be more variable at Chickerell, Moonfleet and beyond, than closer to the mouth. There are also some occasional fluctuations with period about 2-3 days which occur at all the stations (e.g. 10-12 January 1968). These longer period fluctuations are in fact the most important feature of the sea level at Morkham's Lake and Abbotsbury. Because the semidiel tide is superimposed on them, it is not sufficient to be able to predict the time and amplitude of the semidiel tide, but a knowledge of the mean level is also required to determine the actual water depth and hence whether certain mud flats will be exposed or certain channels navigable. It is this combination of semidiel and long period fluctuations which has probably confused the casual observer into believing the water level fluctuations are not tidally regular. The observer tends to notice such things as exposure of mud-flats. It is possible to draw a straight line through the record at Moonfleet or Morkham's Lake, corresponding to a particular height of mudflat, and to note that for periods of several days at a time it may be completely exposed or completely covered, whilst for other periods it will be exposed twice a day in a typical tidal manner.

TIDAL EXPLANATIONS OF SEA LEVEL PHENOMENA IN THE FLEET

It is possible to give explanations of most of the features noted above, in terms of well established theory relating to the propagation of long waves in shallow water. What makes the Fleet so interesting is that these mechanisms should occur in such a short distance, compared with similar features in large estuaries, e.g. the St Lawrence (LeBlond, 1979).

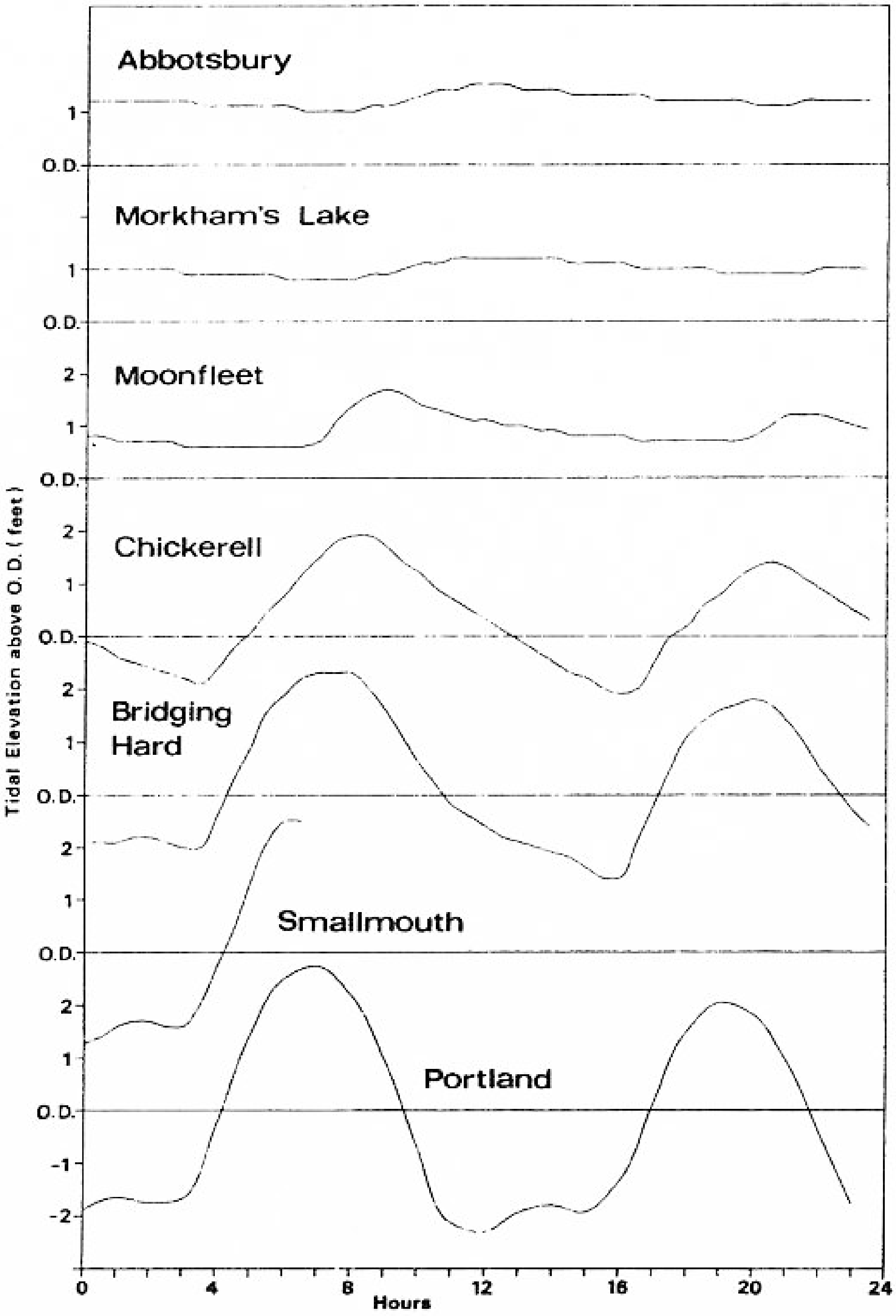
TABLE 1

Phase lag of the tide relative to Smallmouth

Location	Spring tide (17-12-67)		Neap tide (25-11-67)	
	High water	Low water	High water	Low water
Bridging Hard	30 min.	3 h 40 min.*	15 min.	3 h 30 min.* (15 min.)
Chickerell Hive	1 h 20 min.	4 h 5 min.*	1 h 5 min.	4 h 15 min.* (1 h)
Moonfleet	2 h	5 h	2 h 20 min.	-
Morkham's Lake	4 h	7 h	-	-
Abbotsbury	5 h 15 min.	8 h	-	-

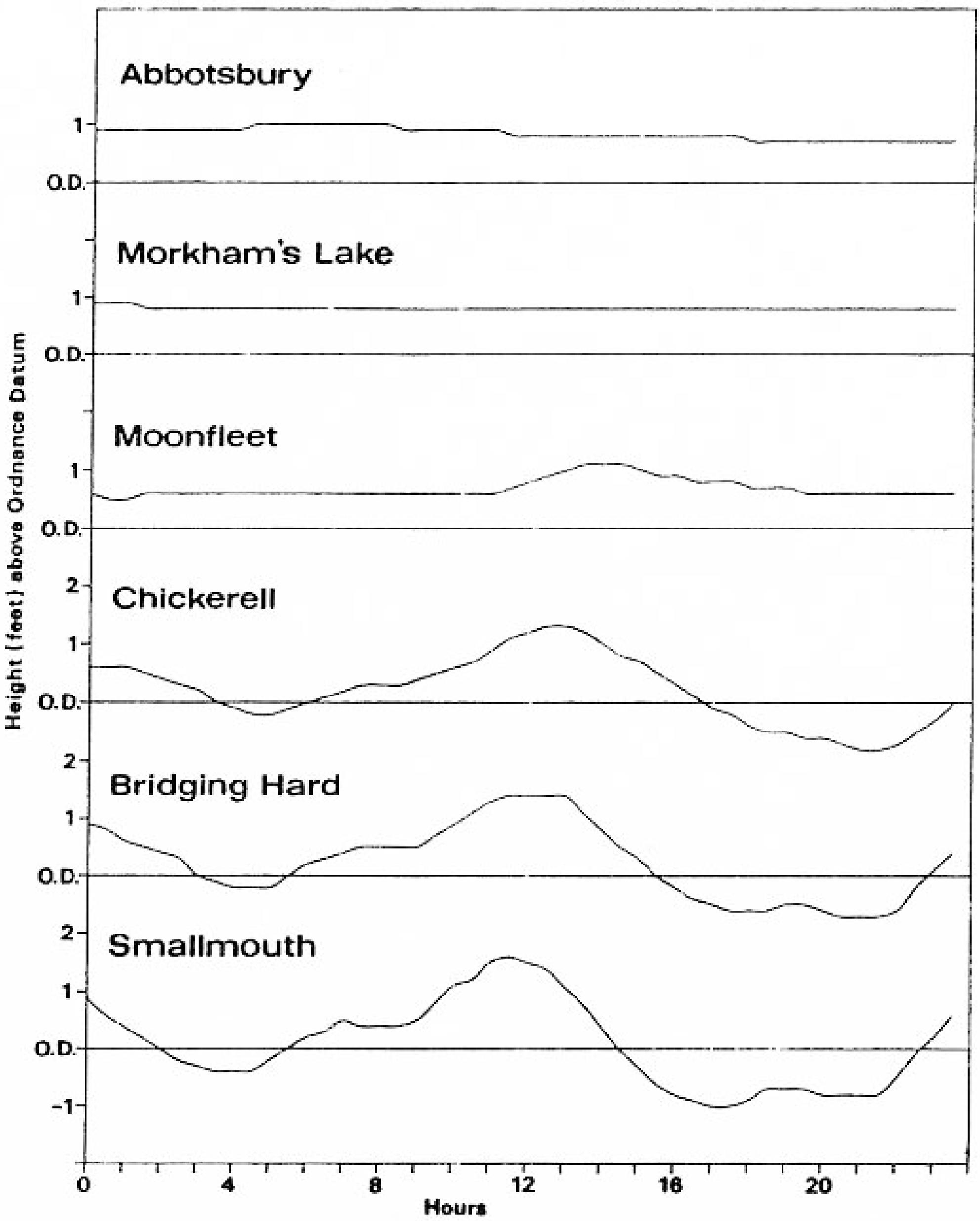
* This the time lag of the second low of the double low water behind the first low at Smallmouth. The bracketed figure is the time lag of the first low when it happens to be lower than the second.

Fig 8(a)



Abbotsbury
Morkham's Lake
Moonfleet
Chickerell
Bridging Hard
Smallmouth
Portland
Tidal Elevation above O.D. (feet)
O.D.
Hours
0
4
8
12
16
20
24

Fig 8(b)



Abbotsbury
Morkham's Lake
Moonfleet
Chickerell
Bridging Hard
Smallmouth
Height (feet) above Ordnance Datum
O.D.
1
2
-1
0
4
8
12
16
20
Hours

Travel time of high and low water

Tidal propagation in the Fleet behaves like a long gravity wave propagating from the mouth, where it is forced by the tides of the adjacent English Channel. In an estuary as short as the Fleet the time for high tide to travel to the head would normally be no more than a few minutes, and the sea level would rise and fall in unison throughout the estuary. The propagation speed of a long gravity wave is proportional to the square root of the water depth. Because the Fleet is so shallow, the propagation speed is slow, and it takes hours rather than minutes to propagate through the whole length. The speed is further slowed by the capacitative effect of mud flats and shallow areas. The wave tends to propagate along the deeper channels, where the flood flows are strongest, but the water flowing through the channels is required to maintain a rising water level over a much larger surface area, and this restricts the speed at which the rise of high tide can propagate further into the lagoon. This is particularly true of Littlesea, off Chickerell Hive, where there are a few narrow deep channels through a wide area of mud flats. Because the tidal range is comparable in magnitude to the water depths, there is a considerable difference between the instantaneous water depth at high and low tide. The wave propagation speed at high tide is therefore greater than at low tide. Consequently high tide travels faster than low tide, as shown in figures 8 and table 1. The difference between spring and neap travel times of high and low water may also be explained in terms of the different water depths through which the tidal wave must propagate.

Tidal amplitude attenuation and intermittency

It is perhaps surprising at first sight to note how the tidal range decays rapidly from more than a metre at Smallmouth to a few centimetres at Moonfleet and beyond. This behaviour is in fact entirely consistent with what happens to a long gravity wave which is attenuated due to friction between the water flow associated with the wave and the sea bed. The effect of the sea bed friction on the tidal flow is inversely proportional to the water depth, and hence in such a shallow lagoon frictional drag rapidly extracts the energy from the tidal wave, in contrast to a deep estuary (eg Southampton Water has a similar tidal range at the mouth, and is of a similar length, but the tidal range is not noticeably attenuated along its length). Because the frictional dissipation is great, the wave barely reaches the end, and there is no reflection from the head as happens in deeper estuaries. Thus the wave is purely progressive, with no standing component, which leads to the time lag of high water already mentioned.

It is evident in figure 7 that the mean level in the West Fleet is lower during neap tides than spring, and so the frictional effect is particularly strong at neap tides, to the extent that for several days at a time the tide at Abbotsbury and Morkham's Lake is not measurable. This accounts for the intermittent nature of the tidal oscillations in the West Fleet; only when the mean level is high enough in the narrow section off Moonfleet Hotel can the tide penetrate to Abbotsbury.

Distortion of the tidal curve

Neither at the mouth nor further inside the Fleet does the tidal profile over $12\frac{1}{2}$ hours resemble a normal sinusoidal profile typical of tides in the open ocean. The profile at the mouth is the same as in Weymouth Bay and is a feature of tides along the central southern coast of England. It occurs because the semidiel tide is relatively weak, this being a nodal area for the semidiel tidal oscillation of the whole English Channel, whilst the quarter and sixth diel tides are relatively strong, being generated in the central English Channel by the strong tidal currents that occur there. Thus the double high water occurs at Southampton, where the low of the quarter diel tide coincides with the high of the semidiel whilst at Weymouth the high of the quarter diel coincides with the low of the semidiel tide, to produce the double low water. The tide at Smallmouth may be thought of as the sum of the basic semidiel oscillation and higher harmonics. As the wave propagates into the Fleet, friction appears to attenuate the higher harmonics more rapidly, and the double low water has normally disappeared by Chickerell Hive.

At the same time, because high tide travels faster than low tide, the symmetry of the semidiurnal tide is distorted to produce the saw tooth shape of a rapid rise of the tide and long slow fall, which is most marked at Moonfleet. Linked to this, the flood streams are very strong and short lived, whilst the ebb is long and gentle. Another way of understanding what is happening is to consider the analogy of a wave running up a beach. A steep wall of water floods rapidly into the beach, spends itself and then slowly drains away. In the case of the West Fleet, Littlesea and the narrows by Moonfleet tend to act as a choke, allowing water to flood in with the high tide, but restricting its outflow once the water level starts to fall.

Fortnightly fluctuations of mean level

This choking effect also leads to the mean level being higher in the West Fleet than the East Fleet. Because friction acts more strongly on the ebb than the flood, the mean sea level slopes upwards to the north west to balance the mean frictional forces. Now at Spring tide the tidal streams are much more rapid and more energy is dissipated by friction, so that the mean surface slope becomes greater at Spring tide than neap tide. Thus the mean water level in the West Fleet is higher at Spring than at neap tide, and the mean level oscillates over a fortnightly cycle. Hence the fortnightly fluctuation of sea level is attributable to the semidiel tidal friction mechanism, operating in such shallow water.

NON-TIDAL EXPLANATIONS OF SEA LEVEL FLUCTUATIONS

The strongest, and the most regular features of the water level fluctuations in the Fleet can be accounted for by well established tidal theory. There remain two features which can be explained by meteorological forcing. The three to four day fluctuations of the tidal mean level are seen to occur in similar strength at all stations, including the mouth, and Portland itself when the record was available. It is concluded that these were storm surges (sea level fluctuations in addition to the astronomically driven tide) generated by atmospheric pressure and wind stresses in the whole of the English Channel, and not locally produced in the Fleet itself, nor even necessarily related to weather conditions in the immediately surrounding area of the English Channel. It is interesting to note that these fairly long period oscillations of a few days appear to penetrate the length of the Fleet without appreciable attenuation - in accordance with long wave propagation theory.

The occasional peaks or troughs of sea level, which appear to be out of line with the normal astronomical tide, are probably due to local wind stresses producing a short lowering or raising of sea level. A numerical model of the tidal dynamics of the Fleet described by Robinson, Warren and Longbottom (1981) indicates that a strong wind blowing along the Fleet could significantly raise or lower the water level, particularly in the West Fleet. However, it is not easy to distinguish between tidal and meteorological effects when they occur over similar time scales, and it is not clear from the record whether these short surges are driven by wind stress inside the Fleet, or are driven by a surge peak or trough in Weymouth Bay.

CONCLUSIONS

It may be concluded that the water level fluctuations in the Fleet are primarily due to the astronomical tide in the English Channel propagating into the Fleet as a long gravity wave. Times of high and low water are fairly predictable, but because of fortnightly modulations of mean level, it is not so easy to predict absolute water levels. Meteorological effects, mainly mediated through wind action in the English Channel, do cause a deviation from the regular tidal pattern, but their influence is not as dominant as casual observation might suggest. Furthermore, all the observed features of the tides can be explained simply by tidal propagation theory, and there is no reason to believe that seepage through Chesil beach contributes to the tidal regime, except of course on catastrophic occasions when the beach has been breached or overtopped by severe storms.

Quite a lot of tidal energy is dissipated in the Fleet, and this must contribute significantly to the stirring and mixing processes, allowing salt to penetrate to Abbotsbury, and to the balance of sedimentation and erosion. The strong tidal streams in parts of the East Fleet, and the fortnightly period of sea level rise and fall in the West Fleet must be important environmental factors in the local ecology. Indeed the maintenance of the existing ecological balance must be dependent on the persistence of the existing tidal regime.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the cooperation of the Central Electricity Generating Board in making available the tidal records for 1967/68. The assistance of Mrs L Warren in processing the data is also acknowledged.

SALINITY STRUCTURE AND TIDAL FLUSHING OF THE FLEET

Dr I S Robinson
Department of Oceanography
The University
Southampton SO9 5NH

INTRODUCTION

The Fleet is truly estuarine in character, ranging in salinity along its length from marine salinities at the mouth to almost fresh water at Abbotsbury from time to time. This is not surprising since although it is connected to the open sea by such a small mouth, it has already been pointed out, by Robinson (ibid) how the tides dominate the water movement in the lagoon. The comparatively large volume of tidal exchanges into and out of the Fleet, particularly at Spring tides, ensure that salt is flushed in and the comparatively small fresh water inflow and land runoff is not sufficient to wash out the salinity. However, it will be shown how the salinity structure varies under different conditions of tide and precipitation. This is important for the ecology of the estuary, and also provides a valuable indicator with which to estimate residence times and flushing rates for different parts of the estuary under different conditions, using a mathematical model tuned to fit the salinity observations.

SALINITY STRUCTURE

Observations of salinity have been made by various workers since 1967. Further details of these are reported by Whittaker (1980) and Robinson (1981). Figure 9 shows all the observed salinities plotted against the distance along the Fleet and indicates the wide variation of conditions which can occur. However, fig.10 selects the profiles typically appropriate to (a) drought, (b) high precipitation and (c) average runoff conditions. In these a pattern emerges with the salt penetrating further towards Abbotsbury as the freshwater input decreases. What is also apparent is that the salinity does not vary linearly with longitudinal distance, but there tends to be a length of about four or five kilometres over which most of the variation occurs. This region of steep salinity gradients moves towards or further away from the mouth as the run off increases or decreases. Under all but the most torrential rainfall conditions, marine salinities penetrate virtually undiluted into Littlesea and are recorded as far as Chickerell Hive. Under drought conditions the marine salinity penetrates beyond Moonfleet, and only drops to about 25‰ at Abbotsbury, whereas with high runoff it has already drooped to 20‰ at Moonfleet and continues falling to around 5‰ at Abbotsbury.

The longitudinal profile also depends on the fortnightly Spring neap tidal cycle as figure 11 clearly shows. These observations were made seven days apart in the summer of 1980, a season of average rainfall. The salinities at either end are not appreciably influenced by the tidal conditions, but the region of steep gradients shifts towards the mouth during neap tide conditions, and fresh water penetrates more noticably towards Littlesea. This clearly illustrates the major part played by tidal exchange in flushing salt water in and fresh water out. As pointed out previously the tidal mean level and hence volume of water in the West Fleet is considerably greater during Spring tides than at Neap tides, and with an increase also of the tidal prism at Spring tides the flushing effect is able to penetrate much further towards Abbotsbury. The Spring-Neap fluctuations and the variation due to rainfall conditions occur over similar timescales, so that it is often difficult to distinguish their separate effects. Thus whilst one expects the West Fleet to become saltier during Spring tides, a spell of heavy rain may in fact decrease the salinity. It has only been possible to present the effects separately in figures 10 and 11 by averaging out the tidal effects in figure 10 and choosing a period of steady precipitation for figure 11.

As well as these longer period fluctuations, the salinities at a point also vary within the $12\frac{1}{2}$ hour tidal cycle. This is principally due to the advection of the longitudinal salinity structure by the tidal oscillations past an observer at a particular station. The amplitudes of salinity oscillation will be greatest where the longitudinal gradient is steepest, for a given tidal oscillation. Salinity is of course at a maximum when the tidal excursion is at its furthest from the mouth, ie at approximately high water. However, at neap tides, the tidal movements are virtually non-existent in the West Fleet, and so even strong salinity gradients there do not give rise to semidiel salinity fluctuations. This is illustrated in figure 12 where the amplitude of semidiel salinity oscillations is plotted against position along the Fleet, for spring and neap tides under high and low rainfall conditions. The Spring tide amplitudes reflect the position of maximum longitudinal salinity gradients in figures 10 and 11 whereas the neap tide oscillations are much smaller in the West Fleet, but much greater in Littlesea and the Narrows when high runoff has pushed the salinity gradients seawards.

There is also a small amount of lateral variation of salinity observed by transect surveys in winter 1967 and summer 1979. The details are reported

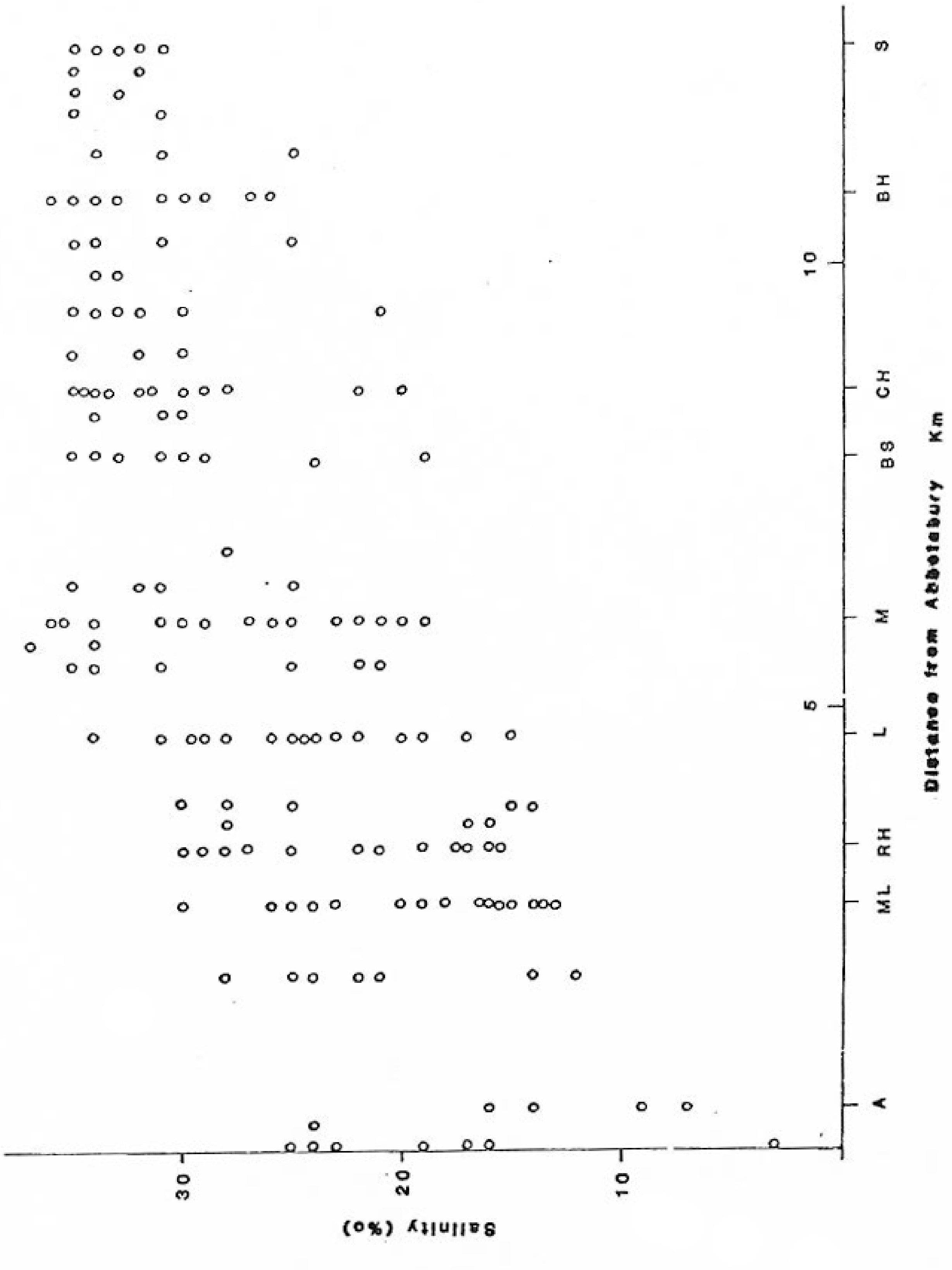
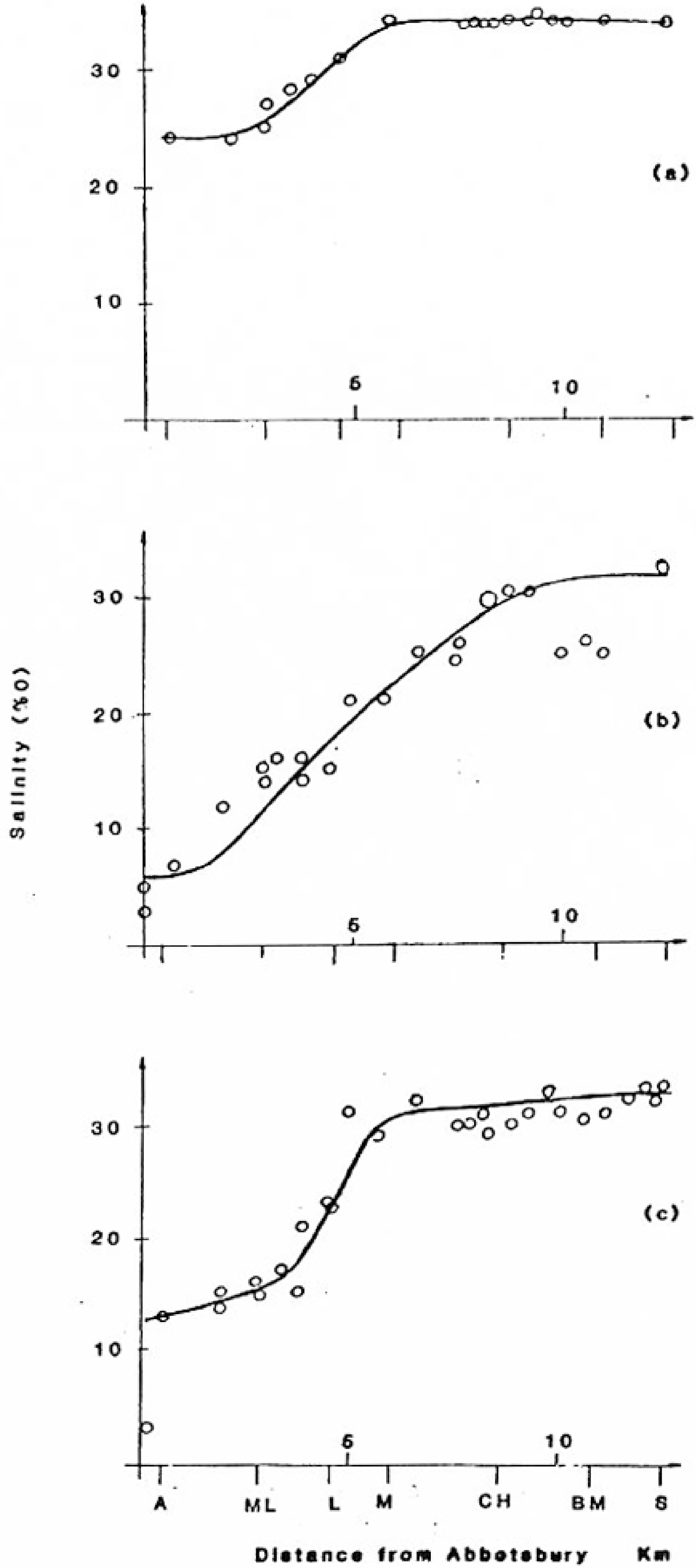
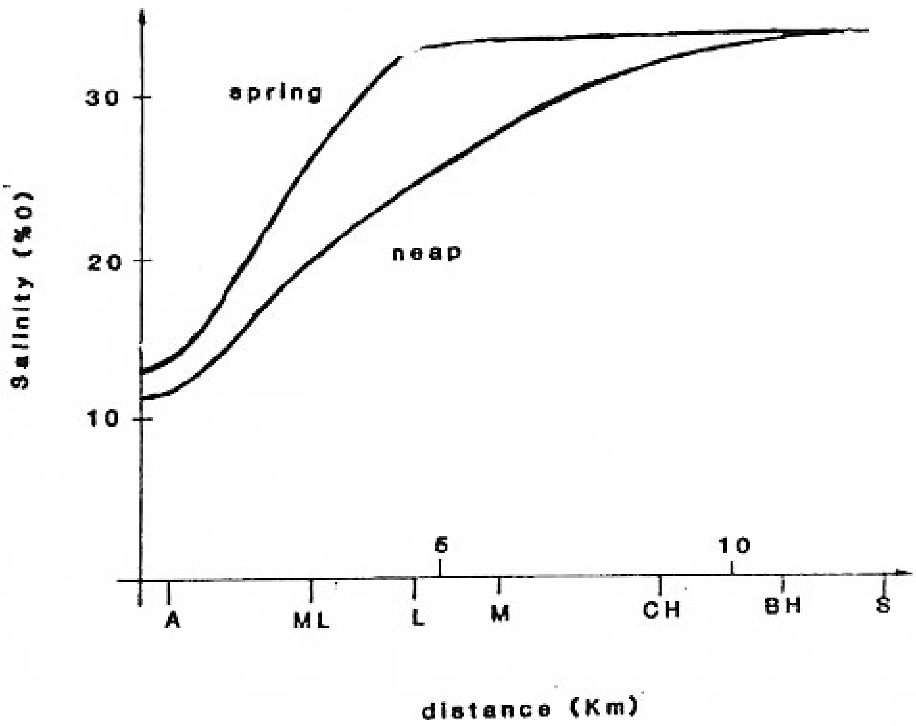

Salinity (%o)
30
20
10
Distance from Abbotsbury Km
A
ML
RH
L
5
M
BS
CH
10
BH
S

Fig 10



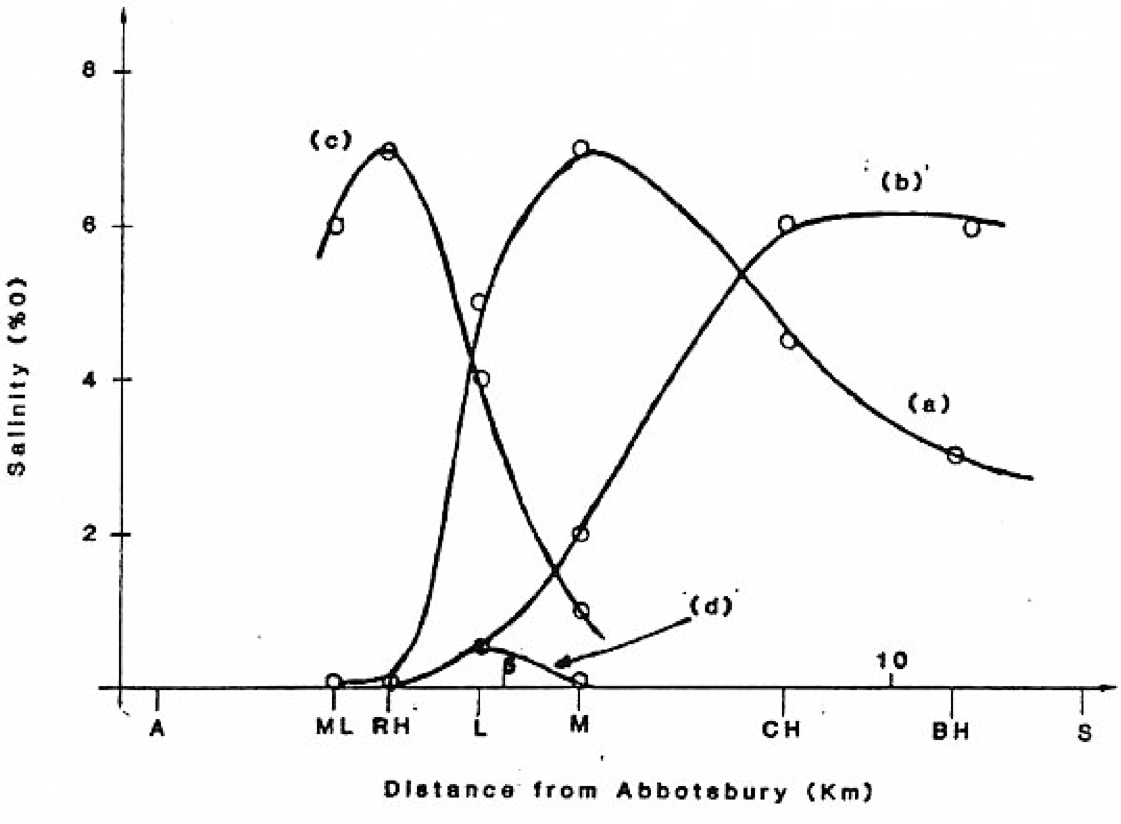
30
20
10
5
10
(a)
30
20
10
5
10
(b)
Salinity (%0)
30
20
10
5
10
(c)
A
ML
L
M
CH
BM
S
Distance from Abbotsbury Km

Fig 11



spring
neap
30
20
10
Salinity (%0)
6
10
A
ML
L
M
CH
BH
S
distance (Km)

Fig 12



8
6
4
2
Salinity (%0)
(c)
(b)
(a)
(d)
10
A
ML
RH
L
M
CH
BH
S
Distance from Abbotsbury (Km)

by Whittaker (1980) and Poulter (1979), but figure 13, showing the salinity at three stations across the Fleet opposite Langton Hive, is typical of other transects.

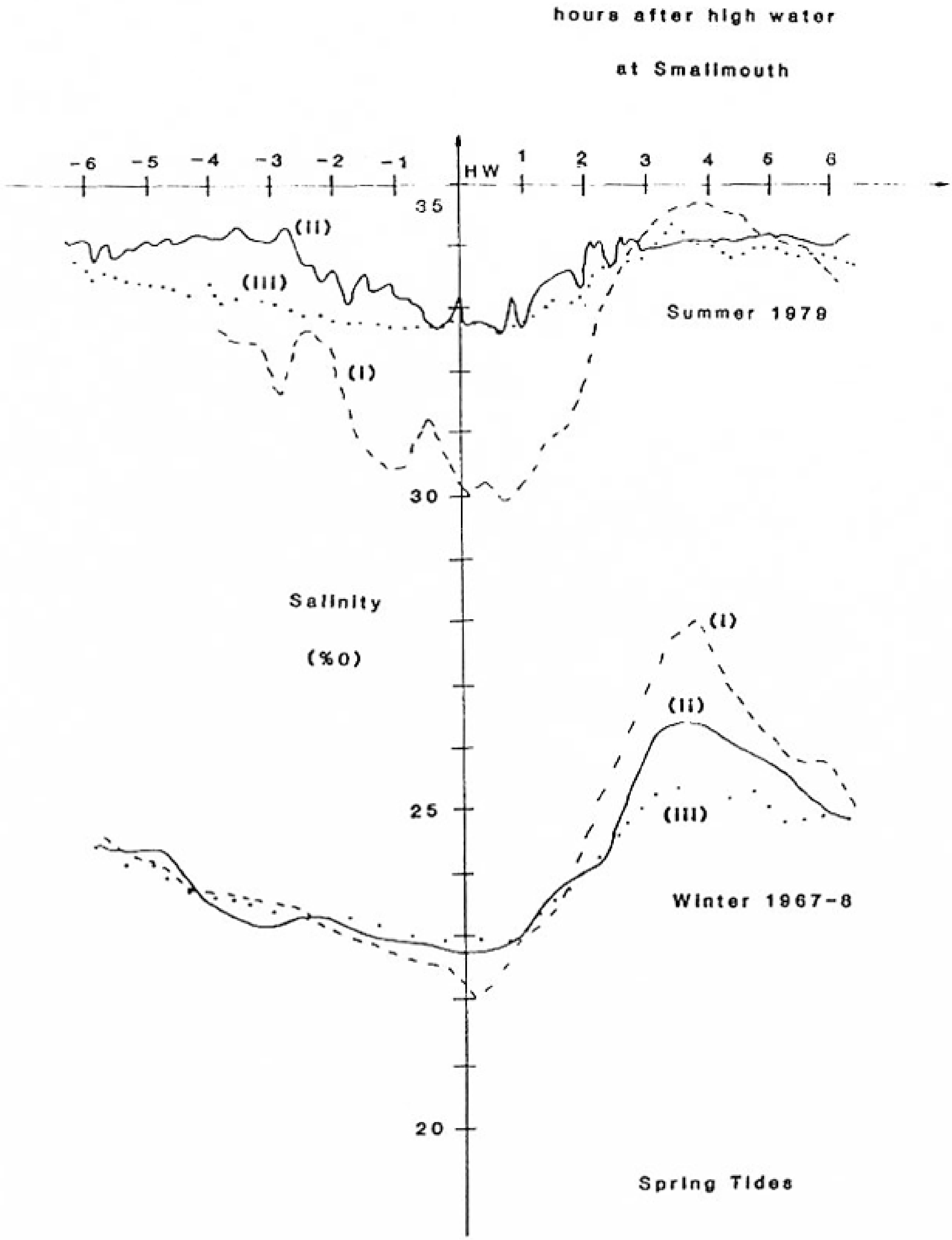
SEEPAGE THROUGH CHESIL BEACH

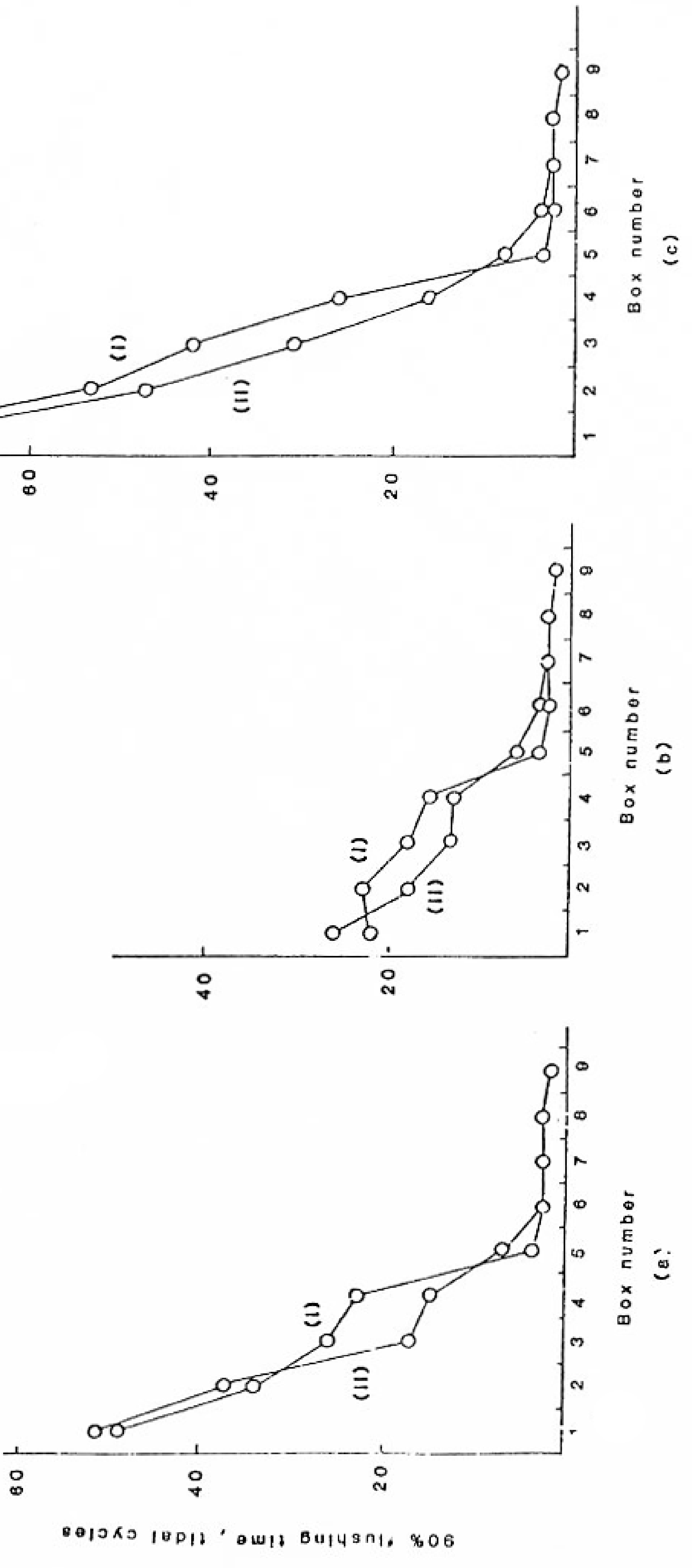
Steepage of sea water through Chesil beach undoubtedly occurs. Indeed at times of high water in West Bay it is possible to see water trickling out of the beach, and in times when the sea level is particularly high due to storm tides and wave set up, the sea water pours through porous passages in the beach at a fairly high level, known locally as "the cans". Some observers in the past have considered that this seepage is a major component of the circulation. Indeed the winter 1967 survey shown in figure 13 indicates an increase in salinity towards the Chesil beach side, and might be considered to confirm that seepage of salt water through the beach is significant for the salinity structure, and hence the circulation. However, apart from the most extreme conditions of storm tides, the volume of water seeping through the beach is probably very small and unimportant to the circulation. Closer inspection of the 1967 data in comparison with summer 1979 records in figure 13 confirms this. The winter survey shows the lateral gradient of salinity increasing towards Chesil beach at high tide only (high tide at Langton occurs between three and four hours after high tide at Smallmouth - (Robinson, ibid). At low water there is a slight gradient in the opposite sense, and this is at the time when the tide is high on the other side of the beach and seepage should be at its strongest. The summer survey shows very little gradient at high water, but a strong decrease of salinity towards Chesil beach at low water, certainly not indicative of seepage occurring. The probable explanation of the lateral variation is that the deepest channel and easiest flow of water is along the Fleet adjacent to the beach. Thus the beach side experiences the greatest tidal fluctuations of salinity as water is advected up and down the Fleet, whilst on the landward side the water is not so readily exchanged longitudinally and the salinity fluctuates less. In the winter, freshwater runoff from the land tends to maintain this side at a lower salinity when high salinity water advects Westward along the beach side at high water. In summer there is little runoff, and the high water temperatures probably lead to evaporation and consequently enhanced salinities on the landward side. Thus lateral gradients of salinity are probably due to land runoff, and the trapping effect of embayments and shallow Zostera beds on the landward side rather than seepage through the beach. Care must therefore be taken when interpreting salinity measurements made on the landward shore which may not be typical of salinities across the whole section at that location along the Fleet.

FLUSHING AND RESIDENCE TIMES

From the observations discussed above, it becomes clear that the salinity structure is the result of the balance between tidal diffusion of salt inwards, and river runoff washing it seawards. Because there is no appreciable vertical stratification of salinity, there can be no significant vertical circulation which is the mechanism for flushing out some estuaries. Neither can lateral circulation play much part because of the narrow constrictions occurring along the length of the Fleet. The freshwater runoff per tidal cycle at times of high rainfall, is about 1/50 of the minimum low water volume of the whole Fleet, so that if no tidal flushing occurred the residence time of water throughout the Fleet would be at least 25 days, and in times of drought about twenty times longer with runoff 1/20 of the maximum. However, the regular tidal exchange of water between the Fleet and Weymouth Bay ensures that the East Fleet is rapidly flushed out within one or two tidal cycles. As the tidal influence decreases towards Abbotsbury, the flushing time increases.

In order to quantify the expected residence time of water in the West Fleet, a mathematical model of the tidal exchange and river run-through processes has been constructed, and predictions of the salinity distribution under different tidal and runoff conditions have been compared with the observed values to validate the model (see Robinson, 1981). The model has been used to estimate the time taken for the water in a particular section of the Fleet to be flushed out until only 10% of the originally identified water mass remains in the section. It is assumed that once a marked element of water leaves the Fleet at Smallmouth, it is not returned on the flood tide. Figure 14 shows how the number of tidal cycles to achieve this degree of flushing varies with location along the Fleet, and also varies with both the type of river runoff conditions and to a lesser extent with the stage during the Spring-neap cycle from which the flushing time is calculated. As expected, in the East Fleet, the water residence time is very short, and is independent of rainfall conditons, but West of Moonfleet the flushing time rises sharply and is much more dependent on river flow conditions. This is because the tides are much less efficient and flushing depends more on the throughflow of stream water. The model indicates that at Abbotsbury, the flushing time may be as much as 40 days under drought conditions, and even with heavy rainfall is as long as 10 days. These are of course only model predictions, and remain to be tested by observations, but the success of the model in predicting the salinity structure suggests that these estimates are realistic. It may seem surprising that the flushing time calculated from a time midway between neap and spring tides is longer, in certain parts of the Fleet, than that measured from a time midway between spring and neap tides. The former


hours after high water
at Smallmouth
-6
-5
-4
-3
-2
-1
HW
1
2
3
4
5
6
35
30
25
20
(II)
(III)
(I)
Summer 1979
Salinity
(%0)
(I)
(II)
(III)
Winter 1967-8
Spring Tides


90% flushing time, tidal cycles
60
40
20
(I)
(II)
Box number
(a)
40
20
(I)
(II)
Box number
(b)
80
60
40
20
(I)
(II)
Box number
(c)

has the benefit of the spring tides to enhance flushing, and might be expected to be less. However, the spring tides also result in an overall increase of tidal mean water volume in the West Fleet, so that in fact the flushing effect of the rivers is inhibited by the spring tides pressing water westwards. Moreover, the model indicates that water labelled at, say, Langton as the tidal range is increasing is flushed inwards by the spring tides and is only slowly released past Langton during the Neap part of the cycle.

The model results have implications for the biochemistry of the water mass and indicate that pollution of the West Fleet by natural or artificial processes would not be rapidly cleansed by the natural circulation. The distribution throughout the Fleet of water from a particular stream can also be modelled, and as expected shows that the quality of water in the Abbotsbury Brooks has an important influence on water quality in the West Fleet. The Langton Brook has a significant effect, but stream inputs east of Moonfleet, unless they were to contain an extremely noxious pollutant, are predicted to have negligible effect on the water quality in the Fleet.

CONCLUSION

The Fleet may be broadly divided into two distinct regions. Seawards of Moonfleet, the salinities are close to marine values, with appreciable freshening only when river runoff is high. At all times the water is well-exchanged with the sea outside and as long as the tidal conditions remain as they are the water should be rapidly flushed out and replenished. West of Moonfleet the salinity rapidly decreases, and becomes more variable with both rainfall and tidal state. The water exchange rates become much slower and pollution problems due to prolonged residence of effluents become more likely to occur towards Abbotsbury.

Seepage through Chesil Beach is not thought to contribute significantly to the circulation and flushing, although a breach in Chesil Beach, or the more likely event of continuous operation of the cans at the Abbotsbury end during storm tide conditions in West Bay will result in a rapid flushing out of the West Fleet. Apart from these exceptional events, it is believed that the normal flushing processes are now well enough understood to provide the physical basis of ecological studies.

Acknowledgements The work summarised in this paper has only been made possible by the co-operation of the Strangways Estate and their staff, who have given every assistance in fieldwork programmes and access to the Fleet, and by the willingness of the C.E.G.B. to make the data of their surveys available for scientific analysis. Dr John Whittaker has also made his salinity data freely available. The author gratefully acknowledges the assistance of Mr Paul Riddy and Mr Philip Poulter in the fieldwork and processing of data, Mrs Linda Warren in aspects of the modelling and several students in the Department of Oceanography who helped with fieldwork.

THE ALGAE OF THE FLEET

E.M. Burrows, Broadmayne

The Fleet, and particularly its sublittoral region, is an unusual and important site for the algae. A total of some 150 species, belonging to the (green algae) Chlorophyceae, (brown algae) Phaeophyceae and (red algae) Rhodophyceae, have so far been recorded. The complete list is given in Whittaker (1978). Bacillariophyceae (diatoms) and Cyanophyceae (blue-green algae) are plentiful in the Fleet, but still need working out. Planktonic algae have been sampled by Dr D. Hibbard of The Culture Centre of Algae and Protozoa, Cambridge and a preliminary account of these has been given to the Fleet Study Group.

There is evidence in Batters (1902) that some of the rare species recorded in the last few years were already here at the end of last century. At that time Weymouth was a favourite collecting area as well as, or perhaps because it was, a popular holiday resort, as it is today. The filamentous green algae, Cladophora battersia and Cladophora retroflexa and the rare stonewort Lamprothamnion papillosum are species in this category.

There are two major regions of the Fleet to which the distribution of the algae can be related:

I. The eastern end from Butterstreet Cove to Ferrybridge and Smallmouth(Figure 4). This is an area strongly affected by tides and with strongly saline water; at low tide, over much of the area, large expanses of sand and mud are exposed, crossed by channels.

II. The western end from Butterstreet Cove to Abbotsbury. This is an area less affected by tides and with generally reduced salinity (Robinson ibid). There is a stretch of water some 1-1.5 m deep at low water of spring tides with an exposed margin which is usually very narrow.

I. The eastern Fleet

There is very little continuous solid substrate at all in the Fleet. What there is is mainly at the extreme eastern end and in the upper part of the shore, where it consists of retaining walls for the road, the bridge and occasional buildings. It carries a sparse zonation of algae such as can be found on the open shore and including the following species:

+	Prasiola stipitata	Fucus spiralis
	Porphyra linearis (winter)	Fucus vesiculosus
	Blidingia marginata	Ascophyllum nodosum
	Blidingia minima	Polysiphonia lanosa
	Enteromorpha prolifera	Cladophora rupestris

Lower down the shore there is an expanse of sand and mud with gravel and stones and a few small boulders large enough to carry Fucus vesiculosus and Fucus serratus. The smaller stones and sand not moved by the tide carry ephemeral populations of algae mostly belonging to the Chlorophyceae, included among which are the following:

* For positions of Fleet sites mentioned, see Figure 4A-D
\+ Nomenclature of species as in Parke and Dixon 1976

Audouinella floridula
Blidingia marginata
Blidingia minima
Enteromorpha intestinalis
Enteromorpha prolifera
Percursaria percursa
Pilayella littoralis
Rhizoclonium riparium
Ulothrix flacca
Urospora penicilliformis

The ephemeral algae disappear when the weather is hot and dry and reappear in the winter and when the air is moist.

The felt of filamentous green algae can be found right up to the salt marsh edge where it consists mainly of Enteromorpha prolifera (including E.torta), Percursaria percursa and Rhizoclonium riparium.

At the western end of this section of the Fleet, the areas of mud are exposed at low tide for shorter periods than they are nearer to Ferrybridge and carry Zostera beds which have been, as yet, little studied for their algae. The sublittoral region here is represented by channels, up to 3 m deep, which cut through the exposed littoral region, the more continuous standing water of the Narrows and the final drainage channel which passes under Ferrybridge. The sublittoral in this part of the Fleet has high salinity water and is occupied by a range of larger algae attached to stones and also loose-lying. Such algae can move around with water movements and sometimes into sites where they can survive, but in which they might not initially have developed. The species occurring here, and some 55 species have so far been recorded, may have developed here or may have travelled in from the sea. They include:

Bolbocoleon piliferum
Cladophora rupestris
Codium fragile subsp. tomentosoides
Phaeophila leptochaete
Ulva lactuca

Acrothrix gracilis
Asperococcus bullosus
Asperococcus fistulosus
Cladosiphon zosterae
Cladostephus spongiosus
Chorda filum
Colpomenia peregrina
Dictyota dichotoma
Feldmannia irregularis
Fucus serratus
Laminaria saccharina
Litosiphon pusillus
Myrionema strangulans
Punctaria latifolium
Cystoseira foeniculacea

Calliblepharis ciliata
Ceramium ciliatum
Ceramium diaphanum/strictum
Ceramium pedicellatum
Ceramium rubrum
Chondria dasyphylla
Chondria tenuissima
Chondrus crispus
Chylocladia verticillata
Cordylecladia erecta
Cystoclonium purpureum
Gracilaria bursa-pastoris
Grateloupia filicina
Grateloupia filicina var.luxurians
Membranoptera alata
Naccaria wiggii
Phyllophora crispa
Phyllophora palmettoides
Plocamium cartilagineum
Polysiphonia nigrescens
Rhodophyllis divaricata
Schottera nicaeensis
Solieria chordata
Sphondylothamnion multifidum
Spyridia filamentosa

Though all of them can be found in the sublittoral region of the open sea, some of them are rare species. Grateloupia filicina var. luxurians and Solieria chordata were recorded in Britain for the first time quite recently, the former by Farnham and Irvine (1968) and the latter by Farnham and Jephson in Parke and Dixon (1976). They are known from only a very few south coast localities and nowhere else in Britain.

II. The western basin of the Fleet

The sublittoral region of the western basin of the Fleet is an important habitat for algae. Interchange with the salt water of the sea is slow in this western basin and the freshwater streams running in are few and small.

The most obvious feature of the vegetation here is the extensive beds of Zostera involving Z.angustifolia and Z.noltii: for the distribution of the Zostera species see Whittaker (ibid). There are two algal systems associated with the Zostera beds, each with a seasonal cycle of occurrence.

The first cycle involves the leaves of Zostera plants which carry a variety of small algae as epiphytes and endophytes: some of the algae are characteristic of this environment, if not confined to it, and some are rare plants. The following are among the algae found on Zostera leaves:

Endoderma perforans
Phaeophila viridis
Ochlochaete ferox
Ulvella lens

Cladisiphon zosterae
Giraudia sphacelarioides
Phaeostroma pustulatum
Audouinella virgatulum
Fosliella farinosa

The Zostera plants die down in the winter and the leaves are shed. We do not know at which stage in the growth of the Zostera leaves the algae appear; certainly they continue to grow after the leaves are shed and may contribute to their decay. This cycle needs investigation, particularly with reference to overwintering stages of the algae concerned.

The second cycle involves algae developing round the bases of the Zostera plants in the early part of the year. The dominant algae in this complex are:

Chaetomorpha linum
Cladophora vagabunda
Enteromorpha flexuosa

but the following algae occupy this habitat also, but in smaller quantity:

Ceramium ciliatum
Ceramium diaphanum/strictum
Ceramium rubrum
Calliblepharis ciliata
Gracilaria verrucosa

Polysiphonia nigrescens
Polysiphonia urceolata

Colpomenia peregrina
Striaria eattenuata

The substratum is gravel, shells and stones over sand and mud. The water is shallow, only about 1 - 1.5 m at low water of spring tides, and in the bright summer sun, the water warms up; as a result the plants produce bubbles of gas which float the algal masses to the water surface. Such trailing masses have been called 'flannel-weed' by Whittaker (1978). The 'flannel'weed' becomes darkened in colour by blooms of associated blue-green algae and diatoms and the dark masses float around in the water and are washed up on the strand in huge quantities.

In some parts of the western Fleet, especially at Abbotsbury, Chaetomorpha linum forms shining masses as a single species: such masses have been called 'silk weed' by Whittaker (1978).

Another alga which forms large populations in this western end of the Fleet is Ulva lactuca. It is known that the growth of this alga is stimulated by levels of ammonia in the water of around 0.7 mg l^{-1}. At concentrations above this ammonia becomes toxic. (Waite & Gregory 1969, Waite & Mitchell 1972, Ho 1975). It was known at the beginning of the century that the growth is stimulated by pollution, both artificial and natural (Cotton 1910). There is a good deal of natural pollution in the form of organic matter from rotting vegetation and from bird droppings at the western end of the Fleet and this could be a stimulating agent for the growth of Ulva lactuca populations. The fact that large populations occur close to the shore, as e.g. at Berry Knapp, might suggest that drainage from adjacent farm land could also be assisting the growth. Such growths of Ulva, and other green weeds perhaps stimulated in the same way, could be detrimental to the survival of the Zostera beds here.*

* It should be realised that the suggested origins of elevated nitrogen levels are speculative. Ed.

The intertidal region of the western Fleet has yet to be studied in detail for its algae. Some parts which have been examined show the presence of species associated with somewhat brackish conditions:

Cladophora brownii
Monostroma oxyspermum
Pseuendoclonium submarinum
Ulothrix subflaccida

Cladophora brownii is known elsewhere at only one site in Cornwall and one in County Wicklow in Ireland. Hoek (1963) includes this species in *Cladophora aegagropila*. This latter species is known in Britain only from the Shetland Isles and from one or two sites in the north of Scotland, so that however the species is accepted, *Cladophora brownii* is a very rare plant.

While most of the algae occurring in the Fleet can be found elsewhere, quite a few are rare plants and the associations they form in the Fleet are unusual, especially those in the western basin. The whole of this basin on which many birds depend, could be a very sensitive area. There are a few signs that changes are taking place which may eventually affect the whole system and these need to be watched. In particular the chemical composition of the water needs surveillance.

TERRESTRIAL PLANT COMMUNITIES OF THE CHESIL BEACH AND THE SHORE OF THE FLEET

Jeanne M FitzPatrick, Preston, Weymouth

As elsewhere, the terrestrial plant communities of the Chesil Beach and the shores around the Fleet coastal lagoon reflect the physical conditions operating in the area. In addition to the geology, soil or substrate and topography, there are strong maritime influences. These include exposure to the S.W. winds, sea spray to all areas, wave action to the seaward side of the Chesil Bank and the tidal waters around the shores of the Fleet. These waters exhibit a gradient of salinity from marine salinities at Ferry Bridge to brackish at Abbotsbury, (Whittaker, Robinson ibid).

It is possible to recognise six main habitat types within the study area. Five terrestrial types are the subject of this study. The intertidal mud flats, although supporting an important *Zostera* community as in Butterstreet cove, are not included here.

1. Shingle This takes the form of a 27.4 km (17 mile) shingle bar, from Portland to West Bay, whose pebbles generally decrease in size from east to west. Stability and vegetation increase from the crest to the back of the beach. Human disturbance is also a factor influencing the amount and diversity of plant cover.

2. Salt Marsh This habitat is distributed all around the shores of the lagoon. The extent of the zone varies considerably with the tidal range and shape of the shore line. It is best developed in inlets and bays and at the two ends of the Fleet. It is only a narrow fringe around promontaries such as Herbury and on the Chesil Beach itself, the salt marsh areas are patchy.

3. Freshwater Marsh The freshwater catchment of the Fleet is about 11 square miles (Sturdy 1972). Only very small streams enter the Fleet and these can dry up in summer. Their influence on the shore is therefore small and local but does produce conditions for freshwater marsh species to grow adjacent to some of the salt marsh areas eg off Pirates Lane. It is best developed at the Swannery which is yet to be studied in any detail.

4. Coastal grass 'cliffs' The land shore of the Fleet varies considerably from very low, gently sloping land to vertical or steep cliffs of 3-5m. Rank vegetation, with or without scrub, covers most of these areas. The geology includes Kimmeridge and Oxford clays, Corallian, Forest Marble, and Fuller's Earth. These last two rock types produce calcareous soils which have a

noticeable influence on the vegetation where they occur eg Herbury to Rodden Hive. As a coastal habitat, the land shore line of the Fleet is not well developed. It is sheltered by the beach and the lagoon to a large extent and the area that remains undisturbed by agricultural development is very narrow in places.

5. Waste Places Where the 'cliff' edge shows erosion and on the inland margins of some areas of shingle eg West Bexington shore path and at Ferry Bridge near the car Park, disturbed and open conditions give opportunity for 'weeds'.

The most important habitat types are, however, the maritime ones, especially the shingle, salt marsh and mud flats.

Areas of the Chesil Beach and Shores of the Fleet visited

The information drawn on for this account has been gradually accumulated from a number of visits to the study area from 1976-79. Twelve different areas were visited and include four areas of the shingle beach and eight shore areas incorporating at least some salt marsh conditions. These areas are listed below.

No attempt has been made to measure the sizes of these areas.

1. Ferry Bridge - Inner face of Chesil Beach. (Fig. 4D). A large area of stable, 'closed' turf surrounded by unstable shingle with more open vegetation and typical shingle species.

2. Ferry Bridge (Fig 4D) - a band of salt marsh between the shingle and the large intertidal sandy shore at the extreme eastern end of the Fleet. *Suaeda fruticosa* lies between the shingle and the salt marsh and runs more or less continuously the full length of the shingle shore of the Fleet. This area is subject to disturbance and bait digging.

3. Pirates Cove (Fig 4D) - a deep inlet with salt marsh and freshwater marsh species

4. East Fleet (Fig 4C) - a narrow belt of salt marsh behind the large area of mud flats of Butterstreet Cove (Oxford clay and Kimmeridge clay).

5. Herbury Gore (Fig 4B) - a very narrow fringe of salt marsh in front of steep or almost vertical cliffs of the promontary. (Forest Marble and calcareous soil).

6. 'Works' inlet (Fig 6) - a small fenced area of salt marsh with freshwater marsh species. A small stream enters the Fleet at the side of the patch. (Fuller's Earth and calcareous soil).

7. 'Works' to Langton Hive (Fig 4B) — a narrow fringe of salt marsh in front of low, gently sloping shore line. (Fuller's Earth)

8. Langton Hive to Rodden Hive (Fig 4B) — a narrow fringe of salt marsh in front of steeper 'cliffs'. (Fuller's Earth).

9. Abbotsbury (Fig 4A) — salt marsh area at the extreme western end of the Fleet on the seaward side of a large freshwater marsh. A small stream runs into the end of the Fleet.

10. Abbotsbury (Fig 4A) — a vegetated shingle area. Plant cover increases away from the Car Park and is best opposite the swannery. Most of the vegetation is on the back of the beach although the crest and, less often the seaward side of the beach, can also support some plants if conditions are suitable.

11. Chesil Beach opposite Chickerell Hive (Fig 4C) - an area of vegetated shingle some distance from the landing point on the more stable back of the beach.

12. West Bexington (Not mapped, See introduction) — a less disturbed area west of the car park. Open vegetation on the crest and back of the beach although the seaward side does support some vegetation. The path contains species of disturbed ground. Transects from the crest to the coastal path show an increase in cover and species diversity. (Helyar 1977).

Most visits to the Fleet were carried out in June or July. Because there is a continuous gradient from maritime to non-maritime conditions in all coastal areas, the landward limit of the coastline is difficult to define. The species recorded in this account were those found from above high tide to the 'cliff' edge on the land side of the Fleet. At Ferry Bridge, the species found on the shingle and the grassy area have been recorded. At West Bexington and Abbotsbury, the areas include the crest and back of the beach as far as the footpath.

This plant survey is still incomplete, both on the total number of species recorded and in the areas visited; although more attention was paid to the coastal species in each area. Because of the need to avoid disturbance to the nesting colonies of Little Tern and other breeding birds, much of the shingle beach has yet to be visited. It is anticipated that more recording will be carried out in future seasons, both on the Chesil and at the Swannery.

III The Floral composition of the study area

The complete list of flowering plant species so far recorded is given in the appendix. It contains 110 species (+ 1 spp of Equisetum). This total is most certainly an under-estimate and some difficult species such as members of the genera *Salicornia*, *Spergularia* and species such as *Geranium purpureum* need closer study. *Limonium binervosum*, *Eryngium maritimum*, *Euphorbia paralias* and *E.portlandica* have been reported in the past (Environmental Records Centre, County Museum Dorchester), but were not found by the author. Their present distribution therefore needs checking. These 4 species have nevertheless been included in this total. Absence of a species from these records does not necessarily mean that it is not present, although in most cases this will be so. No attempt has been made to quantitatively assess the different species found in the area visited. Some attempt however, has been made to give for each species some idea of its ecological range. Relevant information has been taken from the list of coastal vascular plant species given in the Nature Conservation Review Vol 1 (1977). In this way, it is possible to make some kind of evaluation of the species found in the study area (Appendix 1). Table 1 has been made from the list of total species recorded in the appendix 1. The symbols which indicate the habitat types appear beside each plant species listed and at the heads of the columns in Table 1. Species that can occur either on shingle or on salt marshes have been separated from those that have a more restricted range. Sandy/dune species have also been separated from the shingle species even though this habitat is not really represented. This exercise is difficult because many species have a wide range of tolerance to physical conditions. *Phragmites* has been listed in the freshwater marsh species but it can tolerate low salinities as well. Halophytes and other coastal species have also been identified. Table 1 attempts to analyse the flora of each of the 12 areas visited and to show its ecological composition.

Table 1. Number of the main plant species, so far recorded in 12 areas of the Chesil Beach and the shores of the Fleet, found in the different types of habitat.

AREAS OF THE CHESIL BEACH AND SHORE OF FLEET	MARITIME HABITATS				NON MARITIME HABITATS							
	SHINGLE (Sh)	SHINGLE & SALT MARSH (Sh Sm)	SALTMARSH (Sm)	SAND/DUNE (S)	FRESH WATER MARSH (F)	CALCAREOUS GRASSLAND (C)	OTHER GRASSLAND (G)	WASTE AREAS (W)	TOTAL NO OF SPECIES	HALOPHYTES	OTHER COASTAL SPECIES	TOTAL NO OF COASTAL SPECIES
1. Ferry Bridge Shingle	11	9		3		6	10	10	49	15	8	23
2. Ferry Bridge salt marsh	1	5	5						11	10	1	11
3. Off Pirates Cove	2	10	5		6	3	3	4	33	13	6	19
4. East Fleet	1	8	3		1			1	14	10	2	12
5. Herbury Gore	1	4	2			6	3	1	17	6	2	8
6. 'Works'	1	10	9		2			1	23	14	6	20
7. 'Works' to Langton Hive	1	6	8		1	2	1	2	21	11	4	15
8. Langton Hive to Rodden Hive	1	6	2		3	10	6	3	31	5	5	10
9. Abbotsbury salt marsh	1	13	9	1	1				25	19	5	24
10. Abbotsbury shingle	13	6					1	6	26	14	6	20
11. Chesil opp Chickerell	3	9		2			3	4	21	9	4	13
12. West Bexington	8	8				1	6	14	37	11	7	21
TOTALS	16	19	15	5	6	15	15	20	111	41	14	55

Comments

1. Of the 55 coastal species so far recorded for the whole study area, 41 are halophytes and occur on shingle, salt marsh or both habitats. Halophytes are unique in their ability to tolerate some degree of salinity in the soil water around their roots and/or the effects of spray on their shoots. They are the largest group of species found in this study area.

2. About 50% of the total list of species recorded occur more typically in habitats removed from maritime influence eg Lotus corniculatus, Iris pseudacorus. Some species which are included in the coastal list also occur elsewhere eg Anthyllis vulneraria, Rumex crispus, Daucus carota, Ononis repens.

3. In any one area, there may be more than one type of plant community, especially where a transition from one set of conditions to another occurs. Around the western end of the Fleet, there are shingle, salt marsh and freshwater marsh communities adjacent to one another, together with species that are characteristic of disturbed ground. The shingle areas of Ferry Bridge (area 1) and West Bexington (area 12) have 10 and 14 species of waste ground plants respectively. Where small streams or ditches drain into the Fleet, freshwater marsh species grow alongside those of the salt marsh, eg Oenanthe crocata, Iris pseudacorus, and Phragmites grow with Scirpus maritimus, Aster tripolium and Triglochin maritimus in areas such as the 'works' (area 6) and Abbotsbury (area 9) and Pirates Cove (area 3).

4. Where the soil of the land shore line is influenced by calcareous rocks such as Forest Marble and Fuller's Earth, calcicoles such as Blackstonia perfoliata, Brachypodium pinnatum, Primula veris and Poterium sanguisorba are found between Herbury (area 3) and Rodden Hive (areas 7 and 8).

5. At Ferry Bridge (areas 1 and 2) and Abbotsbury (areas 9 and 10), both of which are comparatively large areas, there are a large number of species present - about 60 species and 50 species respectively. Where the shore is narrow as at Herbury (area 5) and Langton Hive (area 8) there is only a fringing salt marsh but where there are inlets, a wider and a more diverse flora occurs as at Pirates Cove (area 3), the 'Works' (area 6) and Abbotsbury (area 9). See also table 2.

6. A comparison of the areas included in this study can most readily be made by examining only the coastal species (Table 3).

Table 2 Comparison of the numbers of Coastal species recorded in the different areas of the Chesil Beach and the shores of the Fleet.

AREA	NO OF SPECIES	COMMENTS
1. Ferry Bridge	26	good - shingle/grass
2. " "	11	poor - disturbed salt marsh
3. off Pirates Cove	19	good - with freshwater marsh spp.
4. E. Fleet	12	poor - salt marsh & cliff but large mud flats.
5. Herbury	8	poor - narrow fringe of salt marsh
6. 'Works'	20	good - salt marsh with freshwater marsh.
7. Langton to 'Works'	15	poor - narrow salt marsh fringe
8. Langton to Rodden Hive	10	" " " " "
9. Abbotsbury	20	good salt marsh.
10. "	24	good - shingle.
11. Chesil opp. Chickerell	10	poor - shingle
12. West Bexington	20	good - shingle

Evaluation of the Chesil Beach and shores of the Fleet.

Although the diversity of species and of habitats make the study area of great ecological/botanical importance, it is the coastal species and the halophytes in particular that make the whole area of special value. It is in fact, listed by N.C.C. as a Grade 1 Internationally important site. The shingle beach is one of the 5 largest, and the Fleet waters itself the largest regularly tidal lagoon, in Britain. In 1939, Tansley stated that the Chesil Beach "is not so rich in flowering plants" as Blakeney, possibly owing partly to "the poverty of drift on the inner margin bordering the Fleet". More surveys are needed to see just how this area in Dorset compares with this north Norfolk site and Dungeness. A comparison of the number of coastal species listed for the South West of England from "A Nature Conservation Review" and those recorded for this Dorset site, is included. The number of coastal species and halophytes of S.W. England however, include species from all marine habitats, whilst the totals for the study area are mainly from shingle and salt marsh (ie sandy/dune typical grass or rocky cliff habitats are not represented on the Fleet).

Table 5. A comparison of the number of Vascular Plant species for the S.W. England and the Chesil/Fleet area.

	CHESIL/FLEET	S.W. ENGLAND	% NO OF S.W. ENGLAND SPP ON CHESIL/FLEET
Shingle	35	50	70%
Salt Marsh	34	65	52.3%
Total no. of coastal spp.	55	182 (all the marine habitats)	30.2%
No. Halophytes	41	85 "	48.2%

*NB These % could well be higher with more survey work.

Conclusions

However well this Dorset site compares with similar sites elsewhere, the shingle flora of the Chesil Beach remains a very rich and important one. This account has dealt only with the Flowering Plants but the shingle is also rich in lichens and to some extent mosses (see Tansley's reference to Watson 1922). The moving pebbles produce a fragile habitat, easily destroyed by storms, trampling feet and fishing activities. The salt marsh areas are not extensive compared to those of Poole and Christchurch Harbours, but nevertheless 34 salt marsh species have been recorded for the shores of the Fleet. There are no very rare species on this list produced here, but there are large and important populations of Lathyrus japonica, Glaucium flavum, Crambe maritima, Suaeda fruticosa and Trifolium scabrum on the Chesil Beach. The Fleet is also the only Dorset site for Althaea officinalis. In conclusion it must be stated that the total environment that this area represents, is of very high scientific value.

FLOWERING PLANT LIST OF THE CHESIL BEACH AND SHORES OF THE FLEET

12 AREAS VISITED FROM 1976-79

		AREAS OF THE BEACH AND FLEET											
		1	2	3	4	5	6	7	8	9	10	11	12
C	Agrimonia eupatoria. Agrimony							X					
Sh Sm	Agropyron pungens. Sea Couch.	X		X	X	X	X	X	X	X			X
Sh Sm	Agrostis stolonifera. Creeping Bent						X						
W	Aira caryophylla. Silvery Hair Grass	X											
W	A. praecox. Early Hair Grass.	X											
Sm	Althaea officinalis. Marsh Mallow						X	X	X	X			
Sh	Anagallis arvensis. Scarlet Pimpernel	X											X
W	Arenaria serpyllifolia. Thyme-leaved Sandwort	X											
C	Anthyllis vulneraria. Kidney Vetch	X											
Sh Sm	Armeria maritima. Thrift	X	X							X			
W	Arhenatherum elatius. False Oat Grass										X		X
Sh Sm	Artemisia maritima. Sea Wormwood										X		X
Sm	Aster tripolium Sea Aster		X		X		X	X		X			
Sh Sm	Atriplex gabriuscula Babington's Orache											X	
Sh Sm	A. hastata. Hastate Orache		X	X	X		X		X	X			X
Sm	A. Littoralis. Grass-leaved Orache				X					X			
Sh Sm	Beta vulgaris. Sea Beet	X	X	X	X	X	X	X	X	X	X	X	X
C	Blackstonia perfoliata Yellow-wort								X				
C	Brachypodium pinnatum. Tor Grass					X			X				
W	Brassica nigra. Black Mustard												X
W	Bromus mollis. Brome grass	X											X
C	Briza media. Quaking Grass								X				
W	Calystegia sepium. Bindweed			X							X		X
Sh	C.Soldanella. Sea Bindweed	X									X		X
Sh	Carex arenaria. Sand Sedge	X									X		
Sm	C.distans. Distant Sedge									X			
Sm	C.divisa. Salt Marsh Sedge							X					
C	C.flacca. Carnation Sedge								X				
Sm	C.obtrubae. False Fox Sedge			X									
Sh	Catapodium marinum. Darnel Grass	X									X		
G	Centaurea nigra. Hardhead								X				
C	Centaurium spp. Centaury	X							X				

		1	2	3	4	5	6	7	8	9	10	11	12
	Cirsium arvense. Creeping Thistle	X										X	X
W	C.vulgare. Spear Thistle.	X											X
C	Carlina vulgaris. Carline Thistle					X							
W	Cerastium vulgatum. Common Mouse-ear	X										X	X
Sh Sm	Cochlearia danica Stalked Scurvy Grass	X								X	X	X	X
Sm	C.officinalis. Common Scurvy Grass				X	X	X						
Sh	Crambe maritima. Sea Kale										X		X
Sh	Crithmum maritimum. Samphire	X		X							X		
G	Dactylus glomerata. Cocksfoot	X				X			X		X	X	X
C	Daucus carota. Carrot	X		X		X			X				X
Sh Sm	Festuca rubra. Red Fescue	X		X		X					X	X	X
F	Epilobium hirsutum Hairy Willowherb			X					X				
F	Equisetum spp. Horsetail			X									
	Erodium cicutarium Common Storkbill	X											
Sh S	Eryngium maritimum. Sea Holly	?											
S	Euphorbia paralias. Sea Spurge	?											
S	E.portlandica Portland Spurge .	?											
C	Galium verum. Lady's bedstraw	X							X				
C	Genista tinctoria. Dyer's Greenweed							X	X				
Sh	Geranium purpureum. Lesser Herb Robert?	X									X	X	X
Sh	Glaucium flavum. Yellow Horned Poppy	X									X		X
Sh Sm	Glaux maritima. Sea Milkwort			X	X	X		X	X	X			
Sh Sm	Halimione portulacoides. Sea Purslane.		X	X			X			X		X	
W	Heracleum sphondylium. Hogweed			X									X
G	Hypochoeris radicata. Cats ear	X											X
	Iris pseudacorus. Flag Iris			X									
G	I. foetidissima. Stinking Iris					X							
Sm	Juncus gerardii Saltmarsh Rush			X	X	X	X	X	X	X			
Sm	J. maritimus. Sea Rush						X	X		X			
Sh	Lathyrus japonicus. Sea Pea										X		
G	L.pratensis. Meadow Vetchling			X									
Sh Sm	Limonium binervosum. Rock Sea lavender												
G	Lotus corniculatus Bird's Foot Trefoil	X		X				X	X			X	X
Sh	Lavatera arborea. Tree Mallow												X
W	Malva sylvestris. Common Mallow	X			X						X		X
F	Oenanthe crocata. Water Dropwort			X			X	X	X				
W	Onobrychis vicifolia. Sanfoin			X									
	Ononis repens. Restharrow	X		X		X			X				
Sh Sm	Parapholis stigosa. Sea Hard Grass	X					X		X	X			

		1	2	3	4	5	6	7	8	9	10	11	12
F Sm	Phragmites communis. Common Reed			X	X				X	X			
Sh	Phleum arenarium. Sand Cat's Tail	X									X		
C/W	Picris echioides. Prickly Ox-tongue	X						X	X		X	X	X
Sh S Sm	Plantago coronopus. Buckshorn Plantain.	X				X	X			X			X
Sh G	P.lanceolata. Ribwort Plantain	X											
Sh Sm	P.maritima. Sea Plantain		X	X			X	X		X			
W	Potentilla anserina. Silverweed			X		X	X	X	X				
C	Poterium sanguisorba. Salad Burnet			X		X			X				
C	Primula veris Cowslip					X							
G	Prunus spinosa. Blackthorn					X						X	
Sm	Puccinellia maritima. Sea Poa		X							X			
G	Rhinanthus minor. Yellow Rattle	X											
Sh Sm	Rumex crispus. Curled Dock	X		X			X	X			X	X	X
S	Sagina nodosa Knotted Pearlwort	X								X		X	
Sm	Salicornia perenne. Perennial Glasswort		X										
Sm	Salicornia spp Glasswort		X				X			X			
Sm	Scirpus maritimus. Sea Club-rush			X	X		X	X		X			
F	Ranunculus sceleratus. Celery-leaved Buttercup			X			X						
Sh	Sedum acre. Wall Pepper	X									X		
G	Senecio jacobea. Ragwort								X				X
W	S.vulgare. Groundsel												X
Sh	Silene maritima. Sea Campion	X									X	X	X
Sh	Smyrnium olusatrum Alexanders										X		X
Sh Sm	Solanum dulcamera. Woody Nightshade	X					X		X		X	X	X
W	Sonchus arvensis. Corn Southistle								X				X
W	S.oleraceus. Corn Southistle										X	X	X
Sm	Spergularia spp Spurrey		X	X	X		X	X		X			
Sh Sm	Suaeda fruticosa. Shrubby Sea Blight	X		X						X		X	
Sh Sm	S.maritima. Annual Sea Blight		X	X	X		X	X		X		X	
Sh	Tamari gallica. Tamarisk										X		
W	Taraxacum officinale. Dandelion	X											X
C	Thume drucei. Thume	X											
G	Trifolium arvense. Hare'sfoot Clover	X											
G	T.campestre. Hop Trefoil	X											
G	T.dubium Lesser Trefoil.	X							X				
S	T.scabrum. Rough Clover	X										X	
Sm	Triglochin maritima. Sea Arrowgrass			X	X		X	X		X			
Sh Sm	Tripleurospermum maritimum. Scentless Maywood	X		X				X	X	X	X	X	X

	1	2	3	4	5	6	7	8	9	10	11	12
Torilis nodosa. Knotted Hedge Parsley			X					X				
Vulpia spp. Rat-tail Fescue.	X											

Ecological Range of the species recorded

	Symbol
Shingle	Sh
Salt Marsh	Sm
Shingle/Salt Marsh	Sh Sm
Sand/dune	S
Freshwater Marsh	F
Grassland - calcareous	C
- other types	G
Waste land	W
[ ]	Not found by author but past records indicate presence

No of Halophytes	41
No of other Coastal spp.	14
No of typically non-maritime spp	56
Total no. of species so far recorded	111

THE DISTRIBUTION OF ZOSTERA AND RUPPIA IN THE FLEET

John E Whittaker
Department of Palaeontology
British Museum (Natural History)
Cromwell Road
London SW7 5BD)

Marine algae, Zostera and Ruppia, occur in rich abundance in the Fleet for much of the year; only in winter and early spring are there large tracts of bare substratum. The distribution of Zostera over the period autumn (October) 1968 to summer (August) 1969, taken from the author's original survey (Whittaker, 1972; 1980), is shown in Fig.15 and discussed further below. A more recent picture, mapped by J Fair (Swanherd, Fox Strangways Estates) in summer 1980, is shown for comparison in Fig.16. In the former the distribution of Ruppia is included under the Zostera community, in Fig.16, an attempt is made to distinguish the two distributions.

ZOSTERA

This marine angiosperm, locally known as "eelgrass", is represented in the Fleet by two species, the more common Zostera angustifolia (Hornem) Rchb., and Z. noltii Hornem. The true Z. marina L. does not appear to be present, but it does occur in Portland Harbour and Weymouth Bay. The Taxonomy of Zostera spp. is difficult (Dandy, 1958, and Clapham, Tutin & Warburg, 1962) and has been the subject of much confusion and dispute. Some authorities, for instance, still regard Z. angustifolia as merely an ecological variant of Z. marina, living in lower salinities and shallower water. Certainly the Fleet populations of Zostera have never been properly studied, a discrepancy the Fleet Study Group is trying to rectify, and it may ultimately be proved that three species, not two, are indeed present. The identifications given in Whittaker (1972; 1980) were however made by botanists (see acknowledgements), and were thought to be accurate at the time.

Zostera angustifolia - forms extensive meadows over the bed of the Fleet from Lynch Cove in the southeast to near Abbotsbury in the northeast (see Figs 15, 16) although it is not yet known for certain that this species occurs throughout West Fleet. It is not found south of Lynch Cove, nor in the channels of Littlesea, water depth and unstable substratum through tidal scour being responsible. It is also replaced to a great extent in the westernmost part of the lagoon by Z. noltii. The last twenty years has seen the largest extent of this plant since its recolonisation after the decimation caused by the wasting disease in the 1930's. Germination begins usually in late February and March and by August it has grown to its maximum extent and is flowering; epiphytic algae cover the leaves. Except for some coves which are clogged with drifted "flannel weed" (see Burrows, ibid) "silk weed" and Ulva, the Zostera community constitutes the main environment for a whole range of invertebrates over almost the whole of West Fleet and much of East Fleet.

During late autumn and in winter the foliage dies back and is driven ashore by the wind to accumulate in some of the coves. The yearly decay of Zostera appears to be associated with the great thicknesses of organic silt which floor much of the Fleet above bedrock. Z. angustifolia grows in no more than 1.0-1.5m of water and except on the tidal flats of Littlesea,; which dry out at low water, the plant is always immersed in water.

Zostera noltii - this slender and shorter-leaved species occurs in the lower salinities of West Fleet, in water depths that never exceed 1.0 m. Its absolute distribution within the lagoon still needs clarification, but it is certainly much rarer than Z. angustifolia. Furthermore, there is some difficulty in separating it from Ruppia, except when the two are in flower. Long thought to be the main source of food for the swan populations of the Abbotsbury Swannery, Zostera spp. are in fact very rare in the Abbotsbury Embayment, where green algae, in particular "silk weed" (Chaetomorpha spp), occur in great abundance (Figs 15 & 16) instead.

RUPPIA

In Fig.16 J Fair has shown the distribution of Ruppia in the Fleet in 1980. He reports (pers. comm.) that it occurs only in West Fleet from Works Cove in the southeast to below Shipmoor Point in the northwest. It is associated mainly with Zostera, then with green algae, before it disappears by the Abbotsbury Embayment. There is some evidence that in the last decade, Zostera and Ruppia, mapped in 1968 (Fig.15) as occurring in the Embayment and certainly at Shipmoor Point, has actually died out, possibly as a result of overfeeding by the bird population, but this is conjectural.
Known locally as "wigeon grass", Ruppia appears to be represented in the Fleet by the species R. spiralis L. ex Dum., although R. maritima L. may ultimately prove to be present. As with Zostera, a detailed survey of its distribution is needed.

ACKNOWLEDGEMENTS

Identification of the Zostera and Ruppia was by Drs A D Boney and P Harwood, formerly of the Department of Botany, University College of Wales, Aberystwyth. J Fair helped greatly by providing Fig.16 and by his many discussions.

Fig 15

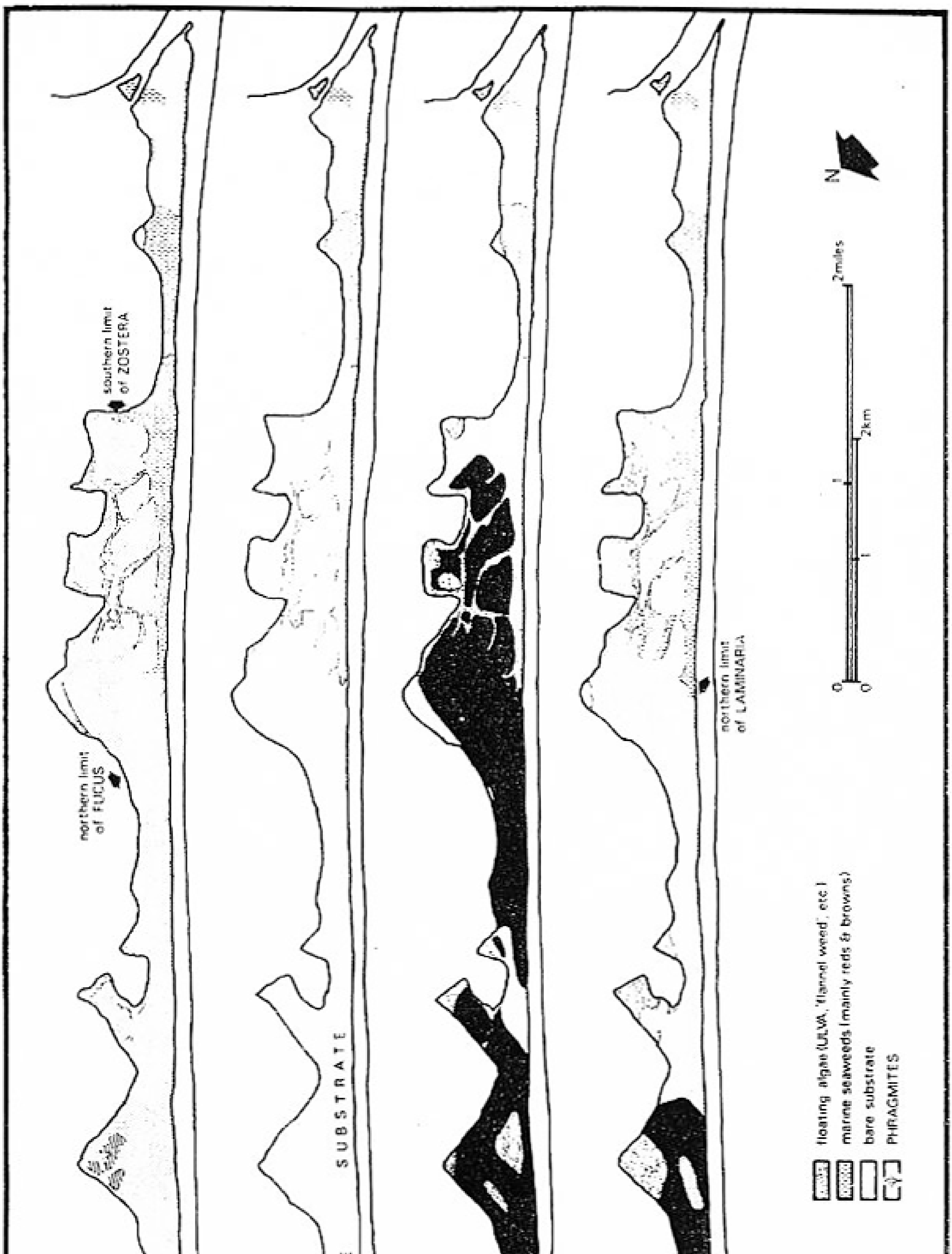
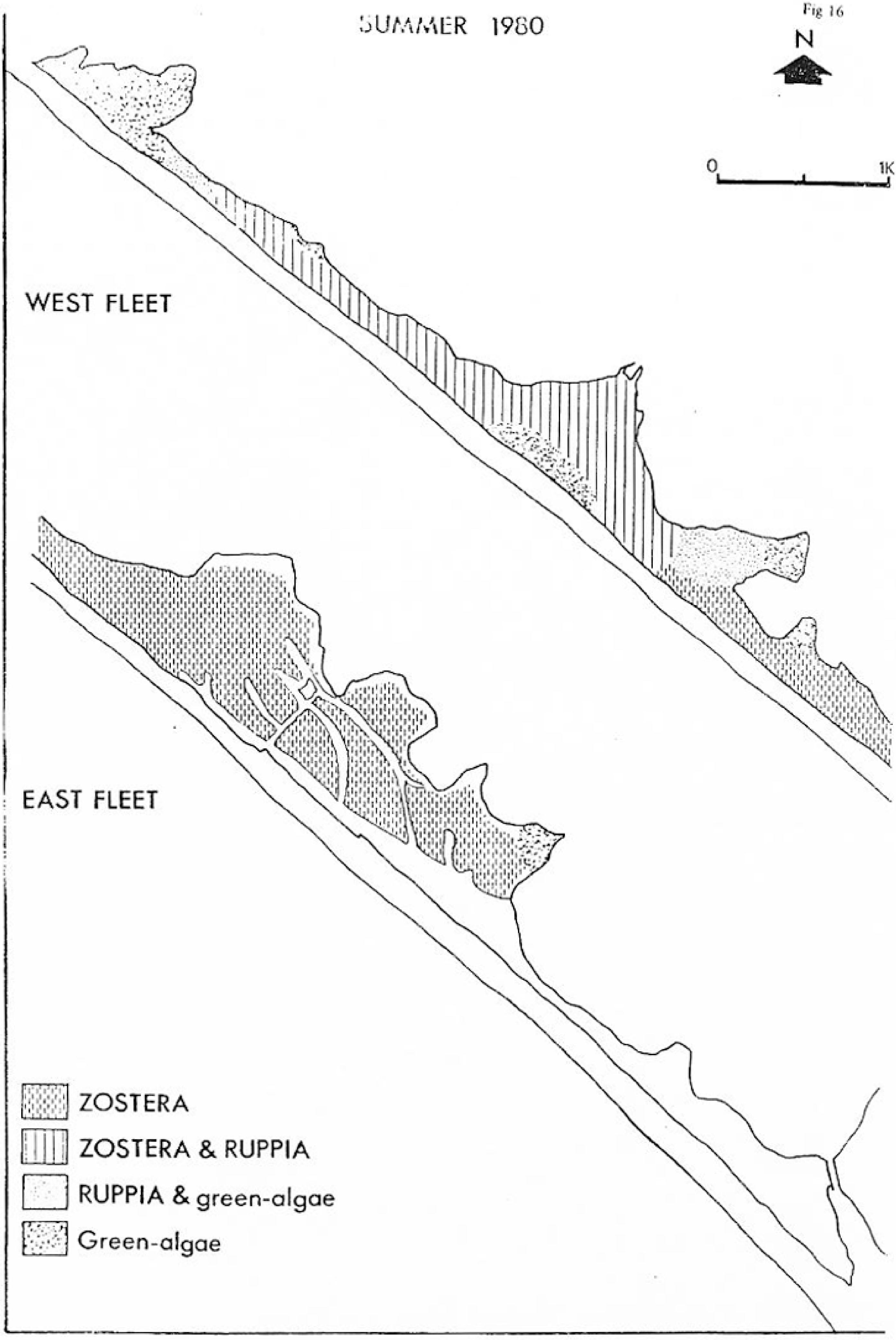

AUTUMN 1968
WINTER 1968-69
SPRING 1969
SUMMER 1969
southern limit of ZOSTERA
northern limit of FUCUS
northern limit of LAMINARIA
BARE SUBSTRATE
ZOSTERA spp
ZOSTERA & 'flannel weed'
'silk weed'
floating algae (ULVA, 'flannel weed', etc.)
marine seaweeds (mainly reds & browns)
bare substrate
PHRAGMITES
0
1
2km
2miles
N

Fig 16


SUMMER 1980
N
0
1K
WEST FLEET
EAST FLEET
ZOSTERA
ZOSTERA & RUPPIA
RUPPIA & green-algae
Green-algae

INVERTEBRATE FAUNA OF THE FLEET

M Ladle
FBA River Laboratory
E Stoke
Wareham
Dorset

Many bottom living marine invertebrate species have, in their life cycles, distribution phases which involve drifting planktonic larvae. At times of settlement (on the sea bed) these larvae can often postpone metamorphosis and, in this manner select, in some degree, the area in which they are to live as adults. The choice of habitat is often determined by the nature of the sediment and may be associated with the presence of bacteria or minute traces of biologically produced chemical substances. Few species are capable of major redistribution after settlement, in consequence, death and destruction of those specimens which, by chance, find themselves in unsuitable habitats, modify the initial patterns of settlement. Differential growth may also result in size differences within the area occupied by a species.

Factors such as the above are secondary to the influences of tidal currents, physical and chemical differences in water quality with respect to the drifting of planktonic larvae.

Table 1 presents a listing of invertebrates recorded from the Fleet. The lines indicate the region(s) of the Fleet from which each species has been reported. A much more satisfactory and comprehensive list of molluscs has been prepared by Seaward (1980). The sources from which the information is derived are indicated by numbers opposite each species. A more detailed account of some records obtained by D. R. Seaward is also included and a short account of the Ostracoda is presented by Dr J E Whittaker.

Table 1. Distribution of invertebrates within the Fleet (numbers indicate origin of records (see below))

		" Lower" Fleet	Narrows-Herbury	" Upper" Fleet
	"Coelenterates"			
	Hydroida			
1	*Obelia geniculata* (L.)			———
	Anthozoa			
5	*Actinia equina* L.	———		
5	*Anemonia sulcata* (Pennant)	———		
	"Worms"			
	Polychaeta			
1,2	*Nereis diversicolor* O.F. Muller	———	———	
2,3	*Nephthys hombergi* Lamarck	———		
2	*Glycera lapidum* Quartrefages		———	
2	*Lumbriconereis lattreilli* (Audouin, Milne Edwards)		———	
2,4	*Scoloplos armiger* (O.F. Muller)	———	———	———
2	*Scolecolepis fuliginosa* (Clap.)	———		
2	*Audouinia tentaculata* (Montague)		———	
2	*Cirratulus Cirratus* (O.F. Muller)	———		
2	*Flabelligera affinis* Sars.		———	
2	*Notomastus latericeus* Sars.	———		
2	*Capitella capitata* (Fabricius)		———	
1,2 & 3	*Arenicola marina* (L.)	———	———	
2	*Pomatoceros triqueter* (L.)	———		
	"Sipunculids"			
	Sipunculoidea			
2	*Golfingia elongata* (Keferstein)		———	
	"Crustaceans"			
	Amphipoda			
4	*Gammarus insensibilis* Stock.			———
4	*Gammarus duebeni* Lillj.	Small drain entering Herbury Bay.		

		" Lower" Fleet	Narrows- Herbury	"Upper" Fleet
4	*Gammarus zaddachi* Sexton	Ditch west of Langton Herring.		
4	*Melita palmata* (Mont.)			———
4	*Microdentopus gryllotalpa* A. Costa.			———
	Isopoda			
4	*Idothea chelipes* (Pallas.)			———
4	*Cyathura carinata* (Kryer.)			———
4	*Ligia oceanica* (L.)			———
4	*Sphaeroma rugicauda* Leach			———
	Decapoda			
4, 5	*Palaemon adspersus* (Rathke)			———
4, 5	*Palaemon squilla* (L.)			
4, 5	*Carcinus maenas* (L.)	———	———	———
5	*Inachus dorsettensis* (Pennant)	———		
5	*Cancer pagurus* L.	———		
5	*Homarus gammarus* (L.)	———		
"Insects"				
4	*Clunio marinus* Haliday			———
4	*Chersodromia arenaria* (Haliday)			———
4	*Ceratinosoma ostiorum* (Haliday)			———

REFERENCES

1. Holme N A & Bishop G M 1980 Report on the sediment shores of Dorset, Hampshire and the Isle of Wight. A biological survey of the littoral zone. SMBA/MBA intertidal survey unit, Jan. 1980, pp 88.
2. Daniel L G & Herbert J 1979 A report on a preliminary survey of the annelid species associated with the Fleet sediments. 1. Ferry Bridge to Langton Herring. Unpubl.
3. Sturdy R 1972 The Fleet Survey, p 29. Unpubl.
4. Spooner G M 1967 Reported in - Marine Biological Association of the United Kingdom. Report of the Council for 1966-67, p. 17. and pers. comm. to D R Seaward.
5. M Ladle pers. obs.

NOTES ON SOME INVERTEBRATES OF THE FLEET, DORSET

D R Seaward
3 Summerlands
Yeovil
Somerset
BA21 3AL

During a study of the marine molluscs of the Fleet (Seaward 1980), some other invertebrates have come to my notice, usually because of an association with molluscs. Thus the following notes are of a somewhat random nature except where the molluscan connection applies, and in a few cases they duplicate entries in the above reference.

COELENTERATA:HYDROIDA

Obelia dichotoma (L.) Abundant on *Zostera* and *Ruppia* in the upper Fleet where it forms the food of the nudibranchs *Eubranchus farrani* and *Tenellia pallida*.

Perigonimus repens Wright. Rare on *Zostera* in the upper Fleet.

COELENTERATA:HYDROMEDUSA

Cladonema radiatum Dujardin. The medusa phase is occasional to frequent in waters of the Fleet and Portland Harbour, but I have not found the hydroid phase.

COELENTERATA:ANTHOZOA

Nematostella vectensis Stephenson. A small anemone frequently found burrowing in mud in mid to upper Fleet is probably this species, but requires satisfactory determination.

PLATYHELMINTHES:TURBELLARIA

Leptoplana sp. (probably *L. tremellaris* (O.F. Muller). This common flatworm is probably the most significant predator of the small gastropods in the upper Fleet; a few in an aquarium sample of weed with associated fauna will radpidly devour most of the Hydrobiids and Rissoids present, leaving clean, empty shells.

CRUSTACEA:ISOPODA

Sphaeroma hookeri Leach. Frequent in debris in the Upper Fleet in December 1977.

Idotea baltica (Pallas). Among *Zostera* etc., in the upper Fleet in August 1974.

I. chelipes (Pallas). Common among *Zostera* in the upper Fleet.

Ligia oceanica (L.). The Sea Slater is widespread along the Fleet shore, but only numerous in the lower Fleet where crevices among available just above HWM.

CRUSTACEA:AMPHIPODA

Melita palmata (Montagu). Among Zostera etc., in the upper Fleet in December 1977.

Ericthonius brasiliensis (Dana). This corophiid is abundant, forming tubes on Zostera etc. in the upper Fleet.

CRUSTACEA:SCHIZOPODA

Praunus flexuosus (Muller). Opossum shrimps are common, often in shoals, in the upper Fleet. This species was present at Langton Hive Point in August 1978.

BRYOZOA:CTENOSTOMATA

Alcyonidium sp., ("perhaps of the 'mytili-polyoum' complex"). Frequent on the gastropods Littorina saxatilis and Rissoa membranacea living permanently submerged among vegetation in the upper Fleet, forming gelatinous incrustations on the shells of the living animals, sometimes completely covering the shell.

Bowerbankia sp., (probably B. gracilis 'Leidy)). Common as gelatinous incrustations around the stems of vegetation in the upper Fleet.

TUNICATA:ASCIDIACEA

Botryllus schlosseri (Pallas). Occasional on vegetation in the upper Fleet.

Acknowledgements I am grateful to the following authorites for checking or determining the above species:- Hydroids : Dr P F S Cornelius, Crustacea : Dr R J Lincoln, Bryozoa : P L Cook, Tunicates : G Paterson, all of the British Museum (Natural History); Flatworm, Dr V F Fretter.

THE DISTRIBUTION OF OSTRACODA IN THE FLEET

John E Whittaker
Department of Palaeontology
British Museum (Natural History)
Cromwell Road
London, SW7 5BD

INTRODUCTION

Ostracods are small bivalved Crustacea, usually between 0.4 and 1.0 mm in length, which live in all manner of aquatic environments. Although the chitinized appendages of the animal quickly disintegrate on death, the calcareous valves are usually preserved and ultimately are readily fossilized, and thus ostracods have become very important to geologists, not only in the dating of rocks (they have evolved rapidly through time), but also in reconstructing past-environments. The present study was indeed initiated as a means of gathering more ecological information in order to assist in such reconstructions.

Until the survey of the Mollusca (Seaward, 1980), my study of the Ostracoda (Whittaker, 1972) had been the only one undertaken on any group of invertebrates on the Fleet. The collecting, from a final maximum of over 80 stations, was carried out on a seasonal basis between 1967 and 1969. Three assemblages were recognised, these corresponding almost exactly to the divisions of the Fleet suggested on the basis of the salinity regime (Whittaker, ibid).

ASSEMBLAGE 1 - THE EAST FLEET 'RESTRICTED MARINE' FAUNA.

The first assemblage is characterised by large numbers of marine 'phytal' (living on fronds of algae and Zostera) species which slowly die out northwestwards with distance from the sea, lowering of salinity and disappearance of most marine seaweeds. The western boundary, at the head of Butterstreet Cove (Figure 4), corresponds with the limit of effective tidal influence and the westernmost limit of the last brown-alga to survive the diminution of salinity, Fucus vesiculosus. No difference in the faunas was found between the deeper-water channels, characterised by luxuriant algae, and the shallow areas of Littlesea, characterised by Zostera, although ostracod populations in the former tended to be more plentiful. Assemblage 1 is termed 'restricted marine' because in comparison to Weymouth Bay there is a lower diversity of species. Nevertheless whatever it may lack in species (though over 10 species per station were present in East Fleet in most seasons), the number of individuals in this sheltered environment is very large, 500-1000 specimens per sample on algae (usually 25-30 gms wet) being commonplace.

Phytal species - twenty species were found living on the fronds of algae (mainly green and red filamentous weeds), on Fucus (and its epiphytes), on the epiphytes of Laminaria-holdfasts and on the sea-grass Zostera angustifolia, as follows:

C Xestoleberis rubens Whittaker
C Hirschmannia viridis (O.F. Müller)
C Paradoxostoma pulchellum Sars
C Paradoxostoma sarniense Brady
C Loxoconcha rhomboidea (Fischer)
C Propontocypris pirifera (G.W. Müller)
M Hemicythere villosa (Sars)
M Cythere lutea O.F. Müller
M Paradoxostoma fleetense Horne & Whittaker
M Sclerochilus gewemuelleri Dubowsky
M Xestoleberis nitida (Liljeborg)
R Callistocythere littoralis (G.W. Müller)
R Semicytherura tela Horne & Whittaker
R Basslerites teres (Brady)
R Paracytherois sp.
P Paradoxostoma variabile (Baird)
P Callistocythere badia (Norman)
P Paradoxostoma sp.
P Aurila convexa (Baird)
P Pseudocythere caudata Sars

In the above list and elsewhere in this paper, 'C' is a common species (usually making up 25-100% of the fauna at most stations); 'M' is moderately common (5-24%); R is rare, and 'P' means present (only a few live individuals have ever been found).

The commonest ostracod in East Fleet is X. rubens, a remarkable local phenomenon; not only is it a new species (Whittaker, 1978), but is has also yet to be recorded elsewhere in Britain (it has recently, however, been found in France). It is replaced in Weymouth Bay by another xestoleberid, X. aurantia (Baird). During the period, early summer to late autumn, X. rubens is the dominant species in Assemblage 1, during the remainder of the year, H. viridis predominates. Two other ostracods, S. tela and P. fleetense are new species, whilst P. pirifera and S. gewemuelleri have not been previously recorded from British waters. X. nitida, the characteristic ostracod of the lower-salinity Assemblage 2 (see below) is found only in Littlesea on Zostera, where the population co-exists with X. rubens, then gradually replaces it northwestwards.

_ _thic species - a further twelve species live either in the non-toxic sediment along the landward shore, in the sediment trapped by the holdfasts of algae, or in the extensive rootmass of the Zostera plant. Nothing can live in the highly reducing organic silts that floor most of the bed of the Fleet above the Narrows. Only 10-20 specimens per sample were found, very low in comparison to the phytal populations; these benthic ostracods, it is thought, feed off algal detritus. The species are as follows:

C Cytherois fischeri (Sars)
C Leptocythere castanea (Sars)
C Leptocythere lacertosa (Hirschmann)
M *Leptocythere macallana (Brady & Robertson)
M *Semicytherura sella (Sars)
M *Leptocythere porcellanea (Brady & Robertson)

R Leptocythere psammophila Guillaume
R *Semicytherura cornuta (Brady)
R *Elofsonia baltica (Hirschmann)
R *Elofsonia pusilla (Brady & Robertson)
R Cytherois sp.
P *Pontocythere elongata (Brady)

Those marked with an asterisk are marine benthic forms and probably cannot withstand salinity reductions below 25°/oo, the remainder are typical estuarine species and are known to tolerate salinities from normal marine down to almost freshwater. The distribution of C. fischeri in Littlesea is curious as it appears to be confined to sediment in the landward littoral fringe, whilst in the West Fleet Assemblage it is very common throughout, associated with Zostera.

ASSEMBLAGE 2 - THE WEST FLEET FAUNA

This assemblage, covering an area from beyond Butterstreet Cove to Shipmoor Point, is characterised by a smaller number of species, both phytal and benthic, and by few individuals except in the summer months. Here the main limiting parameter is the lower salinity (generally 12-30°/oo). It is the realm of the Zostera and Ruppia beds, with their associated mat of 'flannel weed' (Burrows, ibid). The ostracod population is at its maximum in summer, but when the sea-grass dies back in late autumn, very little microfauna can survive except in a few areas of stable oxygenated sediment and green-algae, mainly along the landward shore. In winter the main population of X. nitida appears to migrate into Littlesea, where the salinity is lower than normal, the algae are richer and the competition is less.

Phytal species - there are only two indigenous species which live on the Zostera fronds and their epiphytes in West Fleet, these are:

C Xestoleberis nitida (Liljeborg)
C Cytherois fischeri (Sars)

However in late spring and summer, when salinities are higher, several phytal species from the East Fleet fauna (Assemblage 1) migrate into West Fleet, though never in large numbers, they are:

Xestoleberis rubens Whittaker
Hirschmannia viridis (O.F. Müller)
Loxoconcha rhomboidea (Fischer)
Propontocypris pirifera (G.W. Müller)

Benthic species - Five species live in the Zostera rootmass and non-toxic sediment along the landward shore:

C Cytherois fischeri (Sars)
C Leptocythere castanea (Sars)
C Leptocythere lacertosa (Hirschmann)
M Elofsonia baltica (Hirschmann)
R Cyprideis torosa (Jones)

C. fischeri, therefore, lives both in the flannel-weed of the Zostera-beds and in the sediment of the shore. Of the two species of Leptocythere, L. lacertosa is confined entirely to the landward shore, as it is throughout the Fleet, extending even into the Abbotsbury Embayment (see below), while L. castanea, in comparison, lives associated with the Zostera community.

ASSEMBLAGE 3 - THE ABBOTSBURY BRACKISH FAUNA

The ecology of the Abbotsbury Embayment, with salinities between 3 and 25°/oo, large expanses of deoxygenated mud, Phragmites reedbeds, and perennial freshwater dilution from the Millstream and associated drainage channels, is most like a typical estuary of any of the environments found in the Fleet. It is therefore, not surprising that the ostracod fauna is marked by the appearance, for the first time in large numbers, of the truly brackish estuarine species, Cyprideis torosa and Leptocythere ilyophila (for a review of the ecological significance of these species, see Whittaker, 1981). Seven species were present in Assemblage 3, as follows:

C Cyprideis torosa (Jones)
C Leptocythere ilyophila (Hirschmann)
C Leptocythere lacertosa (Hirschmann)
C Elofsonia baltica (Hirschmann)
R Leptocythere castanea (Sars)
P Cytherois fischeri (Sars)
P Xestoleberis nitida (Liljeborg)

None of the marine benthic forms of Assemblage 1 had survived, while exclusively phytal species (e.g. X. nitida) were at a minimum.

In such an environment the puzzling omission of the low-salinity brackish species, Loxoconcha elliptica Brady, found virtually ubiquitously in estuaries throughout Europe (Whittaker, 1981), is hard to explain. This is particularly so since thousands of its calcareous shells and disarticulated valves have been found in the sediment of the Abbotsbury Embayment and the shore stations of West Fleet. It has never been found live at the present day despite a close search for its possible habitat. A clue to its disappearance may lie in a similar more widespread presence of dead shells of C. torosa, in comparison to its live distribution. Perhaps at some time in the historic past the Fleet presented a much more widespread brackish environment, at least in West Fleet, than today. Whether this can be placed as recently as before the building of Portland Harbour (pre-1850), when the tidal inlet at Smallmouth may have been perhaps more susceptible to silting is debatable. Under such conditions, the Fleet could have been cut off for long periods from the sea, becoming brackish, even hypersaline and stagnant. There is, however, no written evidence, as far as I am aware, to support this hypothesis.

THE FISHES OF THE FLEET

M Ladle
F.B.A. River Laboratory
East Stoke, Wareham, Dorset

At least 23 species of fish have been recorded from the Fleet. The most abundant forms are probably euryhaline species, tolerant of a wide range of salinity conditions. These include, the eel Anguilla anguilla L. a catadromous species which migrates to the sea for spawning purposes. In a similar category are the flounder Pleuronectes flesus (L.)*, the thick lipped grey mullet Crenimugil labrosus (Risso) and the bass Dicentrarchus labrax (L.)*. Adult bass are said to occur in the lower part of the Fleet between the Bridging Camp and Ferry Bridge with large fish present in the Narrows in July and August. There is also a report of supposed spawning of large numbers in the upper reaches of the Fleet from Herbury to Langton Herring in about mid March (Cook W.C.). This is not consistent with the observations of Kennedy & Fitzmaurice (1972) on the coast of Ireland where the main spawning is in May near river mouths or areas of coastal "shoal water".

Cook mentions the occurrence, presumably in the lower Fleet, of three species of wrasse Labrus bergylta Ascanius*, Crenilabrus melops (L.)* and Crenilabrus rupestris (L.), also the sticklebacks Gasterosteus aculeatus L. and Spinachia spinachia (L.)*, the sand smelt Atherina presbyter Val.*, pipe fishes Syngnathus acus L.*, Syngnathus rostellatus Nilsson and Entelurus aequoreus (L.), butterfish Pholis gunnellus (L.), Blennius pholis L.*, a goby, presumably Pomatoschistus microps (Krøyer) and a "cottus", probably Taurulus bubalis (Euphrasen).

In addition to the above there are records, from the Ferrybridge region, of pollack Pollachius pollachius (L.)*, black bream Spondyliosoma cantharus (L.)*, conger Conger conger (L.), dragonet Callionymus lyra L.* and sand eels probably Ammodytes tobianus L. which is abundant in Weymouth Bay. Species marked with an asterisk have been confirmed in the Fleet by the author since 1970.

It is probable that a number of other fish species also occur in the Fleet and, in particular, that large numbers of fry and young fish may occupy the shallow areas in the summer months.

BIRDS OF THE FLEET AND CHESIL BEACH

This information has been abstracted by J FitzPatrick from the detailed account with species distribution maps provided by J Fair of the Abbotsbury Swannery and D Moxom, Tern Warden of the Chesil Beach.

The Chesil Beach, the shoreline of the Fleet and the waters of the Fleet itself are very important to large numbers of bird species. The area is used mainly by wintering flocks of waterfowl and waders and species on migratory passage. The ringing programme of waterfowl at the Abbotsbury decoy - one of the oldest in Britain built in 1655 - shows that some of the birds come from Arctic Russia, Finland, Norway and Sweden.

The area is also important to a lesser extent for breeding species. The most important breeding species is the Little Tern. D. Moxom emphasises that the Chesil's present day population of Little Tern and to some extent Common Tern (except Scilly) and Ringed Plover (except pockets in N. and S. Devon) are the only representatives of their species in the S.W. Peninsula. A reported reduction of the Little Tern numbers of Chesil Beach is said to be related to disturbance associated with a long established mackerel fishery, the training area of the Royal Engineers Bridging Camp and presence of the Royal Navy helicopter training establishment whose machines fly low over the beach. Increased tourism and natural predation also occur (see Tern Warden's Reports 1974-80). This international site has been wardened since 1974, organised by Strangway's Estate and D.N.T.

The whole area offers a gradient of conditions, bays and inlets which are sheltered, mud flats which are tidal and less disturbed areas of shingle. J. Fair has stressed that for successful breeding, a good wintering area with abundant food, readily available without too much disturbance is essential. Six to seven months of the annual cycle may be involved.

Food supplies in the Fleet include Algae, especially Ulva, Zostera and Ruppia, Crustacea, molluscs, polychaetes, and small fish (in the Fleet and in the Channel beyond). D. Moxom has given a list of food items taken by the Terns and Waders and J. Fair has included feeding information on many of the waterfowl. Clearly, the abundant food supply is important to the continued survival of the bird species of the area.

The table in the appendix (1) has been constructed from the information given in J. Fair's maps, which show the distribution of 49 species of birds on the Fleet. For simplicity, the area has been arbitrarily divided into West, Mid and East Fleet.

1. West Fleet - Swannery to Rodden Hive - where no boats are allowed.
2. Mid Fleet - Rodden Hive to Lynch Cove - where shooting is allowed.
3. East Fleet - Lynch Cove to Ferry Bridge and Portland Harbour.

Table 1. The number of bird species using the 3 areas of the Fleet

Group of Bird	Nos. of species using areas of Fleet			Total nos. of species
	West	Mid	East	
Divers	1	1	1	3
Grebes	5	1	2	5
Ducks	19	12	8	22
Geese	2	1		3
Swans	3	3	1	3
Waders	13	17	7	25
Coot	1	1		1
Totals	44	36	20	62

Apart from these groups, 12 species of Gulls and Terns, 12 Birds of Prey and 3 other species use the area. The 59 species that occur in the Swannery at Abbotsbury and around the shore line of the Fleet are listed in the appendix 3.

In all, about <u>150 species of birds</u> have been recorded for the area in recent years.

Table 1 gives some idea of the importance of the Western areas of the Fleet to a large number of species and individual birds. Some species, however, tend to occur at the eastern end of the Fleet and Portland Harbour, e.g. Eider, Slavonian Grebe, Great Northern Diver.

In the 1980 Spring issue of the R.S.P.B. Magazine, a table of the numbers of wintering waterfowl was given for 13 of the Society's reserves. The numbers given were the highest counts of each species 1974-79. J. Fair provided the highest count 1974-81 for the Fleet as a comparison. This table (in appendix 2) shows that the Fleet compares very favourably with these other important ornithological sites.

Mute Swans of the Abbotsbury Swannery

This ancient colony has been owned by the Fox Strangways since 14th Century and is unique for several reasons. It is the only such colony in the U.K. It is relatively isolated and there is little mixing with other swan populations. Compared to the Mute Swans of other habitats such as riversides and lakesides, the Abbotsbury birds are not tempted to fly in search of their food which is artificially supplemented. The cygnets are artificially reared in special pens and as a result, they have a higher survival rate and the Mute Swans on the Fleet therefore are not declining. Elsewhere in Britain a decline has been reported.

The numbers of the Abbotsbury Swans fluctuate around 900. Dr C. Perrins of the Edward Grey Institute, Oxford and Dr M. Ogilvie of the Wildfowl Trust are carrying out studies on the breeding success of the swans at Abbotsbury as part of their research on the species. They have also found that there are physiological differences in the Fleet Swan population when compared with those birds examined in the Thames and Midlands.

Appendix 1

BIRDS USING THE FLEET and CHESIL BEACH

(from data supplied from J. Fair and D. Moxom)

	Status	Species	Max. Nos. (1974-81)	FLEET AREAS West	Mid	East
DIVERS and GREBES	W	Great Northern Diver	(singles)			X
	W	White-billed Diver	1(1975)			X
	W	Red-throated Diver		X	X	
	W & R	Great crested Grebe	6	X		
	W	Red-necked Grebe		X		
	W	Slavonian Grebe		X		X
	W	Black-necked Grebe		X		
	W	Little Grebe	24	X	X	X
		Cormorant	40			
		Heron	30			
DUCKS	W & R	Mallard	400-	X	X	
	W	Teal	400+	X	X	
	W	Garganey	2	X		
	W	Gadwall	143	X	X	
	W	Wigeon	5000+	X	X	
	W	Pintail	260	X	X	
	W	Shoveler	250	X	X	
	W	Red-crested Pochard	7	X		
	W	Scaup	40+	X	X	
	W	Tufted Duck	400-	X	X	
	W	Pochard	600+	X	X	
	W	Ferruginous Duck		X		
	W	Goldeneye	160+	X	X	X
	W	Long-tailed Duck (rarest duck making flat its regular winter quarters)	5	X		X
	W	Velvet Scoter (1 pair once)				X
	W	Common Scoter		X		X
	W	Eider (occasional)				X
	W	Red-breasted Merganser	100+	X	X	X
	W	Goosander	3			
	W	Smew (sporadic)		X		X
	W & R	Shelduck	100+	X	X	X
	W	Ruddy Duck		X		

Appendix 1 (Cont)

	Status	Species	Max. Nos. (1974-81)	FLEET AREAS West	Mid	East
GEESE and SWANS	W	White fronted Goose	100-	X		
	W	Pink footed Goose	1			
	W	Brent (dark bellied)	300-	X	X	
	R	Mute Swan	1238	X	X	X
	W	Whooper Swan	6	X	X	
	W	Bewick Swan	6	X	X	
	W	Coot	3500	X	X	
WADERS	R & P	Oyster Catcher	22	X	X	X
	R	Lapwing	1500+	X	X	
	R & P	Ringed Plover	60+	X	X	X
	W	Grey Plover	94	X	X	X
	W	Golden Plover	200+	X		
	R & P	Turnstone	39			
	P	Snipe	200+	X		
	W	Jack Snipe				
	P	Curlew	2			
	P	Whimbrel	15	X	X	
	P	Black-tailed Godwit	4		X	
	P	Bar-tailed Godwit	32	X	X	
	P	Common Sandpiper				
	R	Redshank	46	X	X	X
	P	Spotted Redshank		X	X	
	P	Greenshank		X	X	X
	P	Long-billed Dowitcher			X	
	P	Knot	3		X	
	P	Purple Sandpiper			X	X
	P	Little Stint		X	X	
	W & P	Dunlin	1000+		X	X
	P	Curlew Sandpiper			X	
	P	Ruff	4			
	P	Avocet	3		X	
	P	Grey Phalarope		X		
		Totals		44	35	20

W = Wintering P = Passage R = Resident

Other species -

GULLS and TERNS	Great black-backed Gull	also Great Skua
	Lesser " "	Fulmar
	Herring Gull	
	Common Gull	
	Black headed Gull	
	Common Tern	35 pairs 1980 (1st count 1917 = 1000 pairs)
	Artic Tern	
	Roseate Tern	
	Little Tern	65 pairs 1980 (1st count 60 pairs 1918) 1967 National Survey = 205 pairs.
	Sandwich Tern	
	Little Auk	(2 strandings in Swannery in last 6 years)
BIRDS of PREY	Buzzard	
	Sparrow Hawk	
	Marsh Harrier	
	Hen Harrier	
	Osprey	
	Hobby	
	Kestrel	
	Merlin	
	Barn Owl	
	Little Owl	
	Tawny Owl	
	Short-eared Owl	

Breeding species on Chesil Beach

A. Regulars

Little Tern	Oyster Catcher
Common Tern	Skylark
Ringed Plover	Linnet
Redshank	Reed Bunting
Lapwing	Meadow Pipet

B. Irregular/or not at present

Sandwich Tern	Blackheaded Gull
Roseate Tern	Wheat ear
Arctic Tern	Pied Wagtail
Great Black Backed Gull	

COMPARISON OF THE FLEET WITH THE PRINCIPAL RSPB RSERVES FOR WINTERING WATERFOWL

This table demonstrates the relative importance of the principal wetland reserves for various wintering waterfowl, bearing in mind their habitats and geographical location.

Notes:

1. Data are the *highest* count of each species for the winter months, October-March during the years 1976-79. Some figures are estimates.
2. The highest count may be exceptional in some cases, *eg* during severe conditions. A few counts are of flocks migrating over but not alighting on a reserve.
3. In some cases higher counts of a few species are recorded during April-September.
4. Figures in italics exceed one per cent of the north-west European wintering population of that species and are therefore of acknowledged international importance.
5. The new Gayton Sands (Dee Estuary) reserve qualifies but comparable data are not yet available. Titchwell, Insh Marshes and Blacktoft Sands also qualify, but have had to be omitted owing to lack of space.

The Fleet: Maximum recorded 1974–1981

	Arne	Dungeness	Elmley Marshes	Fairburn Ings	Hornsea Mere	Leighton Moss and Morecambe Bay	Ouse Washes	Ynys-hir	Havergate Island	Loch of Strathbeg	Lochwinnoch	Snettisham	Minsmere	The Fleet
Great crested grebe	30	24	17	29	18	60	19	1	2	2	18	21	8	6
Cormorant	30	35	60	4	66	12	75	55	15	80	17	28	49	40
Mute swan	6	27	30	89	78	16	331	5	10	426	28	15	26	*1,238*
Bewick's swan	35	60	7	22	11	120	2,303	46	150	—	—	92	58	6
Whooper swan	—	—	—	60	7	20	92	9	—	502	42	19	2	0
Pink-footed goose	—	—	—	107	90	240	39	270	—	*8,500*	46	*4,540*	38	1
Greylag goose (wild)	—	—	—	—	—	405	—	3	—	*7,500*	800	—	—	–
Brent goose	300	31	700	—	16	3	7	1	500	—	—	*1,415*	*2,047*	300–
Shelduck	347	19	*3,000*	14	18	1,200	74	72	280	95	2	*3,075*	230	100+
Wigeon	400	520	*10,000*	82	770	1,360	*26,532*	3,200	3,560	2,300	320	2,590	1,500	*5000+*
Gadwall	9	33	56	53	110	40	391	2	80	3	2	48	200	143
Teal	185	708	*4,000*	600	370	970	*2,755*	420	794	750	146	248	802	400+
Mallard	70	1,510	2,905	1,455	2,400	526	5,406	1,070	965	2,500	476	2,015	480	400–
Pintail	75	50	18	8	125	285	*1,237*	25	139	3	5	434	40	260
Shoveler	10	150	650	268	180	220	513	26	150	19	80	32	201	250
Pochard	70	400	95	407	350	40	*3,055*	92	30	2,050	1,114	130	45	600+
Tufted duck	200	200	30	552	670	46	1,165	5	35	1,900	812	157	27	400–
Goldeneye	30	30	7	69	220	24	15	37	9	450	67	71	20	160+
Red-breasted merganser	120	33	22	2	2	80	2	21	2	4	—	58	10	100+
Goosander	3	24	—	42	20	18	11	2	1	109	16	5	7	3
Coot	—	390	125	1,100	2,000	220	2,300	13	33	2,000	800	498	243	*3,500*
Oystercatcher	500	400	249	2	1	*11,240*	12	450	35	60	7	*12,900*	8	22
Ringed plover	4	14	*400*	4	5	130	24	5	170	26	—	76	30	60+
Grey plover	50	61	*3,300*	9	4	32	—	30	30	19	—	634	15	94
Golden plover	1	820	1,200	29	145	1,500	2,126	7	110	300	35	600	50	200+
Lapwing	666	215	7,000	3,000	1,000	2,740	5,835	720	300	1,500	400	1,200	1,200	1500+
Knot	6	70	*7,000*	4	—	*24,000*	1	25	35	150	3	*32,000*	49	3
Dunlin	1,550	300	10,000	38	25	*23,400*	593	1,200	1,000	300	6	13,000	900	1,000+
Ruff	—	113	38	15	1	--	250	6	8	3	1	1	55	4
Snipe	20	50	100	300	75	350	3,000	16	15	60	200	18	330	200+
Black-tailed godwit	150	4	450	7	1	3	196	3	100	—	—	5	170	4
Bar-tailed godwit	41	12	80	1	1	2,000	1	57	29	4	—	3,880	106	32
Curlew	240	200	2,000	18	5	160	6	680	150	1,400	90	1,292	12	2
Redshank	400	50	1,700	25	9	1,687	156	220	250	250	4	3,006	120	46
Turnstone	5	16	48	—	—	450	2	4	7	20	—	*760*	15	39
Habitat	Saltmarsh and muddy creeks	Coastal freshwater pits	Flooded pasture and saltmarsh	Freshwater pits and marsh	Shallow coastal lake	Fen mere, saltmarsh and mudflats	Inland flood meadows	Saltings and freshwater pools	Shallow lagoons and saltmarsh	Coastal lake	Shallow lake and marsh	Flooded pits, saltmarsh and mudflats	Brackish lagoons and coastal meres	Brackish lagoon

Table derived, with permission, from Chapman, A 1981. Reserves News. Birds 8(5)52-56

Appendix 3.

List of the birds of the Swannery and the Fleet
supplied by J. Fair (incomplete)

---

* Water rail
* Moorhen
Woodcock
* Collared Dove
* Cuckoo
* Swift
* Kingfisher
* Green Woodpecker
* Great spotted Woodpecker
Skylark
* Swallow
* House Martin
* Sand Martin
* Jackdaw
* Great Tit
* Blue Tit
* Marsh Tit
* Willow Tit
Long tailed Tit
* Bearded Tit
* Tree Creeper
* Wren
Dipper
* Mistle Thrush
* Fieldfare
Redwing
* Blackbird
Stonechat
Whinchat
* Redstart
* Robin
* Cetti's Warbler
* Grasshopper Warbler
* Reed Warbler
* Marsh Warbler
* Sedge Warbler
* Blackcap
* Garden Warbler
* Whitethroat
* Willow Warbler
* Chiff chaff
* Wood Warbler
* Goldcrest
* Firecrest
* Spotted Flycatcher
* Pied Flycatcher
* Dunnock
* Pied Wagtail
* Grey Wagtail
* Yellow Wagtail
* Starling
* Greenfinch
* Goldfinch
Linnet
* Bullfinch
* Chaffinch
Yellowhammer
* Reed Bunting
* House Sparrow
* Tawny Owl
* Heron
* Coot
* Short eared Owl
* Snipe
* Jack Snipe
Wheatear

* = Swannery Birds

REFERENCES

Avebury, Lord (= Lubbock, J.) 1902. The Coast, Chapter 4 of The Scenery of England and the causes to which it is due. London. 534 pp.

Batters, E.A.AL. 1902. A catalogue of British marine algae. London.

Belderson, R.H., Kenyon, H.H. and Stride, A.H. 1971. Holocene sediments on the continental shelf west of the British Isles. ICOS/SCOR Working Party 31 Symposium, Cambridge 1970. The Geology of the East Atlantic Continental Margin, ed. Delany, F.K. 1971. Institute of Geological Sciences Report No. 70/14, pp. 157-170.

Bird, E.C.F. 1971a. A 17th Century attempt to drain the Fleet, Dorset: The County Magazine, pt 17, pp. 8-10.

Bird, E.C.F. 1971b. The lost wall, Dorset: the County Magazine, pt 21, p.25.

Bird, E.C.F. 1972. The Physiography of the Fleet. Proc. Dorset Nat. Hist. Archaeol. Soc., 93, (for 1971), pp. 125-131.

Broekhuysen, C.J. 1935. The extremes in the percentage of dissolved oxygen in which the fauna of a Zostera field in the tide zone at Nieuwediep can be exposed. Arch neerl. Zool., 1, pp. 339-346.

Carr, A.P. 1969. Size grading along a pebble beach: Chesil Beach, England. Journal of Sedimentary Petrology, 39, 297-311.

Carr, A.P. 1971. Experiments on longshore transport and sorting of pebbles: Chesil Beach, England. Journal of Sedimentary Petrology, 41, pp. 1084-1104.

Carr, A.P. 1980. Chesil Beach and adjacent area: outline of existing data and suggestions for future research. Report to the Dorset County Council and Wessex Water Authority. Institute of Oceanographic Sciences, Ref. Internal Document 94, 21 pp. plus tables, appendices and figures.

Carr, A.P. & Blackley, M.W.O. 1973. Investigations vearing on the age and development of Chesil Beach, Dorset and the associated area. Trans. Inst. Br. Geogr., 58, pp. 99-111.

Carr, A.P. & Blackley, M.W.L. 1974. Ideas on the origin and development of Chesil Beach, Dorset. Proc. Dorset Nat. Hist. Archaeol. Soc., 95 (for 1974) pp. 9-17.

Carr, A.P. & Gleason, R. 1972. Chesil Beach, Dorset and the cartographic evidence of Sir John Coode. Proceedings Dorset Natural History and Archaeological Society, 93, pp. 125-131.

CEGB, 1968. Report on Hydrographic Survey of the Fleet and the effects of the abstraction of colling water from the Fleet. (Investigation of prospective Nuclear Power Station sites - Portland Harbour and Tidmoor Point). Part 1 - Hydrographic Survey. Central Electricity Generating Board, London (Confidential). 10 pp. plus charts.

Clapham, A.R., Tutin, T.F. and Warburg, E.F. 1962. Flora of the British Isles. Cambridge University Press, x/vii, 1269 pp. 2nd Edit.

Coode, J. 1853. Description of the Chesil Beach, with remarks upon its origin, the causes which have contributed to its formation and upon the movement of shingle generally. Minutes of Proceedings Institution of Civil Engineers, 12, pp. 520-546.

Cotton, A.D. 1910. On the growth of Ulva latissima in water polluted by sewage. Kew Bull., 1, 15-19.

Cotton, A.D. 1911. On the growth of Ulva latissima in excessive quantity, with special reference to the Ulva nuisance in Belfast Lough. Royal Commission on sewage disposal 7th Report II.

Dandy, J.E. 1958. List of British vascular plants. British Museum (Nat. Hist.), London. xvi plus 176 pp.

Dandy, J.E. 1958. (Appendix IV) H.M.S.O. London.

Draper, L. 1977. Waves at Shambles Light Vessel, Portland Bill, during 1968 in A Voyage of Discovery, ed. Angel, M.V., Pergamon Press, 696 pp.

Farnham, W.F. & Irvine, Linda M. 1968. Occurrence of unusually large plants of Grateloupia in the vicinity of Portsmouth. Nature, 219, No. 5155, 744-746.

Good, R. (1948) A Geographical handbook of the Dorset Flora. Dorset Natural History and Archaeological Society.

Hepburn, I. 1966. Flowers of the coast. New Naturalist. Collins.

Helyar, S. 1977. Analysis of vegetation in relation to the main physical factors of an area of the Chesil Beach, West Bexington, Dorset. Special study for Teachers Cert. in Teachers Cert. in Environmental Science. Dorset Institute of Higher Education, Weymouth.

Hibberd, D.J. Observations on the ultra structure of the Cryptomonad endosymbiont of the Red Water Cilitate Mesodinium rubrum. J. Mar. Biol. Ass. U.K.. 1977. 57, 45-61.

Ho, Y-B. 1975. The use of Ulva lactuca as an indicator organism for marine pollution. Ph.D Thesis, University of Liverpool.

Holme, N.A. & Bishop, G.M. Report on the sediment shores of Dorset, Hampshire & Isle of Wight. N.C.C. (Confidential).

Hydraulics Research Station, 1969. Bridport sewage outfall: a study of the security. Report No. Ex. 441 on behalf of Land and Marine Contractors Ltd., 12 pp. plus appendices, tables and figures.

Hydraulics Research Station, 1979. West Bay, Bridport, Dorset: a sea defence and coast protection study. Report No. Ex.863 on behalf of the Wessex Water Authority, 12 pp. plus tables and figures.

The Right Hon. the Earle of Ilchester, OBE. The Abbotsbury Swannery. D.N.H.A.S. Feb. 1930.

Jolliffe, I.P. 1979. West Bay and the Chesil Bank, Dorset. Report to the West Dorset District Council and the Dorset County Council, 86 pp. plus appendices and figures.

Kenyon, H.H. and Stride, A.H. 1970. The tide-swept continental shelf sediments between the Shetland Isles and France. Sedimentology, 14, pp. 159-1973.

LeBlond, P.H. 1979. Forced fortnightly tides in shallow rivers. Atmosphere-ocean 17, 253-264.

Matthews, E.R., 1922. Coast Erosion and its prevention. Journal Royal Society of Arts, 70, pp. 447-89 and pp. 491-505.

Moore, J.A. The current status of the Characeae (Stoneworts) in the British Isles. Watsonia, 1979, 12, 297-309.

Murray, J.W. 1966. A study of the seasonal changes of the watermass of Christchurch Harbour, England. J. Mar. Biol. Ass. U.K., 46, pp. 561-578.

Neate, D.J.M. 1967. Underwater pebble grading of Chesil Bank. Proceedings of Geological Association, 78, pp. 419-426.

Parke, M. & Dixon, P.S. 1976. Check-list of British marine algae, Third Revision. J. mar. biol. ass. U.K. 56, 527-592.

Pingree, R.D. 1978. The formation of the Shambles and other banks by tidal stirring of the seas, Journa. Marine Biological Association U.K. 58, pp.211-26.

Radcliffe, D.R. 1972. Ecology of salt marshes and sand dunes. Chapman and Hall.

Radcliffe, D.R. ed. 1977. A nature conservation review. Camb. Univ. Press.

Poulter, P.A. 1979. Unpublished M.Sc. Thesis, University of Southampton, Department of Oceanography.

Robinson, I.S. 1981. A tidal flushing model of the Fleet - an English tidal lagoon. Submitted to Jour. Est. & Coastal Mar. Sci.

Robinson, I.S., Warren, L. and Longbottom, J.F. 1981. Sea level fluctuations in the Fleet, and English tidal lagoon. Submitted to Jour.Est. & Coastal Mar. Sci.

Seaward, D.R. 1978. The Marine Molluscs of the Fleet, Dorset. Proceedings of the Dorset Natural History and Archaeological Society. Vol. C.

Smith, G.R. & Moryson, C.J. 1977. A comparison of the distribution of Clostridium botulinum in soil and in lake mud. J. Hyd. Camb. 1977, 78, 39.

Smith, G.R., Milligan, R.A. and Moryson, C.J. Clostridium botulinum in aquatic environments in Great Britain and Ireland. J. Hyd. Camb. (1978) 80, 431.

Sturdy, R. 1972. The Fleet Survey.

Tansley, A. 1939. Vegetation of the British Isles. C.U.P. (includes reference to lichen work by Watson 1922).

Waite, T.D. & Gregory, C. 1969. Parameters affecting the growth of Ulva latissima in a polluted estuary. Proc. N.E. Region Antipollution Conference. pp. 12-15.

Waite, T.D. & Mitchell, R. 1972. The effect of nutrient fertilisation on the benthic alga Ulva lactuca. Botanica Marina. pp. 151-156.

Whittaker, J.E. 1972. The taxonomy, ecology and distribution of recent brackish and marine Ostracods from localities along the coast of Hampshire and Dorset (Christchurch Harbour, the Fleet and Weymouth Bay). 2 vols. Unpublished Ph.D Thesis, University of Wales. 643 pp.

Whittaker, J.E. 1978. On Zestoleberis rubens Whittaker sp. no. Stereo-Atlas Ostracod Shells, vol. 5, pp. 35-44.

Whittaker, J.E. 1980. The Fleet, Dorset - A seasonal study of the watermass and its vegetation. Proceedings of the Dorset Natural History and Archaeological Society, 100, 73-99.

Whittaker, J.E. 1981. The living Ostracoda of Christchurch Harbour, Dorset. In: Neale, J.W. & Brasier, M.D. (editors), Microfossils from Recent and fossil Shelf Seas. Ellis Horwood. (In press).