CHANNEL TUNNEL SUBLITTORAL SURVEY

Elizabeth and Christopher Wood

MARINE CONSERVATION SOCIETY

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MARINE CONSERVATION SOCIETY. 4, Gloucester Road, Ross-on-Wye, Herefordshire HR9 5BU.

Contents

Summary

Copt Rocks, just to the east of Folkestone, comprise Greensand rocks of the Folkestone Beds. Elsewhere the shallow sublittoral fringe in the Folkestone-Dover area consists of sand, shingle, or chalk bedrock and boulder scree. All of these substrata grade into a silty-gravel sediment plain, on which there are areas of rough, rocky ground. The water throughout the area is fairly turbid, and currents are strong, especially beyond about 300 m from the shore.

The subtidal areas closest to the existing tunnel entrance and the proposed reclamation are off Shakespeare Cliff and Abbot's Cliff. From the low tide mark on this stretch there is a continuous belt about 250-300 m wide which consists of chalk bedrock overlain with chalk boulders and some flint cobble. Boulders closest to the shore are up to about 2 m high, those furthest out are of lower profile. In places there are flint cobbles and patches of coarse sand or finer deposited material. Silt is present, especially on the animal turf growing on the boulders, but some of the flat chalk bedrock is scoured clean. This essentially rocky sea-bed gradually gives way to a flat sediment bottom as the chalk bedrock is covered by an increasingly thick layer of deposited material consisting of fine silty sand with variable admixtures of small pebbles and shell debris.

Chalk boulders closest to the shore are often dominated on their upper surfaces by red algae and by the kelps *Laminaria digitata* and *L. hyperborea*. The sides of the boulders are generally covered with animal turf consisting of various hydroid species, amongst which are sponges, ascidians and anemones. Some surfaces are dominated by barnacles and young mussels. The boring bivalve *Hiatella arctica* is abundant in these boulders, and the holes provide a refuge for worms and small crabs. The flat bedrock between the boulders and outcrops supports a range of animals, the most obvious being the anemone *Sagartia troglodytes*, the piddock *Pholas dactylus*, and (at Abbot's Cliff in particular), mats of the ascidian *Molgula manhattensis*. Potting for crabs is carried out in these areas.

Lower profile boulders and bedrock outcrops are found beyond the kelp zone, which ends approximately 120 m from the low tide mark at depth of about 3 m below chart datum (6.5 m below mean water level). These rocky surfaces support some red algae, but are increasingly dominated by the sponge *Halichondria panicea*, the Plumose Anemone *Metridium senile*, the soft coral *Alcyonium digitatum* and the erect sea-mat *Flustra foliacea*. Each of these species can withstand some siltation, and all do well in situations where tidal flow is moderately strong.

The sediment bottom supports an infauna of worms and bivalve molluscs, with brittle-stars common on the surface. Trawling for flatfish occurs in these areas.

A monitoring site was established in a defined area in the sublittoral where the benthic communities might be affected by environmental change brought about as a result of the construction of the Channel Tunnel. The communities associated with the inshore rocky habitats in the vicinity of Shakespeare and Abbot's Cliff are most likely to be affected because: a) they are closest to the proposed workings, b) tidal flow is less strong inshore (therefore sedimentation more likely) and c) the biota is adapted for life on hard-bottoms, and probably is more sensitive to increased turbidity and/or sedimentation than the biota of the soft sea-bed.

The shallow zone off Abbot's Cliff and Shakespeare Cliff is especially important because sublittoral chalk habitats are rare in the eastern English Channel, yet support a wide range of species not found on the surrounding sediment sea-bed.

At present, the major impacts on the sublittoral environment in the Folkestone-Dover area are from the sewage outfalls at Copt Point and Dover. The outfall at Copt Point has resulted in a benthic community completely dominated by mussels and starfish. In addition, some disturbance has undoubtedly been caused by a recent cable-laying operation off Folkestone, but the extent of the damage is unknown. However, the sublittoral area off Abbot's Cliff and Shakespeare Cliff appears, at present to be undamaged, and relatively undisturbed.

With regard to sublittoral habitats and communities, the major problems which may arise during construction and operation of the Channel Tunnel are:
a) loss/alteration of the inshore chalk rock habitats off Abbot's Cliff and Shakespeare Cliff, as a result of the reclamation itself, and construction of the retaining walls.
b) damage/alteration to sublittoral communities as a result of increased turbidity due to silt generated during the construction phase, or fines escaping from the reclamation area.
c) smothering of benthic flora and fauna by deposited sediments.
d) damage/alteration to benthic communities adjacent to outfalls carrying waste water from, for example, the working platform, Tunnel and Terminal facilities.

1. Introduction

This report contains the results of a survey of shallow sublittoral habitats carried out for the Nature Conservancy Council in the area adjacent to the proposed Channel Tunnel. The aim was to provide a broad analysis of the different community types in the area, especially those associated with rocky substrata. In addition, detailed studies were carried out at a monitoring site established off Shakespeare Cliff.

An assessment is made of the biological interest of the sublittoral area, in comparison with similar habitats elsewhere in south-east England. The types and degree of disturbance to which the marine environment has already been subjected are described. Finally, the possible impacts on sublittoral habitats and communities during construction and operation of the Channel Tunnel are discussed.

Survey Team

The following people, all members of the Marine Conservation Society, formed the underwater survey team.

Graham Ackers
Dave Featherbe
Robert Irving
Bill Farnham
Dick Manuel
Alice Nunn
Harry Ryall
Chris Spurrier
Christopher Wood
Elizabeth Wood

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During the survey, and the preparation of this report, the following people were consulted, and provided helpful information: Graham Ackers (Marine Conservation Society), Keith Duff (NCC), Bill Farnham (MCS), Sarah Fowler (NCC), Keith Jury (Southern Water Authority), Dick Manuel (MCS), Jim Wharfe (SWA), Trevor Whyatt (MAFF). We would also like to thank Dave Featherbe and the Folkestone Motorboat and Yacht Club for providing facilities and support for the diving team.

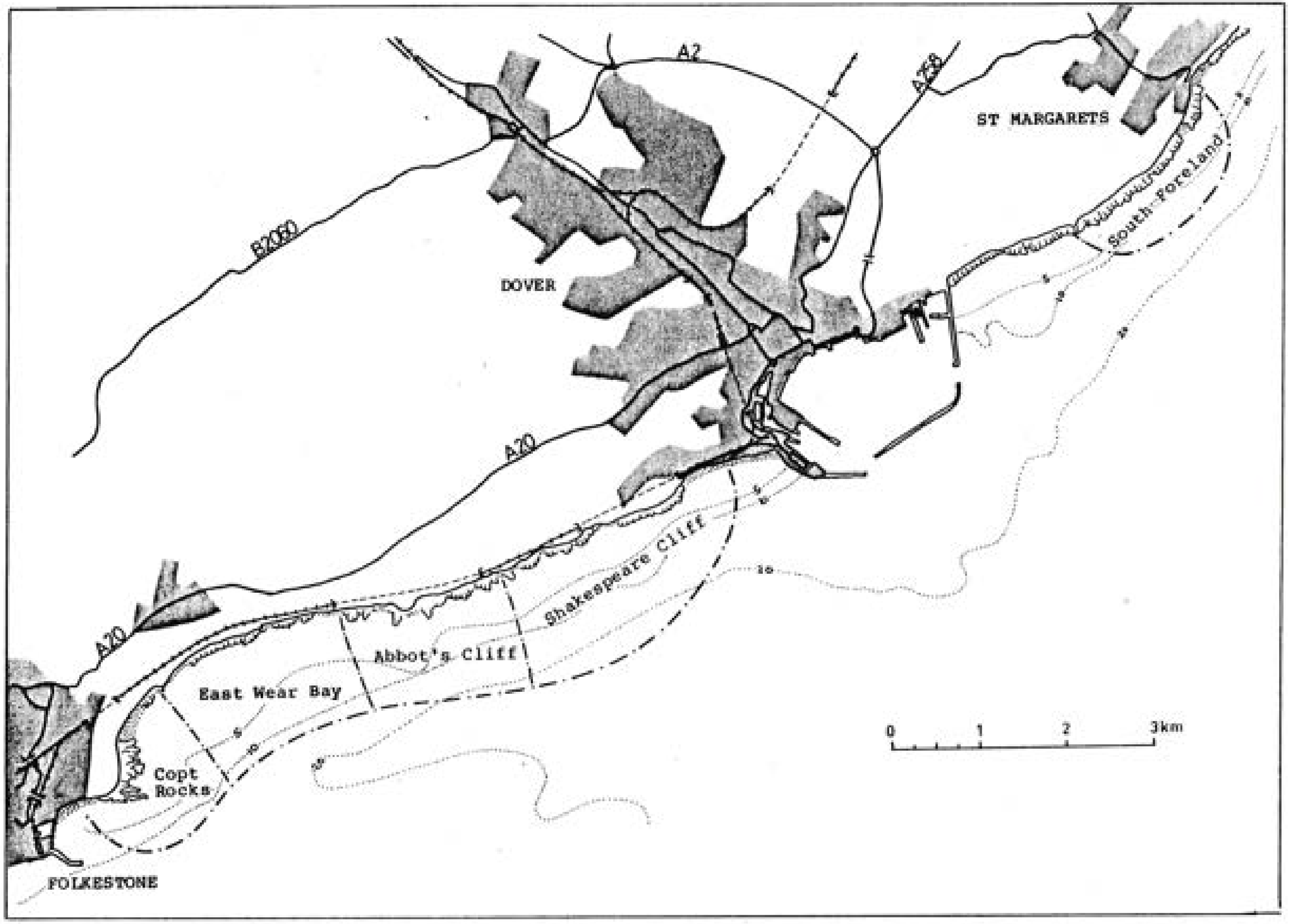


Figure 1. Location of Study Area

2. The Physical Environment

2.1. SEA-BED TOPOGRAPHY

The sea-bed between Folkestone and Dover is characterised by a gently-sloping profile, and an absence of any cliffs or steep slopes. Depth contours are shown in Figure 1.

2.2. GEOLOGY

2.2.1. Introduction

At Copt Point, Folkestone, the topmost part of the Lower Greensand is exposed as the Folkestone Beds. These outcrops are overlain by Gault Clay, which is also exposed in East Wear Bay. Elsewhere, the area is characterised by Chalk cliffs facing on to a foreshore of fine sand, shingle, cobbles and small boulders (flint and Chalk) or chalk rock. These features extend into the sublittoral, and are discussed in more detail in 3.1 to 3.3. Although chalk forms much of the sea-bed in the shallow sublittoral, it is not uniform in texture and hardness, and this is discussed in more detail below.

2.1.2. Chalk

The easterly dip of the Chalk strata has resulted in progressively higher beds of the Chalk being exposed in the cliffs and on the shore towards the eastern end of the region. A similar pattern is also seen in the sublittoral.

Upper Chalk, which is almost pure limestone (less than 5% marl and flints) is exposed at South Foreland, but elsewhere is present on the landward side of the cliffs and is mostly absent from the shore. Middle Chalk, which has flints in the upper layers only, and around 5-10% marl, forms the cliffs and foreshore between South Foreland and Dover, and also appears occasionally on the shore and in the sublittoral (see a) below) between Folkestone and Dover, especially where landslips have occurred. However, most of the latter stretch of coastline is characterised by extensive exposures of Lower Chalk. Lower Chalk is often referred to as Grey Chalk or Chalk Marl, because it contains more impurities than the younger, overlying Chalk beds. Overall, it has a clay content of about 10%, but up to 50% in lower strata (Jones, 1981). The Lower Chalk between Folkestone and Dover forms a bed about 76 m thick, and has been divided by Kennedy (1969) into a sequence of 14 bands, which reflect the geological nature of the Chalk, and its fossil content. Again the trend is for the uppermost bands to be exposed at the Shakespeare Cliff end, and the lower bands at, or to the west, of Abbot's Cliff. The basal band (Glauconitic Marl), which is exposed on the top of Copt Point (Kennedy, 1969), rests on the underlying grey and blue clays of the Upper

Gault, and below this is the Lower Greensand of the Folkestone Beds (Jones, 1981).

The bands of Lower Chalk consist of alternating layers of limestone, marl, and clay, which vary in colour, texture and hardness, and so give rise to a variety of noticeably different 'chalk' substrata on the shore and in the shallow sublittoral.

Three main types of chalk substrata were distinguished in the sublittoral area in the vicinity of the proposed Channel Tunnel site:

a) White chalk boulders.
These were widespread in the shallow sublittoral and to at least 300 m offshore off Abbot's Cliff and Shakespeare Cliff, and some were also found in East Wear Bay (eastern end). The texture and hardness of the boulders varied; for example those examined in East Wear Bay were noticeably softer and more crumbly than those at Shakespeare Cliff. The boulders are probably from the Middle or Upper Chalk, and evidently have fallen from the cliffs above. A boulder examined from the shallow sublittoral off Shakespeare Cliff had the typically 'gritty' nature of Middle Chalk, caused by the presence of numerous fragments of calcite fossil bivalve shells, and broken echinoid fossil spines (Duff, pers. comm).

b) Light grey, marly chalk.
This was found as bedrock off Shakespeare Cliff, and was noticeably softer and more easily eroded than the chalk boulders. This is from the topmost part of the Lower Chalk, probably bed 14 of Kennedy (1969). He describes this as 'most accessible below Shakespeare Cliff. It is pale grey and very soft in the cliff, and a pale blue-grey on the foreshore'.

c) Dark, blue-grey clay/marl chalk, with glauconite.
This was noticeably softer than the bed 14 chalk described in b). It was found as bedrock and outcrops off Abbot's Cliff, and is either Glauconitic Marl (the basal unit of the Lower Chalk), or a glauconitic horizon from the basal part of the next band up (Band 2), (Duff, pers. comm.).

2.3. WATER MOVEMENT

2.3.1. Waves

The stretch of coastline between Folkestone and Dover is fairly open, and is affected in particular by winds and waves coming from the south-west, south and south-east. It is clear that the shallow sublittoral fringe is quite frequently affected by wave surge. It has been estimated that wave heights up to about 4 m could occur close to the shore (Anon, 1985a).

2.3.2. Tides

The closest point for which tidal flow figures are available is approximately 600 m outside Dover Harbour (Admiralty Chart Number 1892), where the flow reaches a maximum of 4 knots shortly after High Water Spring (Table 1). Slack periods occur 2 hours before and about 4.5 hours after High Water, and the slowest flow expected is 0.2 knots. Tidal flow is parallel to the shore, and the net transport of beach sediments is from west to east.

Time, relative to High Water, Dover. (hours)		Current Strength Spring tide (knots)	Neap tide (knots)
-6		2.3	1.3
-5	Flow to	2.5	1.4
-4	south-west	2.4	1.3
-3		1.5	0.8
-2	Slack	0.3	0.2
-1		2.3	1.3
High water		3.9	2.2
+1	Flow to	4.1	2.3
+2	north-east	3.5	1.9
+3		2.6	1.4
+4	Slack	1.3	0.7
+5	Flow to	1.1	0.6
+6	south-west	2.2	1.2

Table 1. Tidal flow 600 m seaward of the southern arm of Dover Harbour (position: 51°06'6N; 1°20'4E).

During our survey, dives were made on or within a few days of neap tide, and although tidal flow measurements were not made, it was clear that tidal flow in the study area varied from the predicted pattern at the location above, as follows:

a) Tidal flow within about 300 m of the shore, at all states of the tide, was considerably weaker than further out. This is in line with the suggestion in the Channel Tunnel Group Hydrography Report (Anon, 1985a) that tidal velocities about 125 m out from the existing sea-wall at Shakespeare Cliff are unlikely to exceed 1.5 knots. We found the weakest flow closest to the shore, which suggests that the reduction in flow is due to alteration of tidal currents by coastal features. It is also quite possible, as suggested by Fincham & George (1986), that eddies occur in places, rather than flows that are parallel with the shore.

b) At distances beyond about 300 m from the shore, momentary periods of slack water were encountered at each turn of the tide, but the flow dropped and picked up extremely quickly, without any extended periods of weaker flow. This may have been due to the effects of winds, which are known to influence tides in this area.

2.4. TURBIDITY

Inshore waters in the vicinity of Folkestone and Dover are relatively turbid, due to suspended material which could be derived from any/all of the following sources.

a) Erosion of shore and sublittoral chalk boulders/bedrock.
Clouds of milky water can be clearly seen around these areas, especially when the sea is rough, but the amount being released has not been measured. Rainwater will also carry eroded chalk from the cliffs and foreshore into the sea.

b) Erosion of the sea-bed
The net transport of beach sediments at the eastern end of the Channel is known to be from west to east, and it is likely that some of the turbidity in the Folkestone/Dover area is due to the easterly drift of fine sediment scoured from the sea-bed further west by the strong tidal currents.

c) Intrusion of North Sea water
Residual currents from the southern North Sea flow into the eastern end of the English Channel, carrying with them sediment-laden water characteristic of the North Sea.

d) Input from streams and rivers
There are no rivers and few streams between Folkestone and Dover, so the amounts of sediment reaching the sea from these sources will be neglible.

e) Sewage
There are two sewage outfalls bringing untreated domestic sewage into the sea between Folkestone and Dover, one discharging off Copt Point, the other to the east of Shakespeare Cliff. These must contribute significant amounts of suspended matter to the water (see 7.1.1).

2.5. SEDIMENTATION

Coastal waters in the vicinity of the proposed Channel Tunnel clearly carry a heavy load of fine particulate material in suspension, but the extent to which this is deposited on the sea-bed depends on the degree of water movement. Close to the shore, continuous or periodic water movement from waves and currents was evidently keeping some of the sediment in suspension or causing its re-suspension. At the time of our survey, some of the smooth bedrock surfaces were scoured clean, with sediment present only in holes and crevices. On other uncolonised surfaces there was a layer of silt a millimetre or two deep, but in sheltered pockets it was thicker, and it was not unusual to find gulleys filled with fine sediment several centimetres deep. At Copt Rocks, adjacent to the sewage outfall, thick layers of glutinous mud were present.

Wherever sessile organisms colonised the inshore rocky fringe, then silt accumulated, particularly on horizontal surfaces. This was especially true of turf species, which clearly acted as sediment traps, for they were always coated with a layer of silt, and had silt around their bases. The same applied to sessile organisms further from the shore even though they were exposed to stronger tidal currents.

The soft sea-bed beyond the inshore rocky zone consists essentially of coarse sand/gravel heavily impregnated with silt. Again, the surface is swept by strong currents for much of the time, so preventing excessive sedimentation. However, wherever there were shelter-spots, then silt accumulated, and several places were found where there was thick mud deeper than a hand's depth.

2.5. TEMPERATURE AND SALINITY

There are two main features regarding sea temperatures at the eastern end of the Channel. Firstly, there are greater annual extremes in temperature than there are at the western end. For example, surface water temperatures range from 17°C (summer) to 7°C (winter), while figures for the western end of the Channel are 16°C and 9°C respectively (MAFF, 1981). Secondly, the water at the eastern end of the Channel is well-mixed and does not become stratified. Differences in temperature between the surface and the bottom are seldom more than 0.5°C (MAFF, 1981), and during our dives in the inshore zone no thermocline was discernable.

Average salinity for the area is around 34.75 parts per thousand, mid-way between that for the western Channel (35 ppt) and the North Sea (34.5 ppt or less), (MAFF, 1981). The major inputs of freshwater into the sea between Folkestone and Dover, are via the sewage systems.

3. Habitats and Communities

3.1. INTRODUCTION AND METHODS

The aim of this part of the survey was to provide detailed information on the range of sublittoral habitats and communities occurring in the vicinity of the proposed Channel Tunnel. Efforts were concentrated on the area between Folkestone and Dover (47 sites), and, in addition, 3 sites were investigated off South Foreland.

Dives were made up to about 1.5 km from the shore but most were within about 500 m from the low water mark. The positions of the sites were located using a hand-bearing compass and/or shore marks, and are shown in Figures 13 and 14 (at the back of this report). They were then plotted on to 1:10,000 Ordnance Survey maps, and grid references calculated for each site. The locations and habitat types identified are shown in Table 15 (see back of report) and described in this chapter. An analysis of the species present in the area is in Chapter 5.

3.2. INSHORE ROCKY HABITAT- COPT POINT, FOLKESTONE

3.2.1. Physical Features

Copt Point differs from other rocky sites in the Folkestone to Dover area because greensand rather than chalk is exposed. These older, harder rocks, known as the Folkestone Beds, outcrop both on the shore and in the sublittoral. A central spur of rock extends outwards from Copt Point and runs directly seawards. It is on this spur (Copt Rocks) that the sewage outfall is placed (Fig 13). The rocky sea-bed also extends northwards, forming the western boundary of East Wear Bay. In these areas there are irregular-shaped outcrops up to about 1 m in height, with some small overhangs, but no highly undercut areas or crevices. Much of the flattish, low-lying rock was covered with thick, muddy sediment. This was essentially a shelly deposit highly impregnated with mud. In places, deep glutinous mud overlay the flat bedrock; at the time of the survey this was black and anoxic only a centimetre or two from the surface.

To the south, an arm of rock (Mole Rocks) consisting of jumbled boulders and lumps of concrete, runs round in front of East Cliff Beach towards the harbour entrance. This is a very shallow reef (0.5 m below CD), and the boulders are mostly rounded with a smooth surface.

Further offshore (about 300 m seaward of the sewage outfall) there is a boulder/bedrock sea-bed (site 7), which grades into mixed ground of gravel, cobble and small boulders (site 8). Fast currents sweep over this area.

3.2.2. Biota

a) Copt Rocks

(Site numbers 4, 5, 6, 7, 8).

The rocks at the three shallow sites (approximately at Chart Datum) were blanketed with thick mats of the mussel Mytilus edulis, and these mats also extended on to adjacent areas of sediment. Enormous numbers of the Common Starfish Asterias rubens were present, feeding on the mussels. There were many dead, gaping shells, where individuals had presumably been killed by the starfish; elsewhere were patches of newly settled spat. In areas closest to the sewer outfall only a small number of other species was found. The anemone Sagartia troglodytes was fairly common, growing between the mussels in muddy areas or on flattish bedrock, and Urticina felina was also present. The hydroid Hydrallmania falcata, the green alga Enteromorpha, and polychaete egg cases (probably Eulalia viridis) were attached to the shells. The tops of the higher rocks were colonised by Laminaria saccharina and L. digitata, while the red algae Plocamium cartilagineum, Chondrus crispus and Dilsea carnosa occurred sporadically on some other upward-facing surfaces. There were occasional patches of barnacles. The crustaceans Hyas araneus, Macropodia rostrata, Cancer pagurus and Carcinus maenas were present but there were no visible signs of life in the glutinous mud.

On some of the underhangs, and in areas slightly further from the influence of the sewage, species such as Halichondria panicea, Scypha ciliata and Dendrodoa grossularia were found, but they were very sparsely distributed. The area as a whole was completely dominated by mussels and starfish.

On current-swept boulder/bedrock areas (7), and on mixed ground (8) further offshore, Halichondria panicea was common, and there was a variety of other species. These included Metridium senile, Alcyonium digitatum, Nemertesia antennina, Urticina felina, Haliclona oculata, Scypha ciliata and Molgula manhattensis. Asterias rubens was still extremely common. In some places, abundance and diversity of fauna appeared poorer than in the Shakespeare Cliff area, and one extremely disturbed area was found, where boulders and cobble appeared to have been dug up or overturned, and encrusting organisms were broken or absent. The former may be related to the proximity of the sewage outfall, while the latter could have been due to trawling, or to the activities of the Central Electricity Generating Board whilst laying the cross-Channel electricity cables (see Figure 13 and Chapter 7.1.2). In other adjacent areas a rich fauna of sponges, hydroids, bryozoans and anthozoans was recorded.

b) Mole Rocks

(Site numbers 1, 2, 3).

Some areas were very barren, with only a few small kelp plants (Laminaria digitata, L. saccharina), red algae, and patches of barnacles and mussel spat. The water was turbid and bare surfaces were covered with a thin layer of fine silt. The end of the reef closest to the Harbour entrance supported slightly richer communities, including Tubularia sp., Halichondria panicea, Metridium senile, Molgula manhattensis and Urticina felina, but individuals were still sparsely distributed.

3.3. INSHORE ROCKY HABITAT- EAST WEAR BAY (central area)

3.3.1. Physical Features

The greater part of the shallow sublittoral in East Wear Bay consists of sandy sediment overlying rock. However, there are outcrops of chalk bedrock in places, and scattered white chalk boulders are also present close to the shore.

3.3.2. Biota

(Site number 11)

Some of the bedrock outcrops protruded only a few centimetres above the surface of the sand, and these areas were generally bare, presumably from scouring or from repeated submergence by the surrounding sand. In places the red alga Gracilaria verrucosa was found, protruding through the sand, but attached to rock below. Higher outcrops and boulders were often heavily colonised by the kelps Laminaria digitata and L. saccharina. Red algae were also present in places, but often undergrowth was absent, probably because of the scouring effect of the kelp blades and/or sand. A few outcrops were dominated by a silty mat of the spionid worm Polydora, rather than by algae. Patches of Mytilus edulis spat were found, and the anemones Sagartia troglodytes and Actinia equina were fairly common. The boring bivalves Barnea candida, Hiatella arctica and Pholas dactylus were present, but there appeared to be fewer than in rocks at chalk rock sites off Abbot's Cliff and Shakespeare Cliff.

3.4. INSHORE ROCKY HABITAT- ABBOT'S CLIFF

3.4.1. Physical Features

From just east of the western entrance to the Abbot's Cliff tunnel to beyond the eastern end of the Shakespeare Cliff tunnel the shallow sublittoral is characterised by an essentially rocky substratum extending outwards to about 300 m below low water. The area immediately off Abbot's Cliff has several features which make it different from the rest of the stretch. Some white chalk boulders are present, but most of the protruding rocks consist of outcrops of soft, dark grey glauconitic deposits (see 2.2). These outcrops are relatively flat-topped, up to about 1-2 m in diameter, sometimes giving the appearance of a series of low ledges. They are seldom more than about a metre high, often about 0.5 m, but sometimes only a few centimetres, and the sides are usually eroded to form narrow crevices. The surrounding bedrock also consists of this material. This dark, soft bedrock continues into the central part of Abbot's Cliff, but protruding rocks here were of white chalk, rather than glauconitic material.

Both the bedrock outcrops and the bedrock itself was silty, and in places the bedrock was covered by a layer of sediment, sometimes over 10 cm deep. This often consisted of silty gravel, but in places was soft, glutinous mud. Also in this essentially rocky area are patches of 'broken ground', consisting of a mixture of the substrata described above.

3.4.2. Biota

(Site numbers 16, 18, 19, 20, 21, 23, 24, 25, 26)

Close inshore off Abbot's Cliff (site 20) at a depth of 2-3 m below CD, the sea-bed is almost flat, with very low outcrops of glauconitic material. These areas were dominated by the sea-squirt *Molgula manhattensis* which formed thick, extensive and silty mats. Red foliaceous algae (especially *Delesseria sanguinea*, *Plocamium cartilagineum* and *Rhodymenia holmsii*), and the green alga *Bryopsis plumosa* were fairly common, and organisms such as *Urticina felina*, *Distaplia rosea*, *Scypha ciliata*, *Sagartia troglodytes* and *S. elegans* generally had a fairly scattered distribution.

Figure 2. The Dahlia Anemone, *Urticina felina*, growing on a mat of the ascidian *Molgula manhattensis* (Abbot's Cliff, 3 m depth; photo: E. Wood).

The terrain alters slightly further offshore, although, even after moving outwards about 100 m the depth was still no more than 3 m below CD. The glauconitic outcrops became more pronounced, and chalk boulders were also present. Again, Molgula manhattensis was extremely common on all horizontal upward-facing rocky surfaces, but species such as Amphilectus fucorum, Halichondria panicea, Nemertesia antennina and Metridium senile began to appear, probably because of the increased tidal flow further from the shore. There was also a rich mixture of other species, similar to those recorded from the Shakespeare Cliff area (see 3.5.2). A noticeable difference, however, was the relatively low density of kelp plants, and the apparent absence of Laminaria hyperborea. Possibly the glauconitic material is too soft and friable to withstand the drag created by these large plants. Conversely the large hydroid Corymorpha nutans was present at Abbot's Cliff on coarse sand/gravel between the bedrock outcrops, but was not seen off Shakespeare Cliff.

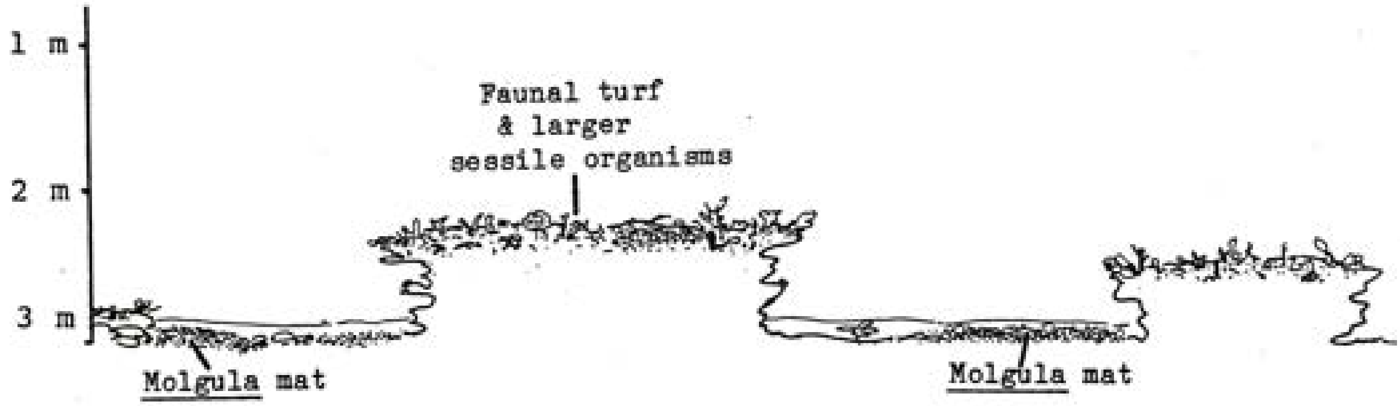


Figure 3. Rocky habitat at Abbot's Cliff (3 m below CD).

By about 500 m from the shore (e.g. site 26, 10 m below CD) low outcrops of glauconitic material were still present, but Molgula manhattensis was not recorded. Instead, the dominant species here were Flustra foliacea and Halichondria panicea, with Metridium senile and Alcyonium digitatum common.

3.5. INSHORE ROCKY HABITAT - CENTRAL ABBOT'S CLIFF TO SHAKESPEARE CLIFF

3.5.1. Physical Features

The rocky sublittoral in this area extends outwards generally to at least 300 m from mean low water, (depth approximately 6 m below CD). The initial 100-150 m, running outwards from the lower shore, is characterised by jumbled white chalk boulders overlying bedrock. There is no consistent arrangement to the gullies and boulders. The boulders vary in size from around 25 cm diameter to about 2 m high and broad, occasionally 3 m; but most are around 1 m (Figure 4). Some are undercut (e.g. off the central part of Abbot's Cliff many are extremely undercut); others drop vertically or slope more gradually. These differences presumably relate to the precise geological characteristics of the rock, and the degree of scour from water and sediment. The tops of the boulders are generally flattish. The bedrock on which the boulders lie undulates very gently in some places, due to uneven erosion of the surface.

At a distance of about 300 m or more from the shore there are progressivly fewer chalk boulders, but a rocky substratum is still present, in the form of low-lying bedrock outcrops. These are surrounded by silty sand/gravel (Figure 5).

Beyond about 400 m from the shore, the substratum is predominantly one of muddy gravel (3.9), but there are also some rocky outcrops. For example, about 600 m offshore from Abbot's Cliff (site 13), at a depth of 10 m below CD there are large boulders and areas of bedrock, broken up by gullies up 1 m deep.

The chalk bedrock off Shakespeare Cliff is off-white to pale grey in colour, and is overlain by white chalk boulders. These differences reflect variations in the geological nature of the Lower Chalk (see 2.2). Off the central part of Abbot's Cliff the bedrock is noticeably darker and softer (see 3.4).

Some of the bedrock is scoured clean and smooth, except for numerous small pockets which are worn piddock holes. In other places the bedrock is covered with a layer of silty sediment, coarse sand, shell fragments, or chalk and flint pebbles and cobbles. Close inshore, the coarse sand is often formed into low ripples.

3.5.2. Biota

(Site numbers 27, 28, 30, 33, 36, 38, 40, 41, 42, 43, 44, 45, 46, 47).

Close inshore, the tops of the boulders (especially the larger ones), were heavily colonised by algae. *Laminaria digitata* and

L. saccharina occurred closest to the shore, but then became intermingled with L. hyperborea (for details of a survey of the density, size, weight and epiphytes of L. hyperborea and L. digitata (see 4.5). Foliaceous red algae occurred with the kelps, and were also found in deeper water, beyond the outer fringe of the kelp zone, which ended about 130 m beyond the low water mark. Typical species were Plocamium cartilagineum, Halurus equisetifolius, Palmaria plamata and Delesseria sanguinea and also the green alga Bryopsis plumosa.

Various sessile organisms were present on the boulder tops, with Molgula manhattensis and juvenile Mytilus edulis and Balanus sp. sometimes densely packed. Where algae were present they extended a short way over the lip of the boulder tops, and then gave way in most cases to a low (1-2cm) silty faunal turf. Hydroids were prominent, particularly Halecium halecinum and Eudendrium sp. Other turf species included the bryozoans Crisia eburnea and Chartella papyracea, the purse sponge Scypha ciliata, the ascidians Dendrodoa grossularia, Botrylloides leachii, and Clavelina lepadiformis (this species appearing in early June) and the polychaete worms Sabellaria spinulosa and Polydora ciliata (and possibly other spionids in mud tubes). Juvenile Mytilus edulis were often present, attached to the turf species. The sides of the boulders were riddled with the bivalve Hiatella arctica, the siphons scattered throughout the turf (for estimates of density see 5.3 - Mollusca). Larger sessile species included Halichondria panicea and Amphilectus fucorum, both of which preferred current-swept positions. A. fucorum was often found growing up Tubularia stalks. Small, mobile organisms living amongst the turf included scale-worms and nemerteans.

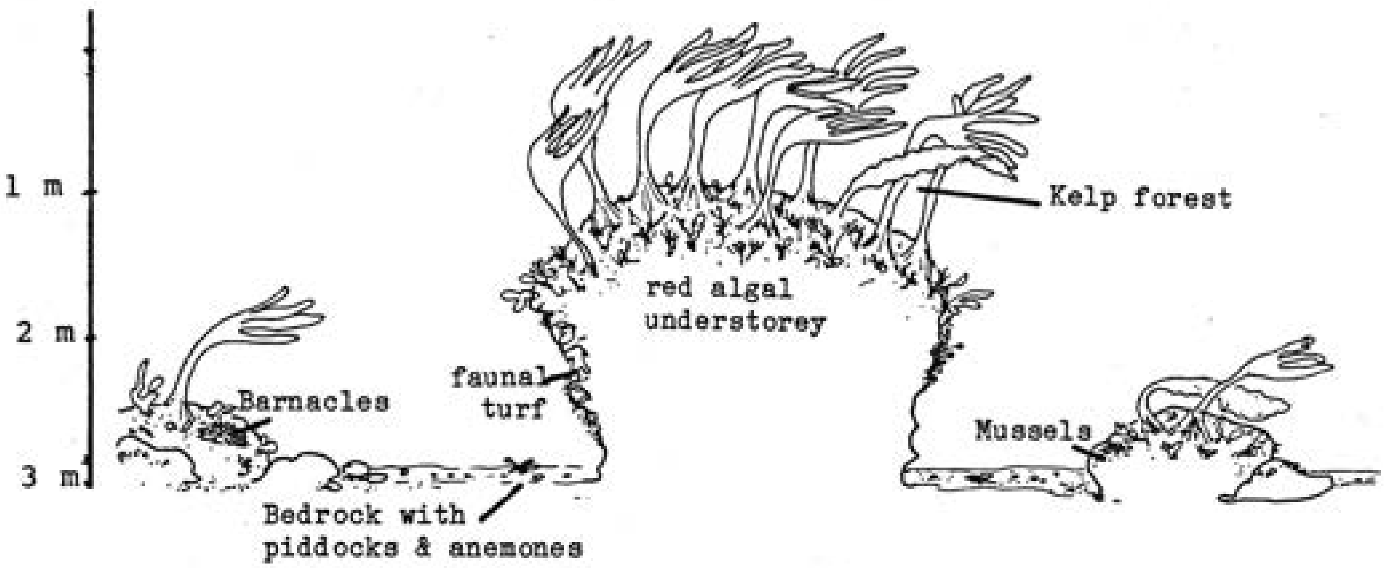


Figure 4. Rocky habitat at Shakespeare Cliff (3 m below CD).

As the depth increased foliaceous algal cover became sparser, with fewer species present. At the same time, presumably because of the increasingly strong currents encountered further from the shore, Halichondria panicea, Alcyonium digitatum, Tubularia indivisa, Nemertesia antennina and Metridium senile became increasingly common, often occurring in distinct, monospecific patches. At depths of around 7m below CD algae were absent.

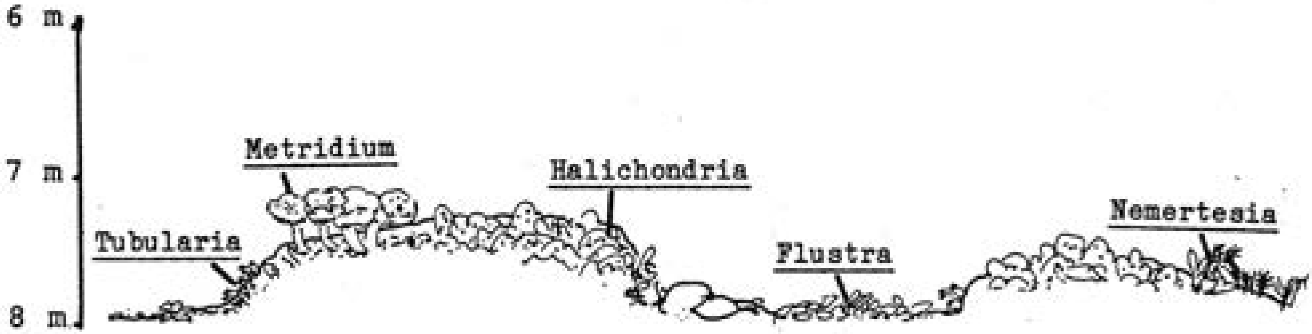


Figure 5. Rocky habitat at Shakespeare Cliff (8 m below CD).

Flat or undulting bedrock was often heavily bored by the piddocks Pholas dactylus (Figure 12) and Barnea candida. There were also many empty holes, some of which were colonised by Sagartia troglodytes (Figure 11). This anemone, together with Urticina felina was also commonly found growing through a layer of sediment (up to 3 or 4 cm thick) from bedrock or pebbles beneath. The bivalve Venerupis saxatilis was sometimes found in shallow water, nestling in holes in the bedrock. Further offshore, where water flow is stronger, Flustra foliacea and Nemertesia antennina were often common on areas of low-lying bedrock, and Alcyonidium sp. seen occasionally.

Crustaceans seen in inshore areas included Galathea strigosa, G. squamifera, Pagurus sp, Carcinus maenas, Cancer pagurus (small specimens), Hyas araneus (often well disguised e.g. with sponges such as Amphilectus fucorum), Macropodia rostrata and Pilumnus hirtellus. The swimming crab Macropipus puber was reported from the area in late September 1985, but was not seen during the main survey (May-June 1986).

A variety of nudibranchs was found, including Coryphella gracilis (feeding on Eudendrium sp), Facelina coronata (feeding on Tubularia), Goniodoris nodosa (feeding on Dendrodoa grossularia), Ancula gibbosa, Archidoris pseudoargus and Aeolidia papillosa.

The only echinoderm commonly found in these rocky areas was the starfish Asterias rubens, which was widespread on all surfaces.

The commonest fish seen was Pholis gunnellus, which sometimes occupied empty piddock holes. Taurulus bubalis was also present, and the pipefish Synagthus acus occasionally seen. A few Goldsinny, Ctenolabrus rupestris, were found beyond the kelp zone, but Ballan Wrasse, Labrus bergylta, were noticeably scarce. Pollack, Pollachius pollachius, were seen in boulder-strewn ground off the central part of Abbot's Cliff.

Mobile cobbles, pebbles, shells and sand surrounding the rocks were uncolonised; larger, more stable pebbles were colonised by Semibalanus balanoides and Pomatoceros triqueter. Often the polychaete worms Eulalia viridis and Anaitides maculata were present on the underside of cobbles or were seen out on the sediment surface.

Much of the sediment in these inshore rocky areas is mobile and present only as a thin veneer overlying bedrock with no evidence of infaunal species. Small hermit crabs, Pagurus sp. moved about on the surface, and the anemones Sagartia troglodytes and Urticina felina were also present, the column sometimes buried in several centimetres of sediment, and attached to the rocks below. The Sand Goby, Pomatoschistus minutus, occurred in sandy patches, and flatfish such as Plaice, Pleuronectes platessa, were also seen. In deeper water, where the sediment around the rocky outcrops was more stable and silty, a fauna similar to that described in 3.9. was present.

3.6. INSHORE ROCKY HABITAT- SOUTH FORELAND

3.6.1. Physical features

The shallow rocky sublittoral in this area appears to be physically less diverse than the comparable area between Abbot's Cliff and Shakespeare Cliff. It is characterised by boulders and flattish chalk bedrock which is eroded to form gullies up to about a metre deep. In places the bedrock is covered with a layer of muddy gravel. Two or three hundred metres from the shore the bedrock grades into a silty plain consisting of chalk and flint cobbles embedded in gravel.

3.6.2 Biota

(Site numbers 48, 49, 50)

Investigations were hampered by extremely poor conditions at the time of the survey, and the work that could be achieved was much less detailed than that carried out in the Shakespeare Cliff area.

Foliaceous red algae were common on bedrock in shallow water about 50 to 100 m from the low water mark, but kelps were not recorded; possibly they were present closer to the shore. Molgula manhattensis was common to abundant, but, further from the shore where the currents were stronger, was replaced by species such as Halichondria panicea, Flustra foliacea and Alcyonium digitatum. At site 49, H. panicea was estimated to form up to 50% cover on the cobble plain, and the Dahlia Anemone Urticina felina was also abundant here. A range of other species was recorded from this rocky habitat, all of which had also been recorded from the Shakespeare Cliff area.

3.7. INSHORE WRECKS

3.7.1. Physical Features

Two wrecks were investigated. The 'Brandyboat' is a fairly broken-up metal wreck, lying at a depth of about 10 m below CD, and approximately 500 m from the shore, opposite the western entrance of the Abbot's Cliff Tunnel (site 14). There are some substantial pieces up to 3 m high, and plates and ribs showing above the sea-bed. The wreck lies partly on rock, partly on a silty/pebble sediment. Deeper pockets of silt occur in places, both on and around the wreck.

The 'Hellene' is approximately 1 km from the shore, almost opposite the eastern entrance to the Abbot's Cliff Tunnel (site 32). The wreck stands several metres high off the surrounding sea-bed, which is at a depth of about 20 m below CD. The substratum around the wreck consists of a predominately silty sand sediment with occasional low chalk outcrops.

3.7.2. Biota

(Site numbers 14 ['Brandyboat']; 32 ['Hellene']).

The main feature of this wreck was the abundance of Metridium senile on almost all surfaces. These included white, pink and green forms. There were localised patches of Tubularia and low hydroid turf on some vertical surfaces, while Halichondria panicea was common in current-exposed situations. Other sponges present included Haliclona oculata and Raspailia ramosa. The sea-squirt Molgula manhattensis occurred on some silty, horizontal surfaces, together with Sagartia troglodytes. Ophiura albida was locally common on patches of sediment. Asterias rubens was common and widespread on most surfaces.

Several species of crustaceans were present, including Cancer pagurus, Hyas araneus and prawns. This was one of the few inshore sites where fish were plentiful. Shoals of Bib, Trisopterus luscus, were present, together with some Pollack, Pollachius pollachius.

Strong currents combined with poor light and visibility prevented a thorough survey of the 'Hellene' being carried out, but the dominant sessile organisms appeared to be Tubularia indivisa, Halichondria panicea and Metridium senile. These species, together with Alcyonium digitatum were present in noticeably higher densities than on surrounding bedrock outcrops, where scouring and submergence by silt/sand/gravel is presumably more of a problem. This might also explain why Mytilus edulis was found on the wreck but not on the rocks.

3.8. INSHORE CLEAN SAND SEDIMENT- EAST WEAR BAY

3.8.1. Physical features

Close inshore in the central part of East Wear Bay is an area where the sediment consists of relatively clean, well sorted sand. At the time of the survey this was thrown into ripples 3-5 cm high, and was obviously mobile and unstable.

3.8.2. Biota

(Site numbers 9, 11, 12).

Only the epifauna and animals visible at the surface were recorded, and it is to be expected that a population of infaunal bivalves and polychaetes is present. A few casts of Arenicola were seen, and Lanice conchilega was also present. Amongst the mobile fauna, the Netted Dogwhelk Nassarius reticulatus was fairly common, and there were numerous juvenile flatfish (about 1-2 cm long, probably Sole and/or Plaice). A few adult Plaice, Pleuronectes platessa were seen, and a shoal of Sand Eels, Ammodytes tobianus.

3.9. SEDIMENT PLAIN AND MIXED GROUND

3.9.1. Physical Features

At a distance of around 300m from the shore, and a depth of about 6 m below CD, the rocky, sand or pebble sea-bed gradually grades into a flattish, predominantly muddy-sand, or muddy-gravel plain. Cobbles and shell remains are also present, scattered or in pockets, and there are occasional low-lying bedrock outcrops. In other places, thick mud has accumulated. This offshore sediment has a fairly smooth surface without ripples, although there are many small mounds a few centimetres across, caused by the activities of infaunal organisms. Strong currents were encountered at these sites.

3.9.2. Biota

(Site numbers 7, 8, 9, 10, 12, 13, 15, 22, 29, 31, 34, 35)

The muddy-gravel sediment surface was generally dominated by the brittle-star Ophiura albida. Often these had the disk buried in the sediment and only the arms protruding. Other mobile surface-dwellers included Natica sp., Nassarius reticulatus, Asterias rubens and Pagurus sp.. Hyas araneus was found on coarser sediments. The nudibranch Onchidoris bilamellata was sometimes present, and at site 13 enormous numbers were found, with individuals following each other in columns across the sea-bed.

Philine aperta was seen just below the sediment surface, and the burrowing anemone Cerianthus lloydii was common in certain areas, especially in coarser sediments. Several species of polychaete worm were seen at the surface of the sediment plain, particularly from fine, silty sand. These included Lanice conchilega, Lagis koreni and unidentified spionids and terebellids. Empty bivalve shells (e.g. Ensis ensis, Cerastoderma edule) were found on the sediment surface; presumably live specimens were part of the infaunal community. The Institute of Offshore Engineering has made a detailed study of the fauna of the sediment sea-bed for Eurotunnel.

The commonest fishes seen on the sediment plain were flatfish, and at one site (13), about 100 large Plaice, Pleuronectes platessa, were seen on a single dive.

Fauna associated with bedrock outcrops or stable cobbles found on the sediment plain was similar to that described for the outer part of the shallow rocky sublittoral zone. Flustra foliacea was often common, and species such as Alcyonium digitatum, Metridium senile, Nemertesia antennina and Haliclona oculata present.

4. Shakespeare Cliff Monitoring Site

4.1. INTRODUCTION

The aim of this exercise was to make a detailed study of a defined area in the sublittoral where the benthic communities might be affected by environmental change brought about as a result of the construction of the Channel Tunnel. The communities associated with the inshore rocky habitats in the vicinity of Shakespeare and Abbot's Cliff are most likely to be affected because: a) they are closest to the proposed workings, b) tidal flow is less strong inshore (therefore sedimentation more likely) and c) the biota is adapted for life on hard-bottoms, and probably is more sensitive to increased turbidity and/or sedimentation than the biota of the soft sea-bed.

One problem with monitoring in the rocky sublittoral is that many species are relatively short-lived (for example in comparison with the species contributing to 'established' terrestrial communities). Partly for this reason, there are likely to be naturally-occurring seasonal and longer-term fluctuations in species composition and abundance of individual species. However, despite this, it should not be difficult to detect overall trends and changes in community structure in the rocky sublittoral adjacent to the proposed Channel Tunnel.

A monitoring site was established at Skakespeare Cliff in an area close to the existing tunnel entrance and the proposed reclamation (Fig 13). The survey was carried out along a transect line running outwards at right angles from the lower shore (bearing 160^{o}), and seaward of the intertidal monitoring site established by the British Museum (Natural History). The line was continued outwards for 420 m, in order that all the inshore habitat types were included. The aim of the work was to collect qualitative and quantitative data on habitats and their biota, and to provide a basis upon which future surveys could be conducted.

4.2. PREPARING AND LAYING THE LINE

A white 2 mm diameter, non-buoyant line was used to mark the transect. A piece of waterproof yellow tape was wrapped around the line every 5 m, and was marked accordingly with a permanent black marker pen. The line itself was ringed round at intervening metre intervals with the same marker. The line was then wrapped around a piece of plastic piping which rotated freely around a narrower central spindle. The spindle projected from either end of the pipe and was held by the line-laying diver. This diver was led outwards by another who swam along a specified compass bearing. Following immediately behind the line-layer was a pair of divers responsible for securing the line to the chalk rocks with large (2") staples. On soft ground the line was held in place with small tubs full of concrete. The main difficulty encountered by the divers was having to contend with strong currents at the outer end of the line.

An alternative method considered was to lay the line directly from the dive boat, but this would still have required a diver to guide the line into place on the sea-bed, and there would also have been problems with boat drift and currents.

It is possible that at some stage the crab pots that are laid regularly in the area will become tangled with the line, and will tear it away from the sea-bed. It may also be pulled loose during storms and by the strong currents. However, the monitoring site can be re-located because both the starting point and the direction of the line are known.

4.3. GENERAL DESCRIPTION OF TRANSECT (TOPOGRAPHY & BIOTA)

4.3.1. Methods

The topographical features were mapped by a diver swimming along the line and measuring features within a 1 m band either side of the line, using a 1 m folding plastic rule and a depth gauge. The data collected were used to create of a strip map which has been represented as an isometric section in Figure 6.

An overall assessment of the types of communities present at the monitoring site was made by recording all prominent species in a belt approximately 1 m either side of the line. Two members of the survey team each completed this task by swimming the length of the line, and the results were then combined. The abundance scale used is shown in Figure 8.

4.3.2. Results

0 to 50 metres

Jumbled white chalk boulders on light grey chalk bedrock with some overlying sediment. Some boulders separated by gullies as narrow as 0.5 m, others by open spaces up to about 5 m across. Boulders of variable size; some low profile, others approx 2 m in height. A few undercut, others vertical or sloping. Intervening bedrock often covered with a thin layer of coarse sand/gravel. Flint and chalk cobble present.

Tops of tall boulders well colonised by red algae and *Laminaria digitata*. *L. hyperborea* sporadic from 20 m outwards. Sides of boulders dominated by low, silty turf consisting predominantly of hydroids. *Hiatella arctica* abundant in boulders. *Sagartia troglodytes*, *Pholas dactylus* and *Barnea candida* present on/in bedrock between boulders, sometimes protruding through sand. Barnacles common, occurring in patches on bedrock and boulders.

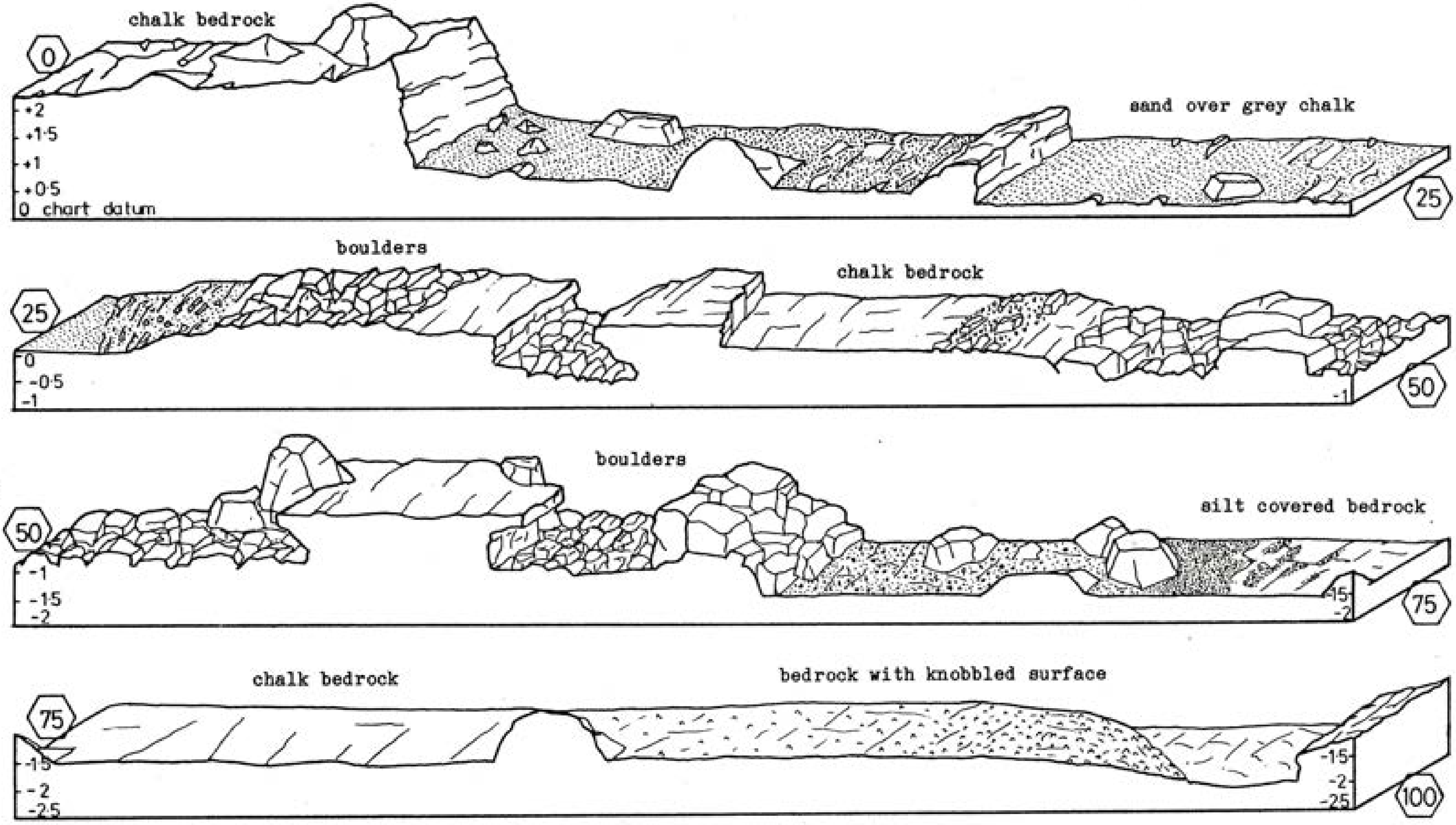


Figure 6a. Shakespeare Cliff Transect - Profile 0m - 100m.

50 to 100 metres

50 to 70 m similar topographical features to 0 to 50 zone, then mostly flattish grey chalk bedrock with a few low-profile boulders.

Kelp often forming dense canopy. Mixture of L. digitata, L. hyperborea and L. saccharina. Foliose red algae abundant on tops of boulders; hydroid turf on sides. Young mussels up to 90% cover in places; Molgula manhattensis common. Sagartia troglodytes, Pholas dactylus and Barnea candida present on/in bedrock; barnacles common on stones.

100 to 150 metres

Flattish bedrock; except between 120-140 m where several boulders and rocks up to 1.5 m high. Gravel overlying bedrock between boulders.

Bedrock and tops of boulders to 125 m with heavy kelp cover; mixture of Laminaria digitata and L. hyperborea. Red algae common. Alcyonium digitatum and Halichondria panicea becoming common beyond about 130 m, also Tubularia and hydroid turf common on sides of boulders. Pholas dactylus abundant on bedrock; Sagartia troglodytes widespread and common. Barnacles and Mytilus spat patchy distribution; Asterias rubens occasional, widespread.

150 to 200 metres

Grey chalk bedrock with boulders and rocks. The bedrock uneven; in places flat and smooth, elsewhere raised or knobbly (presumably due to erosion of the piddock-bored rock). Silt and/or gravel often present over bedrock. Boulders and rocks from a small size up to several metres across, but not more than about 1 m high, usually less. Some undercut, others with sloping sides.

No kelp. Foliose red algae present to sparse on tops of rocks; Molgula manhattensis locally common. Amphilectus fucorum and Halichondria panicea common to occasional on sides/tops of rocks. Nemertesia antennina, Alcyonidium sp. and Flustra foliacea present on flattish bedrock. Urticina felina present on bedrock, often protruding through silty gravel. Pholas dactylus, Barnea candida and Sagartia troglodytes mostly common. Mytilus spat and barnacles patchy distribution; Asterias rubens occasional, widespread.

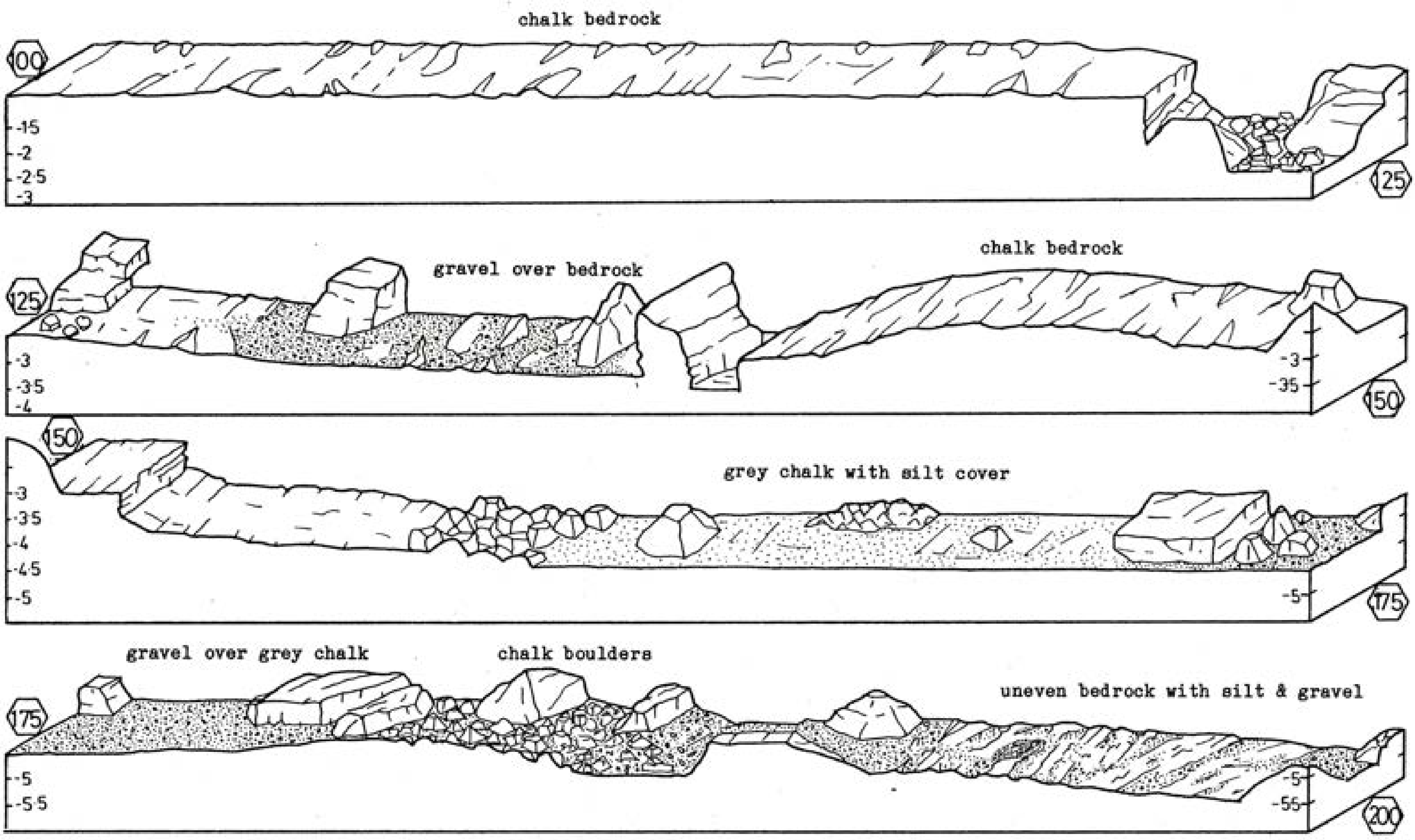


Figure 6b. Shakespeare Cliff Transect - Profile 100m - 200m.

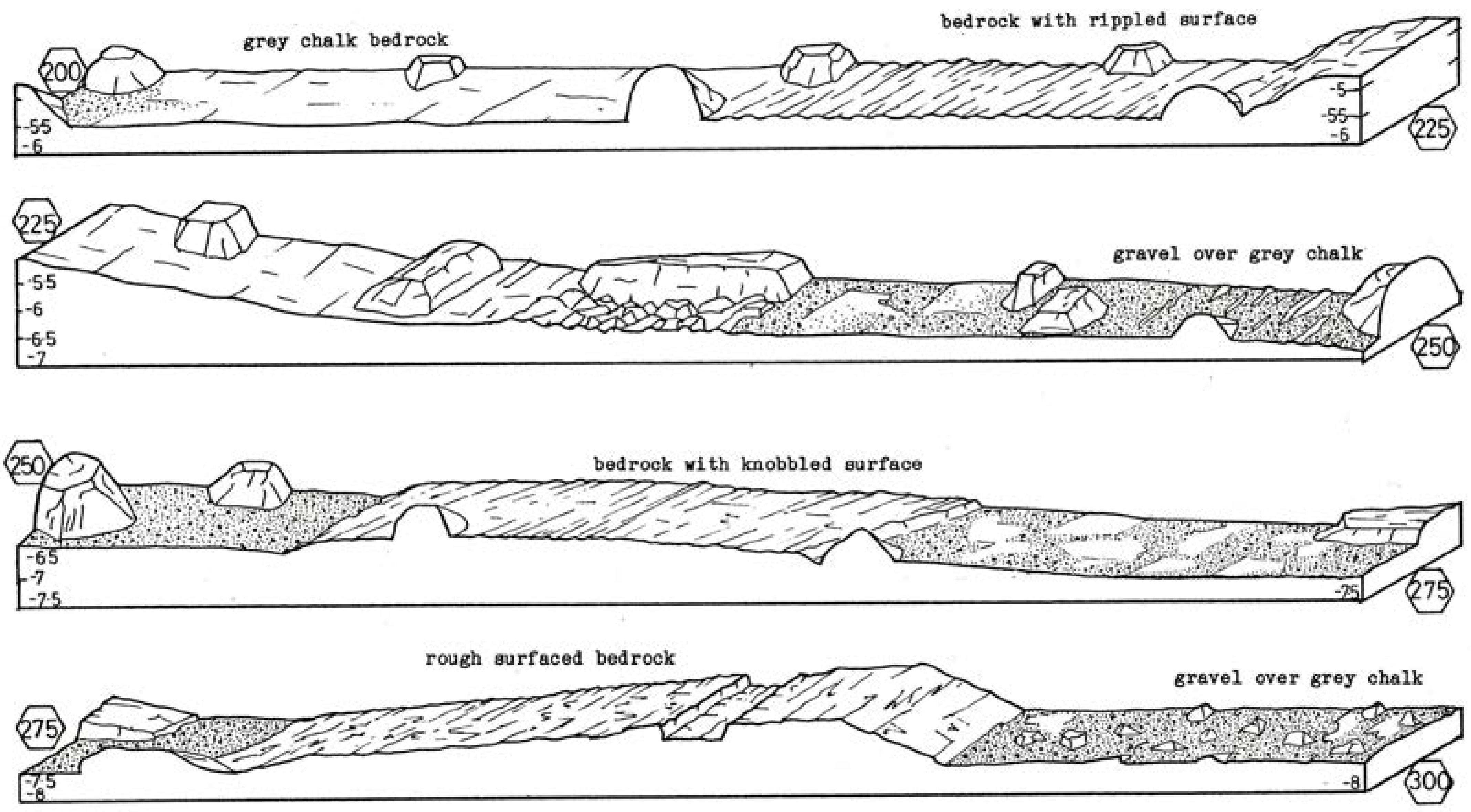


Figure 6c. Shakespeare Cliff Transect - Profile 200m - 300m.

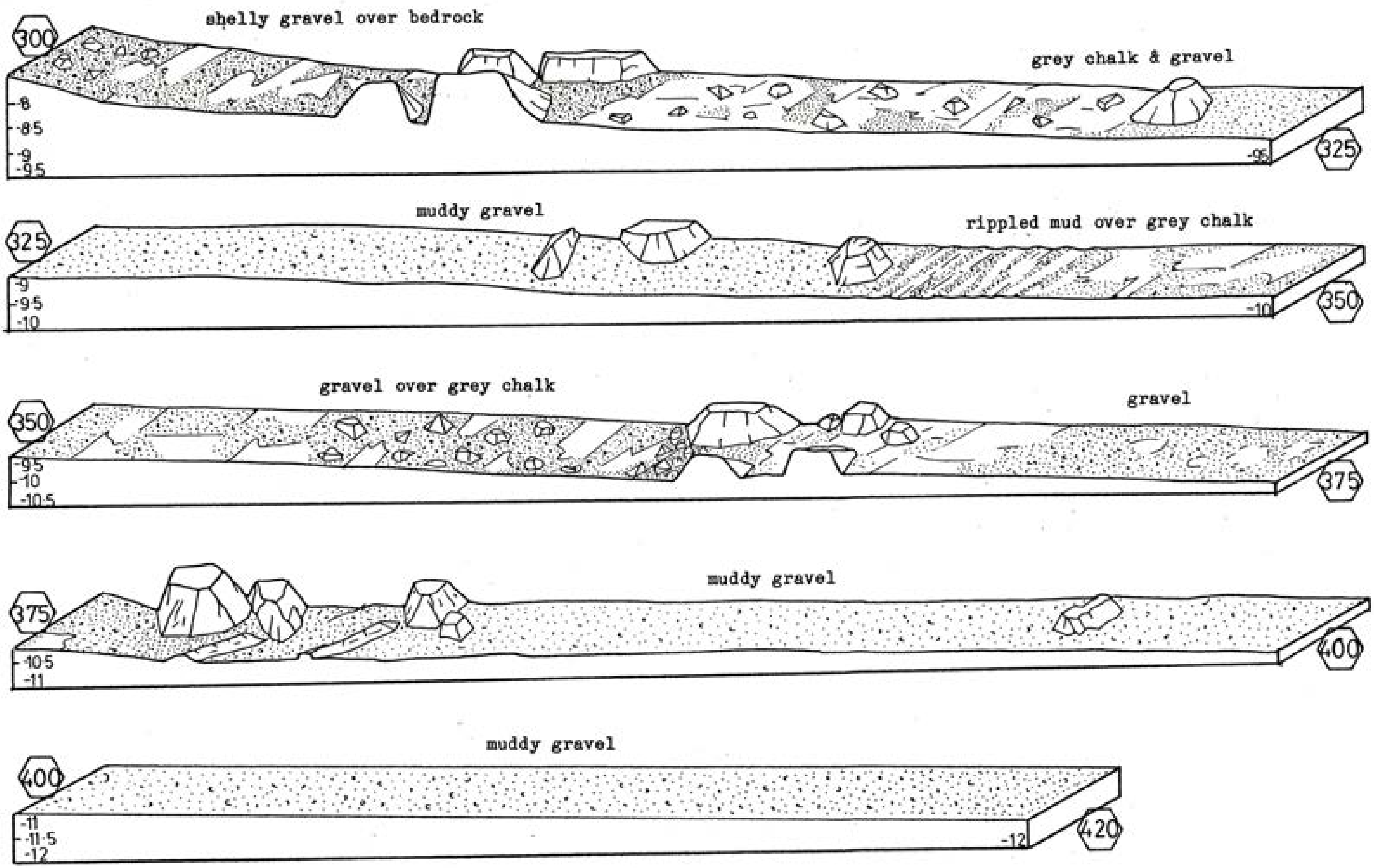


Figure 6d. Shakespeare Cliff Transect - Profile 300m - 420m.

200 to 250 metres

Grey chalk bedrock, knobby in places; often overlain with silty gravel. Scattered small rocks up to 1 m high, with steepish sides.

Red algal cover extremely sparse; plants small, only *Hypoglossum woodwardii* and *Delesseria sanguinea* recorded. *Halichondria panicea* abundant on rocks; *Tubularia* sp., *Amphilectus fucorum* and *Alcyonium digitatum* generally common, *Metridium senile* occasional. *Nemertesia antennina*, *Alcyonidium* sp and *Flustra foliacea* common to occasional especially on bedrock. *Pholas dactylus* and *Barnea candida* common boring into bedrock. *Urticina felina* occasional, also *Cerianthus lloydii* in silty gravel.

250 to 300 metres

Grey chalk bedrock, often knobbly. Scattered rocks, generally long and of low profile. Bedrock mostly overlain with silty gravel.

Halichondria panicea and *Amphilectus fucorum* common to abundant on rocks, *Alcyonium digitatum* patchy, locally common. *Flustra foliacea* and *Alcyonidium* sp occasional to common on bedrock, with *Pholas dactylus*. *Sagartia troglodytes* occasional to common, often in piddock holes. *Cerianthus lloydii* occasional to common in silty gravel. *Asterias rubens* generally common, widespread.

300 to 350 metres

Grey chalk bedrock overlain around 300-320 m with shelly gravel, and occasional small boulders; from 320 to 350 with muddy gravel. A few low rocks protruding.

Halichondria panicea, *Amphilectus fucorum*, *Nemertesia antennina* and *Alcyonium digitatum* common to abundant on rocks. *Metridium senile* present; dense clumps in places. *Sagartia elegans*, *Alcyonidium* sp. and *Flustra foliacea* occasional to common on rock and silty gravel. *Urticina felina* present. *Pholas dactylus* and *Barnea candida* present in bedrock. *Asterias rubens* generally common.

350 to 380 metres

Grey chalk bedrock overlain with silty gravel and occasional small boulders.

M. senile, *A. digitatum*, *H. panicea* and *Tubularia* sp. common to abundant on rocks. *F. foliacea*, *N. antennina* and *Alcyonidium* sp present to common on silty gravel; Urticina felina occasional.

380 to 420 metres

Silty gravel; very few small rock outcrops.

Ophiura albida abundant on surface of silty gravel. Cerianthus lloydii common, burrowing in gravel. Lanice conchilega present; Asterias rubens occasional to common. H. panicea, M. senile and Tubularia sp on rocky outcrops.

4.4. QUANTITATIVE WORK

4.4.1. Methods

0.5 x 0.5 m square quadrats were placed on the eastern side of the line at 10 m intervals, and the following recorded:
a) % of each substratum type.
b) % cover of main elements of the flora/fauna.
c) species present, and their abundance.

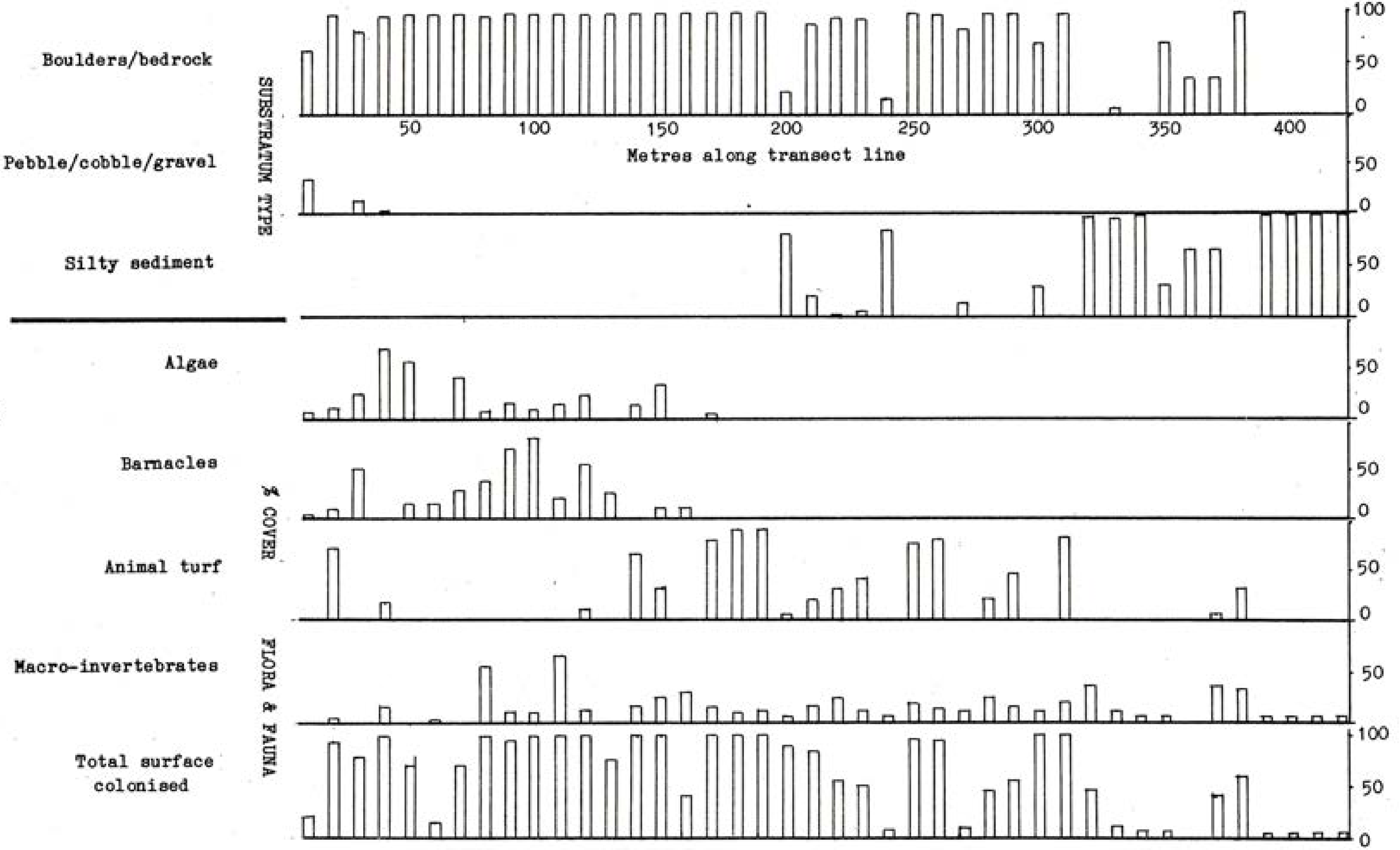
% cover was estimated by eye.

4.4.2. Results

The % of different substratum types, and % cover of the major types of sessile organisms is shown in Figure 7a. Total cover in the predominantly rocky zone is generally high, but clearly, in the silty sediment, infaunal organisms take precedence.

51 macro-species were recorded from the quadrats, and the distribution and abundance of the prominent, longer-lived species is shown in Figure 7b.

Figure 7a. Substratum type and % cover by the main elements of the flora and fauna in 0.5 x 0.5 metre quadrats along the Shakespeare Cliff transect.



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                            Stations along transect line ---->

                            50  100  150  200  250  300  350  400
                        ____|____|____|____|____|____|____|____|__
Bryopsis plumosa        x      x xxx xx x   x
Laminaria digitata       xxxx   x
Plocamium cartilagineum   x x xxxxxx xx
Laminaria hyperborea             xx
Sagartia troglodytes        x  xxxxxxxxx   xxxx  xxx   x xxx x
Pholas dactylus              x xx  x xxx    x x    xxx  x
Asterias rubens                x x x   x    xx xxxxx  x    xx    x
Amphilectus fucorum      x           xx xxx  x  x   x x
Halichondria panicea             xx   x x   xxx  x xxx  x   xx
Alcyonium digitatum                  xx xx  x   xx          x
Flustra foliacea                         x       x x        x
Cerianthus lloydii                         x      xxx xxxxxxx x  x
Nemertesia antennina                        x      xx x
Metridium senile                                 x           x
Ophiura albida                                                xxxx
```

Figure 7b. Distribution of some prominent species in the quadrats along the transect line at Shakespeare Cliff (June 1986).

4.5. KELP SURVEY

4.5.1. Methods

Field work was carried out on 20th June, 1986. The total numbers of kelp plants in 2 x 2m quadrats at the 110 m and 120 m stations along the line were recorded. Collections of the largest five plants of *Laminaria digitata* and *L. hyperborea* were then made adjacent to (but not on) the transect line at stations 100 m, 110 m and 120 m.

The following factors were measured for each plant (fresh weights):

a) length, weight and diameter of stipe.
b) length and weight of blade.
c) Total weight of algal epiphytes.

The algal epiphytes were identified, and the age of the plants was determined by examination of the growth lines in sections taken at the base of the stipe.

4.5.2. Results

The age of the *Laminaria hyperborea* plants collected varied between 4 and 7 years, with the majority of plants in the age group 5-6 years.

The other results are shown in tabular form below:

	Position on transect	
	110	120
L. digitata	8	5
L. hyperborea	16	15
sporelings	22	2

Table 2. Densities of kelp plants in 2 x 2 m quadrats (4 m^2).

	100		110		120	
	length cm	Wt gm	length cm	Wt gm	length cm	Wt gm
L. digitata	81	111	90	121	68	80
L. hyperborea	132	595	143	536	123	459

Table 3. Analysis of plant length and weight (mean of 5 plants of each species).

	100			110			120		
	bl. cm	st.	ratio	bl. cm	st.	ratio	bl. cm	st.	ratio
L. digitata	55	26	2.12	64	26	2.44	37	21	1.76
L. hyperborea	69	63	1.10	68	74	0.92	57	66	0.86

Table 4. Blade to stipe ratios (means of 5 plants of each species).

	100	110	120
	mean diameter in cm		
L. digitata	1.3	1.2	1.1
L. hyperborea	2.3	2.2	2.1

Table 5. Stipe diameter (mean of 5 plants of each species).

	100	110	120
	wt in gms		
L. digitata		negligible	
L. hyperborea	77	159	127

Table 6. Algal epiphyte weight per plant (mean of 5 plants).

	L. hyperborea			L. digitata		
	100	110	120	100	110	120
Laminaria sp	x		x			
Laminaria digitata	x			x		
Audouinella purpurea	x	x				
Callithamnion sp	x	x				
Cryptopleura ramosa	x	x	x	x		x
Derbesia marina (on H. panicea)		x				
Heterosiphonia plumosa			x			
Hypoglossum woodardii	x			x		
Palmaria palmata (dominant)	x	x	x	x		x
Plocamium cartilagineum	x	x	x	x	x	
Halichondria panicea		x				
Electra pilosa	x	x	x	x	x	
Mytilus edulis	x	x	x	x	x	
Semibalanus balanoides	x	x	x	x	x	x
Mollusc eggs	x		x			

Table 7. Epiphytes found on kelp plants (stipes and fronds) adjacent to the transect (5 plants of each species examined).

4.5.3. Discussion

Laminaria hyperborea is an extremely important kelp in the sublittoral around much of the British Isles, and its distribution, ecology and population structure have been extensively studied (for example, see review by Kain (1971)). Prior to the present survey, however, L. hyperborea had not been recorded from Kent, so the data collected are of general interest, as well as providing data for the monitoring programme.

L. hyperborea at Shakespeare Cliff was found no deeper than 3 m below Chart Datum, presumably because of the turbid water. This depth distribution is comparable to that recorded for the Menai Straits, where the lower limit was only 2.5 m below CD (Knight-Jones et al, 1957).

The density of L. hyperborea plants at Shakespeare Cliff, (approximately 4 plants per m^2 where the forest is densest), appears low relative to other sites. For example, off Flamborough Head, 16 and 10 plants were recorded from the 0 - 2 and the 2 - 6 m zones respectively (Whittick, 1969), while as many as 27 per m^2 were recorded from the 2 - 6 m zone at Sennen Cove, Cornwall (Bellamy et al, 1968). These figures indicate that conditions for the growth of L. hyberborea at Shakespeare Cliff are more marginal than elsewhere.

Under optimal conditions, for example in deeper water where light penetration is good, and the effects of storms are minimised, dense forests of L. hyperborea often develop. In these populations there is a significant proportion of larger plants, at least 9 or 10 years old; sometimes as much as 13 years (Kain, 1971). In contrast, at Shakespeare Cliff, most of the largest plants were 5 - 6 years old, and none was older than 7 years. There were plenty of smaller plants (i.e. 1- 3 years), and the age structure was similar to that of populations from various shallow-water localities exposed to considerable wave action. These populations are typified by a predominance of young plants, and relatively few larger ones. Even in these populations, however, some plants over 10 years old were found (Kain, 1971). It appears that conditions at Shakespeare Cliff are even more limiting, presumably because of the friability of the substratum, which means that there is an increased likelihood of larger plants being torn away.

Environmental factors are known to have a marked effect on the frond:stipe ratio in Laminaria hyperborea, and it is possible that the elongated stipes seen in the Shakespeare Cliff population result from the turbid water and poor light conditions.

It was not surprising to find a relatively low diversity of epiphytic algae on the stipes of L. hyperborea, considering the depauperate algal flora found generally in this area.

5. Flora and Fauna

5.1. INTRODUCTION

Although the overall geographic distribution of many sublittoral species around the British Isles is reasonably well understood, this is the first survey to look specifically at the sublittoral communities off Folkestone and Dover. Our study was confined to macro-species, and these are listed in this chapter, together with notes on their distribution and abundance. This is followed, in Chapter 6, with a discussion on species composition and diversity in comparison with similar habitats in South-east England.

5.2. METHODS

Organisms were identified in-situ wherever possible, but collections were made where identification was required. Many of the species occurring in the area were easily spotted and identified, and the records made are likely to be a true reflection of the distribution of these species in the area. However, smaller/infaunal/cryptic species, whose presence was determined from collections, were undoubtedly under-recorded. This is discussed in more detail under the relevant species records.

The overall location and site reference number (see Figures 13 & 14 and Table 15, at the back of this report) is given for each record made, together with an indication of abundance. The scale shown in Figure 8 was used, with numbers and areas being assessed visually.

	ANIMALS			ALGAE		
	Large, solitary & colonial spp. (e.g. large anemones & sponges, starfish, crabs, fish etc.)	Small, solitary spp. (e.g. small anemones, ascidians, sponges etc.)	Small colonial/crustose spp. (e.g. encrusting sponges, ascidians, bryozoans, hydroids).	Kelps	Foliaceous/filamentous spp.	Encrusting spp
Abundant (a)	10 + per m^2	100 + per m^2	50% cover	less than 0.5 m apart	20% cover +	50% cover +
Common (c)	1 + per m^2	10 + per m^2	10-50% cover	50 cm to 2 m apart	less than than 20% cover	20-50% cover
Present (p) Occasional (o)	less than 1 per m^2	1 + per m^2	less than 10% cover	2 m + apart	scattered	20% or less
Present (p) Rare (r)	only 1 or 2 seen	widely scattered	less than 1% cover	few, scattered	few	less than 1% cover

Figure 8. Abundance scale used during the Channel Tunnel Sublittoral Survey, 1986.

5.3 SPECIES LISTS

ALGAE

(Nomenclature follows that of Parke & Dixon (1976)).

CHLOROPHYTA

Chaetomorpha melagonium (Web. et Mohr) Kutz
Shakesp. Cl: 36(p), 45(p).

Bryopsis plumosa (Huds.) C. Ag.
Copt: 6(c); E. Wear: 11(p); Abbot's Cl: 19(c), 20(c), 21(a), 28(p); Shakesp. Cl: 33(c), 36(c), 40(c), 41(c), 42(p), 45(a); S. Forel: 50(p).

Cladophora sericea (Huds.) Kutz
Abbot's Cl: 20(p); Shakesp. Cl: 36(p).

Derbesia marina (Lyngb.) Solier
Shakesp. Cl: 45(p-on Halichondria panicea)

Enteromorpha intestinalis (L.) Link
Copt: 3(p), 4(c), 5(c), 6(p), 8(c).

Ulva lactuca L.
Copt: 4(p), 6(p); E. Wear: 11(p); Abbot's Cl: 20(p), 21(p); Shakesp. Cl: 47(p).

PHAEOPHYTA

Cladostephus spongiosus (Huds.) C. Ag.
Shakesp. Cl: 36(p), 45(p).

Desmarestia aculeata (L.) Lamour
Copt: 6(p).

Ectocarpus sp
E. Wear: 11(p).

Fucus serratus L.
Copt: 4(c); E. Wear: 11(p).

Giffordia granulosa (Sm.) Hamel
Copt: 6(p).

Laminaria digitata (Huds.) Lamour.
Copt: 1(p), 3(p), 4(c), 5(c), 6(c); E. Wear: 11(c); Abbot's Cl: 36(c), 42(p), 45(c).

Laminaria hyperborea (Gunn.) Fosl.
Shakesp. Cl: 36(c), 43(p), 45(c).

Laminaria saccharina (L.) Lamour.
Copt: 3(p), 4(o), 5(o), 6(c); E. Wear: 11(c); Abbot's Cl: 20(p),36(p), 42(p), 43(p), 45(c), 47(c).

Sphacelaria radicans (Dillw.) C. Ag.
Shakesp. Cl: 36(p)

RHODOPHYTA

Audouinella purpurea (Lightf.) Woelkerling
Shakesp. Cl: 45(p).

Calliblepharis ciliata (Huds.) Kutz
Abbot's Cl: 20(p), 21(c), 27(p), 36(p); Shakesp. Cl: 45(p).

Callithamnion sp
Shakesp. Cl: 45(p).

Ceramium diaphanum/strictum (Lightf.) Roth
Abbot's Cl: 24(p).

Chondrus crispus Stackh.
Copt: 5(p), 6(p); Shakesp. Cl: 47(p).

Cordylecladia erecta (Grev.) J. Ag.
Shakesp. Cl: 45(p).

Crytopleura ramosa (Huds.) Newton
Abbot's Cl: 21(p), 28(p); Shakesp. Cl: 36(p), 42(p), 45(p); S. Forel: 50(p).

Delesseria sanguinea (Huds.) Lamour.
E. Wear: 11(p); Abbot's Cl: 21(p); Shakesp. Cl: 27(p), 28(p), 36(c), 40(p), 41(p), 43(p), 45(c), 47(p); S. Forel: 48(p).

Dilsea carnosa (Schmidel) O. Kuntze
Copt: 6(c); E. Wear: 11(p); Shakesp. Cl: 45(p).

Griffithsia flosculosa (Ellis) Batt.
Copt: 5(p); Abbot's Cl: 21(p); Abbot's Cl: 28(p); Shakesp. Cl: 36(p), 45(p).

Gracilaria verrucosa (Huds) Papenf.
E. Wear: 11(p)

Halurus equisetifolius (Lightf.) Kutz.
Abbot's Cl: 21(p); Shakesp. Cl: 36(a), 42(p), 43(p), 45(a); S. Forel: 50(p).

Heterosiphonia plumosa (Ellis) Batt.
Abbot's Cl: 36(p)

Hypoglossum woodwardii Kutz.

Abbot's Cl: 21(p); Shakesp. Cl: 36(c), 44(p), 45(p); S. Forel: 50(p).

Lomentaria orcadensis (Harv.) Taylor
Shakesp. Cl: 36(p).

Membranoptera alata (Huds.) Stackh.
Shakesp. Cl: 36(c).

Polyneura hilliae (Grev.) Kylin
Abbot's Cl: 21(c); Shakesp. Cl: 44(c), 45(c).

Palmaria palmata (L.) O. Kuntze
Copt: 2(p), 3(p); Abbot's Cl: 21(p), 24(p); Shakesp. Cl: 36(a), 45(c).

Phyllopora crispa (Huds.) Dixon
Shakesp. Cl: 36(p).

Phyllopora pseudoceranoides (S.G. Gmel.) Newr. et A.R.A.Taylor
Copt: 6(p); Shakesp. Cl: 36(p).

Phymatolithon laevigatum (Fosl.) Fosl.
Copt: 6(a); E. Wear: 11(c); Shakesp. Cl: 36(c), 43(p), 45(p).

Plocamium cartilagineum (L.) Dixon
Copt: 2(p), 3(p), 6(p); E. Wear: 11(c); Abbot's Cl: 20(a), 21(a), 27(c), 28(p); Shakesp. Cl: 33(p), 36(a), 41(a), 42(c), 43(p), 44(c), 45(c).

Polysiphonia elongata (Huds.) Spreng.
Abbot's Cl: 20(p).

Polysiphonia nigrescens (Huds.) Grev.
Copt: 3(p), 5(p); E. Wear: 11(p); Abbot's Cl: 20(p); Shakesp. Cl: 33(p), 36(p), 45(p).

Pneophyllum ? myriocarpum
Shakesp. Cl: 36(p).

Rhodomela confervoides (Huds.) Silva
Abbot's Cl: 21(p); Shakesp. Cl: 36(c), 45(p).

Rhodophysema elegans (J. Ag.) Dixon
Shakesp. Cl: 36(p).

Rhodymenia holmesii Ardiss
Abbot's Cl: 21(a); Shakesp. Cl: 44(p), 45(p).

The green algae Ulva and Enteromorpha were recorded sporadically from shallow, sheltered sites, particularly at Copt Point. Their growth here may have been encouraged by the input of freshwater from the sewage system. However, these species were restricted to the very shallow zones, and the only green alga commonly occurring in deeper water was Bryopsis plumosa, which grew amongst algal/animal turf to depths about 8m below Chart Datum.

Foliaceous and filamentous red algae were common on upward-facing surfaces of boulders and bedrock outcrops from the low tide mark to depths of about 5 m below Chart Datum. Some of these species were undoubtedly under-recorded, but prominent species included Plocamium cartilagineum, Halurus equisetifolius and Calliblepharis ciliata. Species seen in deeper water, to about 8 m below CD, included Delesseria sanguinea and Rhodymenia holmesii, both of which also occurred in shallower water. Crustose red algae (e.g. Phymatolithon) generally grew only in small encrustations in the sublittoral, and were sparsely distributed, although more in evidence on greensand and flint.

The kelps Laminaria digitata and L. saccharina occurred from extreme low water to depths not exceeding about 3 m below Chart Datum. Laminaria hyperborea, which has not been recorded previously from Kent, was found in slightly deeper water (about 2 - 3 m below CD), generally intermingled with L. digitata. All three species were typically attached to the tops of boulders and rock outcrops, sometimes occurring in dense stands. L. digitata and L. saccharina were found at shallow rocky sites all along the stretch of coast, but appeared to be less common off Abbot's Cliff. L. hyperborea was recorded only from the Shakespeare Cliff area. Possibly the extreme softness of the Glauconitic Marl at Abbot's Cliff makes it difficult for kelp plants to maintain a hold.

The majority of species listed here had been reported from Kent by Tittley & Price (1977), and Tittley et al. (1985). The most prominent new record was Laminaria hyperborea.

PORIFERA

Leucosolenia botryoides (Ellis & Solander, 1786). Sensu Burton 1963.
Copt: 7(p), 8(c); Abbot's Cl: 18(p), 19(p), 20(p), 24(p), 25(p), 27(p), 28(p), 30(p).

Scypha ciliata (Fabricius, 1780). Sensu Burton, 1963.
Copt: 4(o), 6(o), 7(o), 8(c); E. Wear: 13(p); Abbot's Cl: 18(c), 19(c), 20(c), 21(c), 23(c), 24(c), 25(c), 27(c), 28(c), 29(c), 30(c); Shakesp. Cl: 33(c); 35(p), 39(p); S. Forel: 48(p).

Oscarella lobularis (Schmidt, 1862).
Abbot's Cl: 21(p), 25(p).

Cliona celata Grant, 1862.
Boring form: E. Wear: 15(r); Abbot's Cl: 19(r); 24(r).

Stelligera rigida (Montagu, 1818).
Shakesp. Cl: 33(r).

Raspailia ramosa (Montagu, 1818).
E. Wear: 14(p); Shakesp. Cl: 33(p).

Halichondria panicea (Pallas, 1766).
Copt: 1(p); 2(p), 4(p), 6(p), 7(c), 8(a); E. Wear: 13(c), 14(c); Abbot's Cl: 18(a), 19(a), 20(a), 21(a), 23(c), 24(a), 25(p), 26(c), 27(c), 28(c), 29(p), 30(p), 31(p), 32(c); Shakesp. Cl: 33(c), 34(p), 36(p), 38(p), 39(c), 40(c), 41(p), 42(p), 43(p), 44(c), 45(p); S. Forel: 48(c), 49(a).

Hymeniacidon perleve (Montagu, 1818).
Abbot's Cl: 24(p), 27(p); Shakesp. Cl: 33(p), 40(p).

Hemimycale columella (Bowerbank, 1874).
Abbot's Cl: 27(p).

Amphilectus fucorum (Esper, 1794).
Copt: 7(o); E. Wear: 13(o); Abbot's Cl: 18(c), 19(c), 20(a), 21(p), 23(c), 24(a), 25(a), 27(c), 28(c), 30(a); Shakesp. Cl: 33(p), 38(p), 39(p), 41(p), 43(p), 44(p); S. Forel: 48(p).

Myxilla incrustans (Johnston, 1842).
Abbot's Cl: 20(p); Shakesp. Cl: 33(p); S. Forel: 48(p).

Hymedesmia sp ?
Shakesp. Cl: 44(r).

Phorbas fictitius (Bowerbank, 1866)
Shakesp. Cl: 33(r).

Haliclona oculata (Pallas, 1766).
Copt: 7(p), 8(c); E. Wear: 13(c), 14(p); Abbot's. Cl: 18(p), 19(c), 20(p), 23(p), 24(p), 27(p), 28(p), 30(p), 31(p); Shakesp. Cl: 33(p), 34(p), 35(c), 38(c), 39(p), 41(p); S. Forel: 48(p).

Haliclona fistulosa (Bowerbank, 1866).
E. Wear: 13(p); Shakesp. Cl: 33(p).

Dysidea fragilis (Montagu, 1818).
E. Wear: 14(p); Abbot's Cl: 20(p), 24(p); Shakesp. Cl: 36(p), 43(p), 44(p).

The sponges found in the sublittoral zone off Folkestone and Dover fell into three reasonably distinct groups. Firstly, there were a number of small, low-growing species that grew mostly with other 'turf' species (e.g. hydroids, bryozoans) on the sides of boulders in the 0-6 m depth zone, but were also seen in deeper areas. Scypha ciliata and Leucosolenia botryoides were the commonest and most widespread, while species such as Dysidea fragilis and Myxilla incrustans were found only very occasionally. It is likely that these 'turf' species show seasonal changes in abundance.

The second recognisable group consisted of larger, erect species that were found on the tops or sides of boulders or bedrock; generally occurring as isolated growths. Haliclona oculata was the commonest, although still relatively sparsely distributed, while Raspailia ramosa and Stelligera rigida were rare.

Finally, there were two species that grew as small, low-growing clumps close to the shore, but formed taller and more prominent masses further offshore in current-swept areas. Halichondria panicea was the most frequently recorded of all the sponges, and, at some sites was the dominant organism. Amphilectus fucorum was also common, and was often found growing around the stems of Tubularia or Nemertesia.

COELENTERATA

HYDROZOA

Tubularia indivisa Linnaeus, 1758.
Copt: 1(o), 7(o), 8(p); E. Wear: 12(c), 13(c), 14(p); Abbot's Cl: 18(c), 19(c), 20(p), 21(p), 22(p), 24(p), 25(p), 26(p), 27(p), 28(a), 30(c), 31(p), 32(c); Shakesp. Cl: 33(c), 34(p), 35(c), 38(c), 39(p), 40(p), 41(p), 42(p), 43(p), 44(p), 45(c); S. Forel: 48(p), 49(c).

Corymorpha nutans M. Sars, 1835
Copt: 7(p); Abbot's Cl: 18(p), 19(c), 23(p), 24(p), 29(c).

Eudendrium sp.
E. Wear: 15(p); Abbot's Cl: 21(c); Shakesp. Cl: 33(a), 39(a), 41(a).

Halecium halecinum (Linnaeus, 1758)
Copt: 1(o), 8(o); Abbot's Cl: 20(c), 23(c), 24(c), 27(p), 29(p); Shakesp. Cl: 33(p), 35(c), 39(p), 40(p), 42(p), 44(p), 47(p); S. Forel: 48(p), 49(c).

Campanularia ? verticillata (Linnaeus, 1758)
Copt: 8(c).

Obelia ? longissima (Pallas, 1766)
Copt: 8(c); Abbot's Cl: 23(c), 29(c).

Sertularia sp.
Shakesp. Cl: 35(c).

Diphasia ? attenuata Hincks, 1866
Copt: 8(c); Shakesp. Cl: 35(p).

Hydrallmania falcata Linnaeus, 1758
Copt: 2(o), 5(c); E. Wear: 14(p); Abbot's Cl: 22(p), 29(p), 31(p); Shakesp. Cl: 33(p), 35(p), 43(p).

Plumularia setacea (Ellis & Solander, 1786)
Copt: 8(c); Abbot's Cl: 20(p).

Nemertesia antennina (Linnaeus, 1758)
Copt: 7(p), 8(c); E. Wear: 13(p), 14(p); Abbot's Cl: 18(c), 19(p), 20(p), 21(p), 23(c), 24(c), 25(p), 26(p), 27(p), 28(c), 29(p), 30(p), 31(p); Shakesp. Cl: 33(p), 35(c), 40(p), 44(p); S. Forel: 48(p).

Kirchenpaueria pinnata (Linnaeus, 1758)
Abbot's Cl: 21(p), 23(p), 25(p), 30(p); Shakesp. Cl: 38(p).

ANTHOZOA

Alcyonium digitatum Linnaeus, 1758
Copt: 7(p), 8(a); E. Wear: 13(p), 14(p); Abbot's Cl: 18(p), 19(c), 20(p), 21(p), 23(p), 24(p), 25(c), 26(c), 27(p), 28(p), 29(p), 30(c), 31(p), 32(p); Shakesp. Cl: 33(c), 34(p), 35(p), 38(a), 39(p), 40(p), 41(p), 42(p), 43(p), 44(p), 45(c), 47(p); S. Forel.: 48(c), 49(p).

Cerianthus lloydii Gosse, 1859
E. Wear: 14(p); Abbot's Cl: 18(c), 20(p), 22(p), 24(p), 25(p), 30(p), 34(p), 35(c); S. Forel: 48(p), 49(c).

Actinia equina Linnaeus, 1758
Copt: 6(c); E. Wear: 11(c); Shakesp. Cl: 42(p), 47(p).

Urticina felina Linnaeus, 1761
Copt: 1(p), 2(p), 4(p), 5(p), 6(p), 7(p), 8(c); E. Wear: 13(p), 14(p), 15(p); Abbot's Cl: 18(c), 19(p), 20(c), 21(p), 23(p), 24(c), 25(c), 26(c), 27(p), 28(c), 29(p), 30(p), 31(c), 32(p); Shakesp. Cl: 33(p), 34(p), 35(c), 36(p), 38(c), 39(p), 40(p), 41(p), 42(p), 43(p), 44(p), 47(c); S. Forel: 48(p), 49(a).

Diadumene cincta Stephenson, 1925
Copt: 8(a); Shakesp. Cl: 44(r).

Metridium senile (Linnaeus, 1761)
Copt: 1(p), 2(p), 6(p), 7(p), 8(c); E. Wear: 12(p), 13(p), 14(p), 15(p); Abbot's Cl: 18(c), 19(p), 20(p), 21(p), 22(p), 23(p), 24(p), 26(p), 31(p), 32(c); Shakesp. Cl: 33(p), 34(p), 35(c), 38(c), 42(p), 44(p).

Sagartia elegans (Dalyell, 1848)
Copt: 6(c), 8(c); E. Wear: 13(p); Abbot's Cl: 18(c), 19(p), 20(p), 24(p), 26(p); Shakesp. Cl: 38(p), 41(p); S. Forel: 49(p).

Sagartia troglodytes (Price, 1847)
Copt: 3(p), 5(c), 6(a), 7(p); E. Wear: 11(c), 13(p), 14(p), 15(p); Abbot's Cl: 18(a), 19(c), 20(c), 21(a), 23(a), 24(a), 25(a), 26(p), 27(p), 28(a), 29(a), 30(a); Shakesp Cl: 33(c), 35(p), 36(c), 38(a), 39(c), 40(c), 41(a), 42(c), 43(c), 44(p), 45(a); S. Forel: 48(p).

Cereus pedunculatus (Pennant, 1777)
Abbot's Cl: 21(p), 25(p), 27(p), 30(p); Shakesp. Cl: 33(p), 38(c), 39(p), 41(p), 43(p), 44(p), 45(p).

Sagartiogeton undatus (Muller, 1788).
E. Wear: 15(p); Shakesp. Cl: 44(p), 45(p).

Hydroids were an important component of the sessile fauna, and often were the dominant organism on the sides of boulders, where they formed a low-growing turf. These species were small, and often were silt-covered, making field identification extremely difficult, and there is no doubt that they were under-recorded. It is also possible that there is a seasonal rotation of species, and that others might be found later in the year. Four relatively large and easily identified species were present in the area. *Tubularia indivisa* was commonly recorded, although was dying back by mid-June. It was especially abundant on the sides of boulders or bedrock outcrops in current-swept situations. *Nemertesia antennina* was found in similar situations. *Hydrallmania falcata* was less common, and was found mainly on low-lying bedrock, or attached to stones or shells in silty sediment. The large and distinct hydroid *Corymorpha nutans* was seen only off Abbot's Cliff, on coarse sand/gravel between the bedrock outcrops, and on one occasion attached to *Molgula manhattensis*.

Alcyonium digitatum was recorded from shallow sites close inshore, but colonies here were small, sparsely distributed, and confined to current-swept situations on the sides of boulders. It became more conspicuous in deeper water, sometimes occurring in large clumps.

The most frequently recorded anemones were *Sagartia troglodytes* and *Urticina felina*. *U. felina* was the less numerous of the two species, but some of the individuals were large, measuring 20 cm across the expanded tentacles. They were especially common in silty gravel a few hundred metres beyond low water, attached to stones or to underlying bedrock, but also occurred closer to the shore. *S. troglodytes* (Figure 9) was common at many rocky sites, often occupying empty piddock holes in scoured bedrock, or with the column buried in silty sediment, and the base attached to bedrock or stones beneath. It also occurred amongst 'turf' species on vertical surfaces, although was much less common in these situations.

Figure 9. Sagartia troglodytes on silty bedrock at Abbot's Cliff (photo: D. Manuel).

Sagartia elegans was much more sparsely distributed than S. troglodytes, except at site 8 (Copt Rocks), where it was common, and S. troglodytes unusually absent. This could possibly be due to some factor connected with the different rocky substratum in this area. Cereus pedunculatus was found in habitats similar to those harbouring Sagartia spp., but was recorded much less frequently. The only burrowing anemone seen during the survey was Cerianthus lloydii, which occurred in silty sediments at a range of sites.

Metridium senile grew in greatest profusion on the wreck of the Brandyboat, where it dominated many of the vertical structures. It was sparsely distributed in inshore rocky habitats, but became more common in depths of 8 m or more below CD. Here it occurred in current-swept situations on bedrock outcrops, or attached to stones or shell debris on rough ground.

NEMERTEA

Oerstedia dorsalis (Abildgaard, 1806)
Shakesp. Cl: 33(c).

Lineus/Tubulanus spp.
Abbot's Cl: 20(p), 21(p), 27(p), 28(p), 30(p); Shakesp. Cl: 41(p), 43(p), 44(p).

ANNELIDA

POLYCHAETA

polynoid spp.
E. Wear: 11(p); Abbot's CL: 24(p), 27(c); Shakesp. Cl: 42(p), 43(c).

syllid sp
Shakesp. Cl: 44(p).

Eulalia viridis (Linnaeus, 1769)
Shakesp. Cl: 28(p).

Anaitides maculata (Linnaeus, 1767)
Abbot's Cl: 18(c), 30(c).

phyllodocid egg cases (pale green, ? _Eulalia viridis_)
Copt: 3(p), 4(p), 5(c); E. Wear: 11(c); Abbot's Cl: 24(p), 25(c), 27(p), 30(p); Shakesp. Cl: 36(c), 40(p), 41(p), 42(c), 43(p), 45(p); S. Forel: 48(p).

Polydora ? ciliata (Johnston, 1838)
E. Wear: 11(c); Abbot's Cl: 25(c).

spionid spp.
E. Wear: 14(p), 15(c); Abbot's Cl: 24(p), 27(c); Shakesp. Cl: 42(p).

Arenicola marina (Linnaeus, 1758)
E. Wear: 9(p), 11(p); Shakesp. Cl: 42(p).

Sabellaria spinulosa Leuckart, 1849
Abbot's Cl: 18(c), 20(c), 21(p), 25(p); Skakesp. Cl: 45(o).

Lagis koreni Malmgren, 1867
Copt: 5(p); E. Wear: 10(p), 15(p).

terebellid sp.
E. Wear: 15(p).

Lanice conchilega (Pallas, 1766)
E. Wear: 6(o); Abbot's Cl: 9(c), 11(p), 12(c), 13(p), 15(a); 20(p), 22(p); Shakesp. Cl: 42(p), 47(p).

Sabella sp.
Copt: 8(p).

Pomatoceros triqueter (Linnaeus, 1761)
Copt: 3(p), 6(p), 8(a); Shakesp. Cl: 36(p), 44(p).

Filograna implexa Berkeley, 1827
Abbot's Cl: 19(p), 20(p), 23(p), 24(p), 25(p), 30(p).

Filograna implexa Berkeley, 1827
Abbot's Cl: 19(p), 20(p), 23(p), 24(p), 25(p), 30(p).

PHORONIDA

Phoronis sp.
Abbot's Cl: 18(p), 20(p), 21(p), 25(p), 27(p), 28(p), 30(p).

Bootlace-worms belonging to the genus Lineus and/or Tubulanus were seen occasionally, especially amongst turf on the sides of rocks. Numerous specimens of the smaller species Oerstedia dorsalis were found in a sample of turf, and it is likely that these small nemerteans were widely distributed.

Scale-worms (polynoid spp.) were common amongst the faunal turf, although were difficult to spot in-situ, and were undoubtedly under-recorded. Sabellaria spinulosa also tended to be obscured in the silty turf, although in places formed more obvious crusts over the surface of the rocks. Polydora ? ciliata, and other spionids living in mud-tubes, occurred in silty mats overlying, and possibly partially buried in chalk and marl. Phyllodocid worms (e.g. Eulalia viridis, Anaitides maculata) occurred on the surface of silty sediment, and beneath stones. They were widely distributed and apparently present in large numbers.

It was beyond the scope of this survey to investigate the infauna of sediments, but there is little doubt that they would be an ideal habitat for a wide range of species. Species seen at the surface included Lanice conchilega, Lagis koreni (empty tubes), and terebellids (feeding tentacles).

CRUSTACEA

CIRRIPEDIA

Semibalanus balanoides* (Linnaeus, 1767) (*see note in text)
Copt: 1(p), 2(c), 3(c), 4(o), 5(p), 7(p); E. Wear: 11(p), 12(a), 13(c): Abbot's Cl: 18(a), 19(c), 20(a), 24(a), 25(a), 27(a), 28(c), 30(a); Shakesp. Cl: 33(a), 36(a), 38(a), 39(a), 40(a), 41(a), 42(c), 43(c), 44(a), 45(a), 47(c).

AMPHIPODA

Dyopedos porrectus Bate, 1857
Copt: 8(p); Shakesp. Cl: 33(p), 35(c), 39(p).

DECAPODA

Palaemon sp
E. Wear: 14(p); Abbot's Cl: 20(p); Shakesp. Cl: 35(p), 40(p), 47(p).

Homarus gammarus (Linnaeus, 1758)
Copt: 7(p); Abbot's Cl: 18(p), 24(p), 32(p); Shakesp. Cl: 47(p).

Galathea squamifera Leach, 1815
Abbot's Cl: 19(p), 25(c); Shakesp. Cl: 33(p), 36(p), 39(p), 44(p); S. Forel: 48(p).

Galathea strigosa (Linnaeus, 1767)
Shakesp. Cl: 38(p), 42(p).

Pagurus or Anapagurus sp(?p)
Copt: 1(c), 2(p), 3(p), 5(p), 7(p), 8(p); E. Wear: 11(p), 12(c), 13(c), 15(c), 18(c), 19(c), 20(c), 21(p), 22(p), 26(p), 27(p), 31(p); Shakesp. Cl: 33(p), 34(p), 41(p), 43(p), 45(p).

Pagurus bernhardus (Linnaeus, 1758)
Abbot's Cl: 18(p), 20(p), 24(p), 31(p); Shakesp. Cl: 35(p), 38(c), 39(p), 42(p), 47(c); S. Forel: 48(p).

Ebalia tuberosa (Pennant, 1777)
E. Wear: 11(p); Abbot's Cl: 27(p).

Corystes cassivelaunus (Pennant, 1777)
Copt: 8(p-dead); Shakesp. Cl: 47(p).

Liocarcinus holsatus (Fabricius, 1798)
Shakesp. Cl: 34(p).

Liocarcinus puber (Linnaeus, 1767)
Shakesp. Cl: 47(c).

Liocarcinus sp.
Abbot's Cl: 22(p); Shakesp. Cl: 38(p).

Carcinus maenas (Linnaeus, 1758)
Copt: 2(p), 4(c), 5(p); E. Wear: 11(p); Shakesp. Cl: 43(p), 47(p).

Cancer pagurus Linnaeus, 1758
Copt: 4(p), 5(p), 6(p), 7(p); E. Wear: 12(p), 13(c), 14(p); Abbot's Cl: 18(c), 19(c), 20(p), 21(p), 24(p), 26(p), 27(c); Shakesp. Cl: 32(p), 38(p), 40(p), 43(p), 44(p), 46(p), 47(p).

Pilumnus hirtellus (Linnaeus, 1761)
Abbot's Cl: 20(p), 27(p); Shakesp. Cl: 42(p), 43(p), 44(p).

Hyas araneus (Linnaeus, 1758)
Copt: 6(p), 7(p), 8(p); E. Wear: 14(p); Abbot's Cl: 18(c), 20(c), 22(c), 23(p), 24(c), 26(p), 27(p), 31(p), 33(p), Shakesp. Cl: 34(p), 35(p), 39(p), 43(p), 44(p); S. Forel: 48(p).

Hyas sp
E. Wear: 13(p); Abbot's Cl: 18(p); Shakesp. Cl: 35(c); S. Forel: 49(p).

Inachus phalangium (Fabricius, 1775)
Shakesp. Cl: 35(p).

Macropodia rostrata (Linnaeus, 1761)
Copt: 6(p); Abbot's Cl: 23(p), 24(p); Shakesp. Cl: 33(p), 35(p).

Some of the barnacles collected for identification were small and difficult to identify. Others were found to be Semibalanus balanoides, and it is suspected that most of the records of barnacles were of this species. Barnacles were common throughout the shallow sublittoral, and were found on a variety of surfaces, including flint cobbles, chalk boulders and bedrock, and algae. They often occurred in dense clusters and in these cases it was not unusual to find indivduals with an extremely etiolated growth form. One detached barnacle shell was found harbouring a small hermit crab.

The whip-forming amphipod Dyopedos porrectus was seen on several occasions, especially on Tubularia. Amphipods and isopods were also present in the turf, amongst algae and beneath stones, but a detailed investigation of these small species was beyond the scope of this survey.

Hermit crabs were widely distributed, occurring in a range of habitats. Large specimens of the hermit crab Pagurus bernhardus were relatively scarce, but small hermit crabs (some of which may have been juvenile P. bernhardus) were often common, especially on the soft sea-bed.

Apart from Corystes cassivelaunus and Pagurus sp., other decapods were found mostly amongst boulders and on rough ground, where they could find refuge in holes and other sheltered spots. For this reason, they were commonest in the shallow (0 - 8 m) zone. The Edible Crab, Cancer pagurus was one of the most frequently recorded species, although all the specimens seen were small (less tha 10 cm across the carapace). The lobsters seen were also small. The spider crab, Hyas araneus was widely distributed, and many specimens were encrusted with epizoites such as Clavelina lepadiformis and Amphilectus fucorum. Other small spider crabs present, especially amongst bryozoans, hydroids and other sessile organisms, included Macropodia rostrata and Inachus phalangium.

The Hairy Crab, Pilumnus hirtellus occupied a similar habitat, but was well camoflauged and probably under-recorded.

Swimming crabs were noticeably scarce. The only record of Liocarcinus puber was made during a dive in September, rather than during the May-June survey, and it is possible that these crabs migrate shorewards or eastwards along the Channel at this time, since they were also recorded in August, 1985 (Anon, 1985b) and in February, 1986 (Fincham and George, 1986).

MOLLUSCA

GASTROPODA

Patina pellucida (Linnaeus, 1758)
Copt: 6(p-dead).

Gibbula cineraria (Linnaeus, 1758)
Copt: 6(p); Abbot's Cl: 20(p); Shakesp. Cl: 36(p), 42(p).

Calliostoma zizyphinum (Linnaeus, 1758)
Shakesp. Cl: 41(r).

Crepidula fornicata (Linnaeus, 1758)
Shakesp. Cl: 44(p).

Trivia arctica (Montagu, 1803)
Abbot's Cl: 22(r); Shakesp. Cl: 35(r).

Natica sp.
E. Wear: 10(p), 15(p); Abbot's Cl: 29(p); Shakesp. Cl: 38(p).

Buccinum undatum (Linnaeus, 1758)
Shakesp. Cl: 35(p), 42(p).

Nassarius reticulatus (Linnaeus, 1758)
E. Wear: 11(p), 12(c), 13(c), 14(p), 15(p); Abbot's Cl: 20(c), 22(p); Shakesp. Cl: 47(c).

Philine aperta (Linnaeus, 1767)
E. Wear: 10(p), 15(p).

Tritonia hombergi Cuvier, 1803
Abbot's Cl: 19(r); Shakesp. Cl: 33(p).

Dendronotus frondosus (Ascanius, 1774)
Abbot's Cl: 18(r), 32(r).

Goniodoris nodosa (Montagu, 1808)
Abbot's Cl: 19(p), 27(c); Shakesp. Cl: 41(p); S. Forel: 48(p).

Ancula gibbosa (Risso, 1818)
Shakesp. Cl: 36(p), 40(p), 42(p), 43(p), 45(p).

Onchidoris bilamellata (Linnaeus, 1767)
E. Wear: 12(c), 13(a).

Polycera quadrilineata (Muller, 1776)
Copt: 6(p).

Cadlina laevis (Linnaeus, 1767)
Abbot's Cl: 26(r), 29(r).

Archidoris pseudoargus (Rapp, 1827)
Copt: 8(p); E. Wear: 14(p); Abbot's Cl: 19(p), 20(p), 23(p), 24(p); Shakesp. Cl: 44(p); S. Forel: 48(p).

Coryphella gracilis (Alder & Hancock, 1844)
Abbot's Cl: 21(p), 25(p); Shakesp. Cl: 33(c), 38(a), 39(c), 40(a), 41(p), 42(p), 43(p), 44(p), 45(p).

Coryphella pellucida (Alder & Hancock, 1843)
Copt: 3(p); E. Wear: 15(p); Abbot's Cl: 26(p); Shakesp. Cl: 41(p), 43(p).

Facelina coronata (Forbes & Goodsir, 1839)
Copt: 6(p), 8(p); E. Wear: 13(p), 18(c); Abbot's Cl: 19(c), 20(p), 24(p), 27(p), 28(c), 30(p); Shakesp. Cl: 33(p), 39(p), 40(p).

Aeolidia papillosa (Linnaeus, 1761)
Copt: 6(p); E. Wear: 13(p), 14(p); Abbot's Cl: 20(p), 23(p), 24(p), 26(p); Shakesp. Cl: 33(p), 35(p); S. Forel: 48(p).

BIVALVIA

Mytilus edulis Linnaeus, 1758
Copt: 3(p), 4(a), 5(a), 6(a); E. Wear: 11(a); Abbot's Cl: 25(c), 32(p); Shakesp. Cl: 33(c), 36(a), 39(p), 41(p), 42(c), 43(a), 45(a), 47(p); S. Forel: 49(a).

Venerupis saxatilis (Fleuriau de Bellevue, 1802)
Shakesp. Cl: 33(p).

Ensis ensis (Linnaeus, 1758)
Shells only: E. Wear: 15(p); Abbot's Cl: 22(c).

Barnea candida (Linnaeus, 1758)
E. Wear: 11(p), 12(a); Abbot's Cl: 24(a), 30(a); Shakesp. Cl: 33(c), 44(p), 45(p).

Barnea parva (Pennant, 1777)
Shakesp. Cl: 33(p).

Hiatella arctica (Linnaeus, 1767)
E. Wear: 11(c); Abbot's Cl: 20(c), 24(c), 27(a), 28(c); Skakesp. Cl: 33(c), 36(a), 41(a), 42(c), 43(a), 44(c), 45(a); S. Forel: 49(c).

Pholas dactylus Linnaeus, 1758
E. Wear: 11(c), 13(c); Abbot's Cl: 18(c), 19(c), 20(c), 23(p), 24(a), 25(a), 27(c), 28(a), 30(a); Shakesp. Cl: 33(c), 36(c), 41(p), 42(p), 43(p), 44(c), 45(a); S. Forel: 48(p).

Zirfaea crispata (Linnaeus, 1758)
Shakesp. Cl: 43(p), 44(p-dead).

Ensis ensis (Linnaeus, 1758)
E. Wear: 15(p); Abbot's Cl: 22(p).

CEPAHALOPODA

Sepia oficinalis Linnaeus, 1758
Abbot's Cl: 26(r); Shakesp. Cl: 33(p-eggs), 45(r).

Sepia/Sepiola sp (juvenile)
Copt: 8(r): Shakesp. Cl: 47(r).

squid eggs
E. Wear: 12(r); Abbot's Cl: 18(r), 20(r) 28(r).

Prosobranch gastropods were sparsely distributed; only the Netted Dogwhelk, Nassarius reticulatus, was seen in significant numbers. Opishobranchs were recorded more frequently, and there was a wider range of species, with some recorded as common or abundant at certain sites. Onchidoris bilamellata, although seen only at two sites, was present in huge numbers, crawling in columns over rough ground. Species commonly found amongst faunal turfs included Coryphella gracilis (feeding primarily on Eudendrium and Halecium), Dendronotus frondosus (feeding on hydroids, including Tubularia), Coryphella pellucida and Facelina coronata (both feeding on Tubularia). Other frequently recorded species included Aeolidia papillosa and Archidoris pseudoargus, both of which were found on rocky and rough ground. Philine aperta is a burrowing opisthbranch and was seen at the surface of the soft sea-bed.

The most abundant molluscs associated with rocky habitats were the boring bivalves. This was evident from the large numbers of siphons visible at many sites and the presence of numerous individuals extracted from small samples of chalk rock. The large, black-edged siphons of Pholas dactylus were seen only in the flat bedrock, but occurred both where the surface of the rock was scoured clean, and where it was covered with a layer of silty sediment. Although empty shells were found in the bedrock, and innumerable siphons seen, we failed to remove a sample of bedrock deep enough to include any living animals.

One rock sample 7 cm deep with a surface area of 115 cm^2 had 30 holes on its upper face and 18 on the lower face. The latter were evidently leading to live individuals, and indicate a population similar to that for Hiatella arctica.

Figure 10. Siphons of the piddock Pholas dactylus protruding from bedrock, through a layer of silt. (Abbot's Cliff, photo: D. Manuel).

Hiatella arctica had a clear preference for boulders and bedrock outcrops, and was present in enormous numbers. Two samples, about 8 cm deep, and with surface areas of 110 cm^2 and 150 cm^2, yielded 11 and 25 live individuals respectively, in burrows about 5 cm deep. This is equivalent to 2272 and 733 individuals per m^2 of surface area. Zirfaea crispata was found with H. arctica but was evidently much less common, while Barnea candida and B. parva appeared to prefer the flat bedrock.

Mytilus edulis was widely distributed, but except for the area around the sewer outfall at Copt Rocks, only juveniles were recorded. During the early part of the survey in particular, there were numerous Mytilus edulis spat (about 1 mm long) temporarily attached to filamentous algae and some of the larger turf species. It appears that conditions are unsuitable for permanent colonisation by adult M. edulis in the sublittoral, possibly because of the friability of the substratum. At Copt Rocks, the combination of hard rocks (greensand) and a plentiful supply of food (sewage) enables adults to thrive.

Cephalopods (adults and eggs) were recorded infrequently.

ECHINODERMATA

Asterias rubens Linnaeus, 1758
Copt: 1(p), 3(p), 4(a), 5(a), 6(a), 7(c), 8(a); E. Wear: 11(p), 12(c), 13(c), 14(c), 15(p); Abbot's Cl: 19(c), 20(c), 21(c), 22(c), 23(a), 24(c), 25(c), 26(c), 27(p), 29(a), 31(c), 32(a), 34(p), 35(c); Skakesp. Cl: 33(c), 36(c), 38(c), 39(c), 40(c), 41(c), 42(p), 43(c), 44(p), 45(p), 47(p); S. Forel: 48(a), 49(c), 50(p).

Crossaster papposus (Linnaeus, 1767)
Abbot's Cl: 26(p); Shakesp. Cl: 35(p); S. Forel: 49(p).

Ophiothrix fragilis (Abildgaard, 1789)
Copt: 8(p); S. Forel: 48(p).

Ophiura albida Forbes, 1839
E. Wear: 10(c), 14(p), 15(a); Abbot's Cl: 22(p); Shakesp Cl: 45(o).

Psammechinus miliaris P.L.S. Muller, 1771
Copt: 8(r); Abbot's Cl: 22(r); Shakesp. Cl: 35(r-test only).

Holothuroidea sp
Shakesp. Cl: 35(r).

Asterias rubens was one of the most widely distributed animals in the area, being found in all rocky habitats, on broken ground, and often on the silty gravel. It was present in huge numbers at Copt Rocks, feeding on Mytilus edulis adjacent to the sewage outfall.

The brittle-star Ophiura albida was also present in large numbers, but was restricted to the offshore sediment plain.

The other echinoderms were recorded only infrequently. Holothurians were absent from rocky habitats; the only species seen was in the silty gravel.

BRYOZOA

Alcyonidium diaphanum (Hudson, 1762)
Copt: 7(p); Abbot's Cl: 19(c), 23(p), 26(p), 28(p), 29(p); Shakesp. Cl: 33(p), 35(c), 38(p), 40(p); S. Forel: 48(p), 49(p).

Crisia eburnea (Linnaeus, 1758)
Shakesp. Cl: 33(c), 34(p).

Vesicularia spinosa (Linnaeus, 1767)
Copt: 8(a); Shakesp. Cl: 34(a).

Electra pilosa (Linnaeus, 1767)
Copt: 2(p); Shakesp. Cl: 33(c), 45(c); S. Forel: 49(c).

Chartella papyracea (Ellis & Solander, 1786)
E. Wear: 14(c); Shakesp. Cl: 34(p), 43(p), 45(c).

Bicellariella ciliata (Linnaeus, 1758)
Copt: 8(a).

Eucratea loricata (Linnaeus, 1758)
Copt: 8(a).

Bugula flabellata (Thompson, in Gray, 1848)
Copt: 8(c); Abbot's Cl: 18(o), 23(c), 24(p); S. Forel: 48(p).

Bugula plumosa (Pallas, 1766)
Abbot's Cl: 18(o), 25(p), 30(p).

Escharella immersa (Fleming, 1828)
Copt: 8(p).

Escharella ventricosa (Hassall, 1842)
Copt: 8(p).

Schizoporella unicornis (Johnston, in Wood, 1844)
Copt: 8(c).

Cellopora pumicosa (Pallas, 1766)
Copt: 7(p), 8(p); Abbot's Cl: 24(p), 26(p); Shakesp. Cl: 36(p), 38(p).

Bryozoans were found in a range of habitats. Firstly, there were several small, erect species contributing to the faunal turf, and found especially on the sides of boulders and bedrock outcrops. These included Crisia eburnea, Bugula spp., Chartella papyracea, Bicellariella ciliata and Eucratea loricata. Although some of these species could be identified in-situ, others were too small and/or silt-covered, and were undoubtedly under-recorded. Vesicularia spinosa was a straggly broyzoan found in deeper water on rough ground.

Electra pilosa was one of the most obvious of the encrusting bryozoans, occurring on kelps and foliaceous algae in shallow rocky areas. Other encrusting species were found on stones (greensand) on rough ground off Copt Point.

The two bryozoans whose distribution was probably most accurately recorded were Flustra foliacea and Alcyonidium diaphanum. F. foliacea was particularly common on low-lying, current-swept bedrock, and was not recorded from depths shallower than about 5 m below CD. It was sometimes the dominant organism on rocky outcrops on the sediment plain. _A. diaphanum_ occupied similar habitats although was much more sparsely distributed.

ASCIDIACEA

Clavelina lepadiformis (O.F. Muller, 1776)
Copt: 7(p); E. Wear: 13(p); Abbot's Cl: 18(c), 19(c), 20(c), 21(p), 24(c), 25(c), 27(c), 28(a), 30(c); Shakesp. Cl: 47(p).

Distaplia rosea Della Valle, 1881
Copt: 8(p); E. Wear: 13(p); Abbot's Cl: 18(c), 19(c), 20(c), 23(p), 25(c), 30(c); S. Forel: 48(p).

Synoicum pulmonaria (Ellis & Solander, 1786)
Shakesp. Cl: 33(p).

Sidnyum turbinatum Savigny, 1816
Abbot's Cl: 28(p), 30(p); Shakesp. Cl: 33(p).

Diplosoma listerianum (Milne-Edwards, 1841)
Abbot's Cl: 20(p), 28(p); Shakesp. Cl: 44(p).

Ciona intestinalis (Linnaeus, 1767)
Abbot's Cl: 18(p).

Ascidia conchilega O.F. Muller, 1776
Shakesp. Cl: 33(p).

Dendrodoa grossularia (van Beneden, 1846)
Copt: 3(p), 4(p); Abbot's Cl: 20(p), 21(p), 25(p); Shakesp. Cl: 33(p), 36(p), 38(c), 40(p), 41(c), 42(c) 43(p), 45(p).

Botrylloides leachi (Savigny, 1816)
Copt: 7(p), 8(p); E. Wear: 12(p), 13(c); Abbot's Cl: 18(c), 19(a), 20(c), 21(p), 23(c), 24(c), 25(c), 27(c), 28(c), 30(c); Shakesp. Cl: 33(p), 41(p).

Molgula manhattensis (De Kay, 1843)
Copt: 2(p), 7(p), 8(a); E. Wear: 12(c), 13(a), 14(c); Abbot's Cl: 18(a), 19(a), 20(a), 21(a), 24(p), 25(a), 27(a), 28(a), 30(a); Shakesp. Cl: 33(c), 36(c), 38(a), 39(a), 41(c), 43(a), 44(p), 45(c).

The most prominent ascidian was _Molgula manhattensis_, which was especially common in the Abbot's Cliff area, where it formed extensive silt-covered mats on upward-facing surfaces.

The other ascidians were typically found amongst the faunal turf on the sides of boulders and bedrock outcrops, and were seen less often on upward-facing surfaces. Botrylloides leachi, Dendrodoa grossularia and Clavelina lepadiformis were the most frequently recorded species, and C. lepadiformis was much more prominent during the latter part of the survey. Several of these small species probably show distinct seasonal changes in abundance.

PISCES

Scyliorhinus canicula (Linnaeus, 1758)
Copt: 7(r).

Conger conger (Linnaeus, 1758)
Copt: 5(r).

Gadus morhua Linnaeus, 1758
Abbot's Cl: 19(r).

Trisopterus luscus (Linnaeus, 1758)
E. Wear: 14(c); Abbot's Cl: 20(p); Shakesp. Cl: 47(p).

Pollachius pollachius (Linnaeus, 1758)
Abbot's Cl: 27(p), 28(p), 30(p).

gadid spp. (juveniles)
Copt: 8(c); Abbot's Cl: 18(c), 20(p).

Syngnathus acus Linnaeus, 1758
E. Wear: 11(r); Abbot's Cl: 19(r), 23(r); Shakesp. Cl: 36(r), 38(r), 42(r), 46(r).

Myoxocephalus scorpius (Linnaeus, 1758)
Copt: 1(p); E. Wear: 11(p); Shakesp. Cl: 33(p).

Taurulus bubalis (Euphrasen, 1786)
E. Wear: 14(p); Abbot's Cl: 20(p), 28(p); Shakesp. Cl: 36(p), 42(p), 43(p), 44(p), 45(p), 46(p), 47(p); St. Marg: 48(p).

Agonus cataphractus (Linnaeus, 1758)
Copt: 2(r).

Ctenolabrus rupestris (Linnaeus, 1758)
Copt: 7(p), 8(p); E. Wear: 13(c); Abbot's Cl: 18(p), 19(p), 20(p), 24(p), 25(p), 28(p), 30(p) Shakesp Cl: 33(p), 38(p), 39(p), 41(p).

Labrus bergylta Ascanius, 1767
Shakesp. Cl: 44(r).

Lipophrys pholis (Linnaeus, 1758)
E. Wear: 13(r); Abbot's Cl: 32(r).

Pholis gunnellus (Linnaeus, 1758)
Copt: 2(p), 7(p); E. Wear: 11(p), 13(p); Abbot's Cl: 18(c), 19(p), 20(p), 25(p), 26(c), 27(p), 30(p), 32(p); Shakesp. Cl: 33(p), 38(p), 40(p), 41(p), 43(p), 44(p), 45(p), 46(p).

Ammodytes tobianus Linnaeus, 1758
E. Wear: 11(p); Abbot's Cl: 20(p).

Callionymus sp
Copt: 7(p); E. Wear: 12(p); Abbot's Cl: 19(p), 25(p).

Pomatoschistus minutus (Pallas, 1770)
E. Wear: 8(p), 11(p), 12(p); Abbot's Cl: 20(c), 22(p), 25(p), 27(p); Shakesp. Cl: 33(p), 38(p), 40(p), 41(p), 43(p).

Thorogobius ephippiatus (Lowe, 1839)
E. Wear: 13(r).

Platichthys flesus (Linnaeus, 1758)
Copt: 7(p); E. Wear: 13(c); Abbot's Cl: 19(p).

Pleuronectes platessa Linnaeus, 1758
E. Wear: 11(p), 12(p), 13(a); Abbot's Cl: 25(p); Shakesp. Cl: 47(p).

Solea solea (Linnaeus, 1758)
Abbot's Cl: 19(p), 20(p); Shakesp. Cl: 35(p).

juvenile flatfish
Copt: 8(c); E. Wear: 11(c), 12(c).

As expected, there was a clear division between fish associated with inshore rocky habitats, and those occurring on sand patches, broken ground and the offshore sediment plain. The three species seen most frequently amongst the rocks were the Gunnel, Pholis gunnellus, the Long-spined Sea Scorpion, Taurulus bubalis, and the Goldsinny, Ctenolabrus rupestris. T. bubalis was usually hidden in the turf, or amongst algae, and P. gunnellus was seen in similar situations, and also in crevices or disused piddock holes. C. rupestris was found around boulders and gullies. However, although widely distributed, none of these species was abundant in terms of numbers of individuals.

Bib, Trisopterus luscus, were common around the wreck of the Brandyboat, but were seldom seen elsewhere. Pollack, Pollachius pollachius were recorded only at Abbot's Cliff, hovering in small numbers around rock outcrops.

The Sand Goby, Pomatoschistus minutus was recorded from the sediment sea-bed in both shallow and deeper water, and often were present on isolated sandy patches amongst rocks. In contrast, flatfish were seen in greatest numbers on larger expanses of soft sea-bed. Numerous juvenile flatfish were seen in East Wear Bay. These were about 10-20 mm long, and presumably had only recently settled on to the sea-bed. Adult Plaice, Pleuronectes platessa, Flounder, Platichthys flesus, and Dover Sole, Solea solea, were recorded from the sediment plain at a range of sites between Folkestone and Dover.

Figure 11. Adult Sole, Solea solea (Abbot's Cliff, 4 m below CD. Photo: E. Wood).

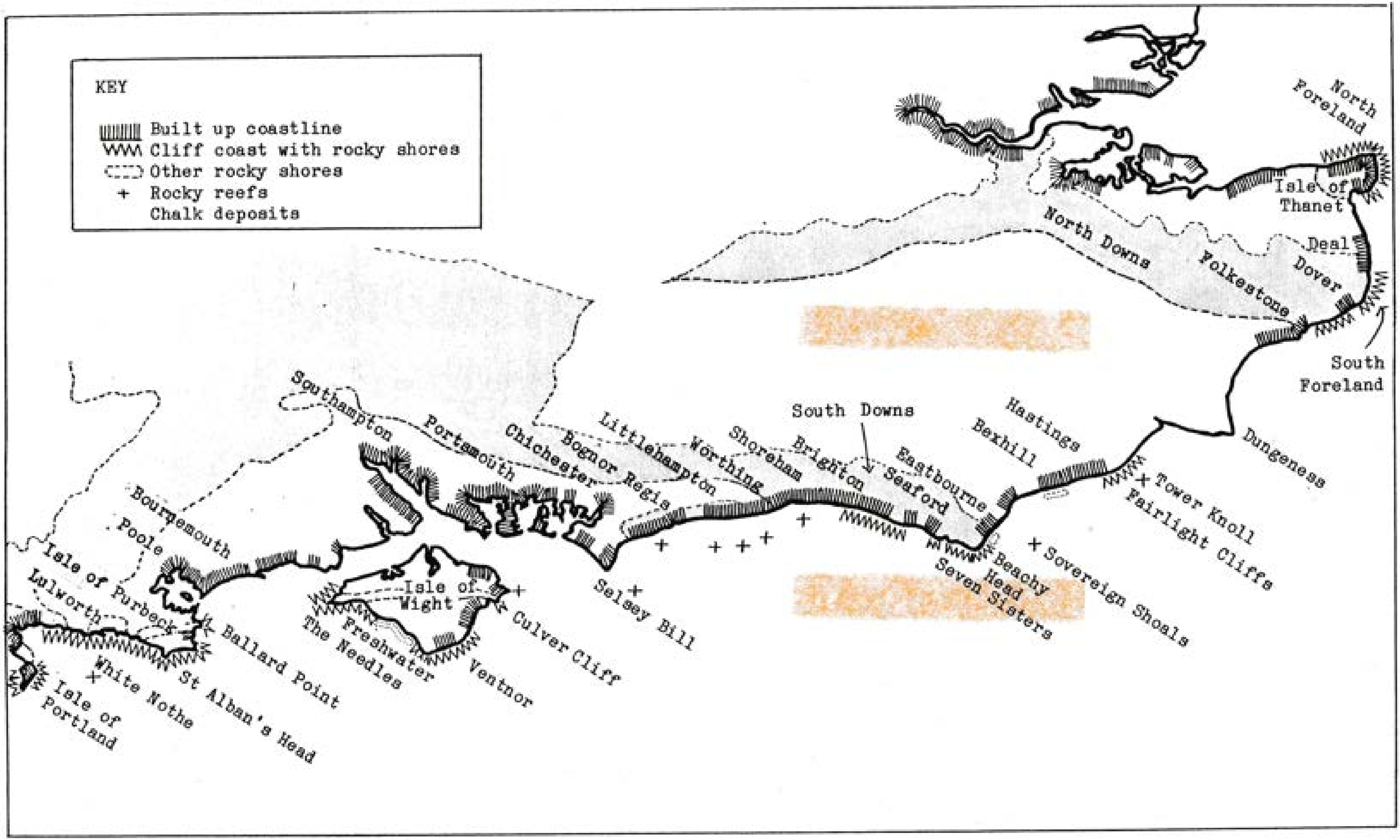

Figure 12. The coastline of the eastern English Channel

6. Assessment of Biological Interest

6.1. INTRODUCTION

There is no universally accepted method for assessing the biological importance of sublittoral sites, mainly because there are so many contributory factors to consider, and because biologists from different disciplines place particular emphasis on different criteria. Generally high species and habitat diversity and/or the presence of rare species/habitats are considered important. However, this approach can mean that areas with low species/habitat diversity but high productivity (and therefore high biological importance) are ranked low.

The area under consideration here is the sublittoral fringe and nearshore zone between Folkestone and Dover, and for this assessment we have concentrated on the former approach. However, it is relevant to mention that the fishery off the Kent coast as a whole is important and that the Folkestone-Dover area must contribute to this high productivity.

Comparisons of habitat type and species diversity and composition can be made at different levels. The most relevant comparisons that can be made in assessing the status of the Folkestone-Dover area are:

a. with all sublittoral habitats in South-east England,
b. with other sublittoral chalk habitats in England.

Figure 12 shows the sites which are considered in these comparisons.

Sources of information for both comparisons are limited and mainly comprise studies carried out by the Marine Conservation Society. Information in published form is available for the following areas:

- Hastings, East Sussex (Wood C, 1986).
- Seven Sisters and Beachy Head, East Sussex (Wood & Jones 1986).
- Selsey Bill to Beachy Head, East & West Sussex (Wood C, 1984).
- Inner Mulberry, Pagham West Sussex (Cunliffe 1981).
- Outer Mulberry, Pagham West Sussex (Stebbing 1982).
- Mixon Hole, Selsey West Sussex (Ackers 1977).
- Sussex (McDonald 1985).
- Selsey Bill to East Solent, West Sussex & Hampshire (Collins & Mallinson 1983).

In addition to published works we have been able to utilise raw data collected by members of the Marine Conservation Society as a part of its current Chalk Cliffs project. It is intended that these will be published during 1987. Areas covered by these data are:

West Runton, Norfolk.
Botany Bay, Isle of Thanet, Kent.
Horse of Wilingdon reef, Eastbourne, East Sussex.
Offshore chalk reefs between Brighton and Littlehampton, East Sussex (Kingswest Ledge, Looe Gate, South-West Rocks, Worthing Lumps and Winter Knoll).
The Needles and Scratchells Bay, Isle of Wight.
Old Harry and Ballard Point, Dorset.
White Nothe, Dorset.

6.2. SUBLITTORAL HABITATS IN SOUTH-EAST ENGLAND

The open coastline of South-east England between Margate, at the entrance to the Thames estuary, and Chichester Harbour, at the entrance to the Solent, is about 230 km in length. Of that total some 75% is low lying coastline with sand, pebble or man-made foreshore and only 25% rocky shore. The total length of rocky shoreline is about 58 km and includes areas of built-up coastline, such as at Margate, amounting to 21 km and undeveloped coastline amounting to 37 km. Undeveloped rocky coastline thus amounts to only 16% of the open sea coastline in South-eastern England. Even within this limited area, stretches of the shoreline have been affected by coastal protection works, sewage discharges and other human activities.

The coastline between Folkestone and Dover has 7 km of rocky shores, only 3 km of which is unaffected by such activities. However the rocky areas in the sublittoral are unlikely to have been greatly affected by groynes and seawalls high on the foreshore and thus the effective length of natural sublittoral rocky habitiats is about 5 km. This excludes the existing reclamation at the old colliery site and the area of Copt Rocks.

The main areas of undeveloped rocky coastline are:

South Foreland, 3 km
Folkestone - Dover, 5 km
Hastings, 8 km
Beachy Head - Seaford Head, 10 km
Newhaven - Peacehaven, 2 km.

The sublittoral habitats in each of these areas have been studied and all possess an inshore rocky zone, except at Hastings where the rocky foreshore does not appear to extend significantly below low water mark (Wood, 1986). The study area therefore includes the second longest stretch of largely undeveloped coastline with sublittoral rocky habitats in South eastern England.

Shallow sublittoral rocky habitats, together with artifical substrata, such as wrecks, have been shown to support an abundant and varied marine macro-flora and fauna yet they are clearly a limited habitat resource in South-east England. Their importance is heightened by the lack of rocky sublittoral habitats away from the immediate coastal fringe. There appear to be no offshore rocky reefs in Kent, and in East Sussex they are limited to the sandstone reefs between Eastbourne and the Royal Sovereign Light Tower, and the Tower Knoll east of Hastings. The latter is shown on the chart but does not appear to be known to divers as it is not included in the comprehensive review of Sussex dive sites (McDonald 1985). The remainder of the sea-bed around South-east England consists largely of soft sediments or mobile substrata with distinct and quite different communities.

The importance of the Seven Sisters-Beachy Head area has been recognised and the East Sussex County Council has taken the initiative, following a proposal by the Marine Conservation Society, in exploring the possibility of declaring the area a voluntary marine reserve (Wood 1984, Wood & Jones 1986).

Most of the rocky areas referred to above are based on chalk. The harder Greensand rocks off Copt Point are limited in extent and much affected by the adjacent sewer outfall. Sublittoral Greensand areas also occur subtidally to the west at Head Ledge, Beachy Head and offshore in reefs near the Royal Sovereign Light Tower. In both cases these areas provide a greater variety of depth and habitat and support a richer marine community than the Copt Rocks site.

6.3. <u>SUBLITTORAL CHALK HABITATS IN ENGLAND</u>

Outside South-east England chalk has a restricted distribution of coastal exposures comprising the following locations:

Culver Cliff and the Needles, Isle of Wight.
Ballard Point and Old Harry, Studland, Dorset.
Arish Mell, Lulworth, Dorset.
White Nothe to Durdle Door, Lulworth, Dorset.
North Norfolk.
Flamborough, Yorkshire.

Areas of chalk bedrock, being relatively soft and friable, are prone to wave erosion in exposed shallow waters. In East Sussex the chalk typically forms a system of ridges and gullies running at right angles to the shore, presumably caused by wave surge. The gullies are up to 2m in depth. A similar topography is found at West Runton, Norfolk and at Botany Bay, Isle of Thanet, though at the latter site the gullies are only 300mm deep. The Folkestone-Dover area does not have a regular ridge and gulley topography, comprising instead areas of flattish bedrock, some raised, surmounted by large numbers of boulders from the cliffs. Despite this difference the range of habitats, including current-exposed and sheltered flat surfaces, vertical faces, overhangs and crevices, is similar in each case.

The sublittoral chalk sites in the Isle of Wight and Dorset differ from the sites in South-eastern England in that the outside rock surfaces are generally covered with a layer of coralline algae. This provides a much harder outer surface to the rock and makes it less prone to erosion. Ridge and gully formations are not generally found at these sites. However, at the most exposed location, on the southern side of The Needles, Isle of Wight, there are signs of wave-eroded gullies running in a south-westerly direction into the open sea and prevailing wind. In the Isle of Wight and Dorset, whilst boring activities of piddocks and other animals occur, the relative stability makes the range of habitats and communities similar to the harder sandstone and limestone rocks in the same area.

Only at one site, apart from the Folkestone-Dover area, does a significant proportion of the sublittoral chalk comprise boulders recruited from the cliffs. This is Ballard Point in Dorset, a relatively sheltered site which, like the Shakespeare and Abbot's Cliff sites, is subject to strong tidal currents. Unlike the study area there is little exposed chalk bedrock below the boulders at Ballard Point.

6.4 SPECIES DIVERSITY AND COMPOSITION

A decline in the number of 'western' species towards the eastern end of the English Channel is to be expected although for many of these the limit of distribution is around the Isle of Wight. Conversely the Folkestone-Dover area may support greater numbers of 'northern' species. However, other species with a cosmopolitan distribution might be expected to be absent from the Dover-Folkestone area because of the turbid conditions and strong currents.

The species recorded during the present survey reflect a bias towards the macro-fauna and flora associated with rocky habitats. Comparisons with other areas are therefore most meaningful where similar sampling techniques have been employed. Of the more local studies, that of the Seven Sisters area in East Sussex (Wood & Jones, 1986) is the most relevant, having been carried out over a similar period of time and with similar recording techniques and personnel.

The total number of species recorded in the two studies was broadly similar (Seven Sisters 180 species, this study 202 species), although species composition was not identical. Many of the species recorded from the Folkestone-Dover area which were not found during the Seven Sisters survey have been recorded from elsewhere in Sussex (Wood, 1984). The only species which can reliably be said to occur commonly in the Folkestone-Dover area but not further west in any numbers is the spider crab <u>Hyas araneus</u>. In the Folkestone-Dover area this was the commonest spider crab, but elsewhere on southern and south-western coasts it is generally replaced by the Spiny Spider Crab, <u>Maja squinado</u>. Both species have been recorded in the Thames and East Channel areas, as well as all round the British Isles (Ingle, 1980) but a distinct difference in regularity of occurrence can be observed.

Species regularly recorded in the Seven Sisters area but which were not recorded from the Folkestone-Dover area are:

Phaeophyta - Dictyota dichotoma
Porifera - Halichondria bowerbanki
Anthozoa - Actinothoe sphyrodeta
Annelida - Bispira volutacornis
Pisces - Crenilablrus melops (Corkwing Wrasse)
- Parablennius gattorugine (Tompot Blenny)
- Gobiosculus flavescens (Two-spot Goby)

All of these are significant, easily identified and non-seasonal species which are unlikely to have been overlooked.

Other species which were recorded much less frequently in the Folkestone-Dover area than in the Seven Sisters area include:

Crustacea - Liocarcinus puber (Velvet Swimming Crab)
Ascidiacea - Ciona intestinalis
Pisces - Labrus bergylta (Ballan Wrasse)
- Trisopterus luscus (Pouting)

Apart from these examples, there were no striking differences in species composition in the study area and at the Seven Sisters, some 100 km to the west. In terms of abundance of individuals, however, the mobile groups were much less prominent in the Folkestone-Dover area. Examples are shown in Tables 8 and 9 below.

In Table 8 the records for five of the larger types of crustacea from the Seven Sisters show both a wider distribution amongst the sites studied, and a higher densities at each site, than in the Folkestone-Dover area.

	SEVEN SISTERS (11 sites) sites at which recorded				DOVER AREA (49 sites)			
	total		common		total		common	
	No	%	No	%	No	%	No	%
Edible Crab (Cancer pagurus)	8	73	6	55	21	42	4	8
Large Swimming Crabs (Carcinus/Liocarcinus)	9	82	6	55	1	2	1	2
Large Spider Crabs (Maja/Hyas)	7	64	3	27	19	38	4	8
Small Spider Crabs (Macropodia/Inachus)	7	64	3	27	6	12	0	0
Lobster (Homarus)	6	55	0	0	5	10	0	0

TABLE 8. Occurrence of some crustacea off the Seven Sisters and in the Folkestone-Dover area.

In the case of fishes, whilst comparable numbers of species are recorded for the two areas, again the numbers of individuals at sites in the Folkestone-Dover area was low. Table 9 shows that within the study area many of the fish species recorded were seen only at a very limited number of sites.

Sites at which recorded (%)	Number of species Seven Sisters	Dover Area
more than 50%	1	0
40% - 50%	2	1
30% - 40%	6	0
20% - 30%	3	3
10% - 20%	4	1
less than 10%	8	17
Total species	24	22

TABLE 9. Distribution of fishes recorded off the Seven Sisters and in the Folkestone-Dover area.

Species comparisons with areas other than the Seven Sisters are less straightforward. However, a crude comparison with other areas along the eastern English Channel can be obtained by a comparison of the total species recorded in this study with records from eastern Dorset (Brachi, Collins & Roberts, 1977; Dixon, Harrison, Holder & Roberts, 1978), Selsey Bill to the East Solent (Collins and Mallinson, 1983), West Sussex - Beachy Head (Wood, 1984) and the Seven Sisters (Wood & Jones, 1986). This is shown in Table 10. It must be remembered that these lists include only the macro-organisms associated with rocky habitats and the epifauna of soft substrata. An investigation of soft-bottom infaunal communities would have increased the species numbers dramatically in each case.

	Dorset *	Selsey/ Solent	Sussex	7 Sisters	Dover
Algae -green	40	2	9	4	6
-brown	56	13	13	5	9
-red	109	20	65	28	28
Porifera	19	17	41	15	16
Cnidaria	41	22	41	16	22
'worms'	29	12	17	15	18
Bryozoa	46	8	21	5	13
Mollusca	99	36	30	25	32
Crustacea	93	19	30	26	20
Echinodermata	10	7	6	2	6
Tunicata	22	21	16	11	10
Pisces	34	27	48	24	22
Total	598	204	345	180	202

* includes inter-tidal species

TABLE 10. Total sublittoral species recorded at south coast sites.

6.5 CONCLUSIONS

The shallow sublittoral in the Folkestone-Dover area is of biological importance because similar rocky habitats are rare in the eastern English Channel, yet support a wide range of species not found on the surrounding sediment sea-bed.

The biological interest is centred on the chalk reefs between Abbots Cliff and Shakespeare Cliff. The greensand reefs at Copt Rocks and the chalk reefs at South Foreland appear to support less diverse communities.

The Folkestone-Dover area supports a comparable number of species to the Seven Sisters area in East Sussex. The latter has been identified as a site of marine conservation interest and is likely, with the support of the local authorities and the Nature Conservancy Council, to become a voluntary marine reserve. No other rocky sublittoral site east of the Seven Sisters/Beachy Head area is likely to be as rich and varied as that off Shakespeare Cliff and Abbot's Cliff.

7. Impacts on the Sublittoral Environment

It is important, when considering the possible effects of the Channel Tunnel on the sublittoral environment, to have some knowledge of other uses and impacts, both past and present, in order that the Tunnel scheme can be put into perspective.

7.1. EXISTING USES AND IMPACTS

7.1.1. Waste Disposal

The major man-made influences on water quality in the vicinity of the proposed Channel Tunnel appear to be from the sewage outfalls at Folkestone (Copt Point) and Dover, and from small amounts of freshwater that are discharged periodically from the drainage tank of the existing tunnel. This water empties onto the sea-wall at the Old Colliery Site at Shakespeare Cliff, and then flows into the sea. There are no noticeable effects from this discharge on adjacent sublittoral communities.

Details of the Copt Point and Dover discharges are shown in Tables 11-14, below (data obtained from Southern Water Authority). Discharge from both outfalls is continuous, and consists of domestic sewage together with wastes of a general nature from local commerce and light industry. For comparative purposes the maximum Biological Oxygen Demand (BOD) level for discharge into an inland watercourse is 20 parts per million (ppm), and the maximum level of suspended matter is 30 ppm. Bathing beach designation in EEC countries requires that there are less than 2,000 *Escherichia coli* bacteria and 10,000 total coliform bacteria per 100 ml sample, and that in general, levels should not exceed 100 and 500 respectively.

Outfall	length below LW	Type of treatment	Dry flow m^3/day	Population (summer)
Copt	550	untreated, no screens	16,400	86,500
Dover	690	comminution, no screens	17,500	64,700

Table 11. Sewage effluents discharged to tidal waters at Folkestone and Dover (locations of the outfalls are shown in Figures 13 and 14). 1982-3 data.

Outfall	BOD mg/l (ppm) range	BOD mg/l (ppm) mean	suspended solids mg/l (ppm) range	suspended solids mg/l (ppm) mean
Copt	140-285	231	200-400	289
Dover	70-330	148	140-370	219

Table 12. Copt Point and Dover outfalls: levels of BOD and suspended solids for the period December 1985 to August 1986 (9 records from Copt Point, 7 from Dover).

Outfall	Metals mg/litre (ppm) copper	zinc	cadmium	lead	chromium	nickel
Copt	0.13	0.05	0.02	0.23	0.02	0.05
Dover	0.12	0.19	0.04	0.35	0.18	0.08

Table 13. Copt Point and Dover outfalls: levels of metals (single record from Copt Point [November 1985]; mean of 5 records for Dover from November 1985 to August 1986).

	Bacteria numbers per 100 ml range	mean
E. coli	10 - 5,540	1,679
Total coliformes	40 -16,500	3,635

Table 14: Numbers of bacteria in seawater at Folkestone Beach (Grid reference: TR2370036300) over the periods 31.07.85 to 26.09.85 [5 records] and 09.05.86 to 17.09.96 [10 records].

The effect of the sewage outfall on sublittoral communities at Copt Rocks is extremely obvious, and fairly predictable. Conditions are particularly favourable for the mussel, Mytilus edulis, which thrives in areas rich in organic debris, and for the starfish, Asterias rubens, which feeds on the mussels. These are the overwhelmingly dominant species of an otherwise depauperate community. Considerable quantities of silt are present on the sea-bed and around the mussels, sometimes forming a thick, glutinous layer which is anoxic extremely close to the surface. There is a plan to replace the existing outfall with a long sea outfall, but this is unlikley to be in operation before 1992.

In 1981, the Southern Water Authority initiated a bioaccumulation monitoring programme designed to identify 'hot-spots' of heavy metal pollution around the Kent coast (Wharfe & Friend, 1985). Mytilus edulis, Patella vulgaris and fucoid algae are being used in the survey. The results so far for M. edulis indicate a general pattern of decline of trace metal concentration from the Medway Estuary on the north Kent coast around to the south Kent coast. Adult Mytilus edulis in the Folkestone to Dover area are confined to a large population at Copt Rocks, but these are not included in the monitoring programme. Elevated levels of heavy metals (and other persistent pollutants) could be expected, because of the proximity of the sewage outfall.

7.1.2. Construction and engineering work

Parts of the foreshore between Folkestone and Dover have been considerably altered by man over the past century or so, and it is likely that these alterations have had some form of impact on the sublittoral environment. Unfortunately, in the absence of any historical data, it is impossible to know what changes may have occurred.

In 1983, civil engineering work began on a major project to provide a cross-Channel electricity link between Britain and France, with the cables running between Folkestone and Sangatte. The Central Electricity Generating Board (CEGB) is responsible for the British end of the operation, and this has been carried out without any marine environmental impact studies being undertaken. The trenches for the cables running into Folkestone were cut 1.5 m deep and 0.6 m wide, by a 175-tonne, rock-trenching machine (RTM III). More than 150,000 tonnes of chalk, rock and clay were excavated and washed out of the way by jets of water. The cables were then laid using a purpose-built cable-laying and embedding machine (CLEM).

Although the impact of this operation has not been monitored, it is clear that there must have been considerable damage to sublittoral communities both as a direct result of the excavation and from the effects of sediments thrown into suspension. In addition, sand was brought into the area in barges and dumped over the trenches in order to try and keep the cables covered. Recovery and/or recolonisation will presumably occur once the operation has been completed, but the rate at which this will happen is unknown.

7.1.3. Fishing

The major use of the sea area included in our survey is for fisheries. Potting for crabs occurs in inshore rocky habitats, while trawling for flatfish takes place on the offshore sediment plain. Edible Crabs, Cancer pagurus appeared to be plentiful, although all those seen were of a small size; perhaps due to intensive fishing. The sediment sea-bed appears to be an important habitat not only for adult flatfish, but also for juveniles, for large numbers of both were seen during our dives. Separate fishery statistics are not available for the Folkestone-Dover area, but details of the fishermen working in the area are given in the Channel Tunnel Group Report 6 (Anon, 1985b).

7.1.4. Recreation

At present, apart from some SCUBA diving, there are no other recreational pursuits affecting the sublittoral. The area is known by divers to be good for flatfish.

7.2. PROTECTED AREAS

The Folkestone Warren Site of Special Scientific Interest, (first scheduled in 1951) incorporates 332.7 ha in the coastal strip between Folkestone and Dover, and was designated for its geological, physiographical and biological interest. It is also a Grade I Nature Conservation Review Site. The seaward boundary of the SSSI at present follows the mean low water mark.

The coastline between Folkestone and Dover is also designated a as an Area of Outstanding Natural Beauty and as Heritage Coast for its landscape value.

There are no conservation areas which protect the sublittoral environment.

7.3. POSSIBLE IMPACTS ON SUBLITTORAL HABITATS AND COMMUNITIES DURING CONSTRUCTION AND OPERATION OF THE CHANNEL TUNNEL

A preliminary appraisal of the potential impacts is included in Report 6 of the Channel Tunnel Group, October 1985, but at this time no information on the sublittoral zone was available. The potential problems are re-assessed here, in the light of information collected during our survey, and on the assumption that the scheme remains as proposed at that time.

7.3.1. Construction of retaining wall for reclamation area

The area of reclamation would extend approximately 125m outwards from the existing wall, and this would inevitably lead to the loss of chalk rock habitat in this part of the shallow sublittoral fringe. Physical damage would also be caused by the construction of the retaining wall which, practically, is unlikely to be carried out wholly from within the area subsequently to be covered with spoil. Thus the physical impact on sublittoral habitats is likely to cover a wider area than the reclamation itself.

It would be advantageous if construction of the wall could be carried out in such a way as to minimise loss of, and damage to, the nearshore chalk habitats and crab fishing grounds.

7.3.2. <u>Emission of fines</u>

Much of the spoil removed from the tunnels (at least 2.9 million cubic metres of grey chalk marl) would be contained on the foreshore between Shakespeare Cliff and Abbot's Cliff (Fig 14), in boxed areas behind a concrete sea-wall. The boxes and toe-drain would be lined with filter fabric which should prevent coarse material from escaping, but fine particles could leach out both during and after the construction phase.

The Hydrography Report of the Channel Tunnel Group (Anon, 1985b) suggests that sedimentation would be greatest at slack tides, after the material had been carried as a plume for distances up to about 15 km along the coastline in either direction by longshore currents. However, we found tidal flow to be significantly reduced at all states of the tide up to distances of about 150 m out from low water off Shakespeare Cliff and Abbots Cliff. The weaker tidal currents in the sublittoral fringe, and also the presence of kelp (which reduces water flow beneath its canopy) would make deposition of sediment more likely in these areas, although water movement from wave action would presumably re-suspend the sediment in time and gradually carry it away.

Sessile organisms already have to contend with a fairly high level of siltation, and additional siltation could lead to them being smothered. A swing from filter-feeders to deposit feeders might occur, but there will be little of nutritional value in the chalk fines, and so a decline in species diversity and biomass is much more likely.

Increased turbidity cuts down light penetration, and this would adversely affect the growth of macro-algae in the sublittoral fringe. Apart from altering community structure, this could also have repercussions for commercial fisheries, especially for the flatfish fishery. The reason for this is that most of primary production by attached algae is known to degrade to detritus and to be utilised by benthic soft-bottom invertebrates such as polychaetes and bivalve molluscs. These in turn provide food for predatory animals such as flatfish.

Deposition of chalk fines on the soft sea-bed would again lead to an increase in the proportion of inorganic to organic matter in the sediment, and could be expected to cause changes in the structure of the benthic community, and possibly a drop in productivity.

Escape of fines is potentially the most serious of all the impacts likely to affect the sublittoral environment in the vicinity of the proposed Channel Tunnel. It is extremely important that release of fines is kept to an absolute minimum in order to avoid damage to adjacent sublittoral communities, and possible declines in productivity. The nearshore rocky habitats appear to be particularly vulnerable, as well as being a relatively scarce resource in South-east England.

7.3.3. Liquid emissions

It is intended that drainage and cooling water from the Channel Tunnel will be discharged into the sea close to the access tunnel at Shakespeare Cliff. This water is likely to be of low salinity, above ambient sea temperatures, and may also carry contaminants such as oil, chlorine and biocides. A discharge such as this could be expected to adversely affect communities in the immediate vicinity of the outfall. Sewage arising from the Old Colliery Site may be discharged into the sea off Shakespeare Cliff, and both the Folkestone and Dover sewage systems will probably carry a variety of effluents originating from the Terminal facilities (e.g. sewage, train washing water).

It is likely that less damage would be caused if the outlet for the discharge pipe was situated at least 500 m offshore, where the fresh water and contaminants should be dissipated by tidal currents more rapidly than from a pipe discharging at or around the low water mark. A detailed hydrographic survey is necessary in order to locate a position for the outfall that will ensure rapid dispersion of the effluents and minimal damage to adajcent benthic communities. The sewage outfall at Folkestone already has had a marked impact on the sublittoral environment and on the health of bathing waters. There is a danger that additional inputs from Channel Tunnel-related activities will increase the severity of the impact. Waste water and effluents produced as a result of the Channel Tunnel scheme should be treated so that it conforms with standards laid down in the Control of Pollution Act.

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Site No.	Grid Ref	m below CD	Habitat
1	TR239361	0.5	rocks + concrete
2	TR240360	2.5	rocks
3	TR243362	0.5	small boulders
4	TR246365	+0.5	rocky ground
5	TR246366	+0.5	rocky ground
6	TR247366	+0.5	rocky ground
7	TR253677-246358	7.0	rocks/mixed ground
8	TR255364-254360	13.5	silty gravel/pebble
9	TR252373	1.0	rippled, clean sand
10	TR260379	4.5	predominantly silty gravel
11	TR260381	1.0	sand + scattered boulders
12	TR265381	3.0	sandy ground
13	TR269378	10.0	rough, mixed ground
14	TR269379	9.0	wreck
15	TR269381	11.0	silty gravel
16	TR269383-267383	6.0	rock + patchy soft ground
17	TR270382	3.0	rocky ground
18	TR271383	4.0	rocky ground
19	TR276383-269383	5.0	rocky ground
20	TR272383	3.0	rocky ground
21	TR273382	3.0	rocky ground
22	TR274380	11.0	silty gravel
23	TR277381	8.0	rock + patchy soft ground
24	TR277382	6.5	rocky ground
25	TR277383	4.0.	rocky ground
26	TR279380	10.0	mixed ground
27	TR279383	4.0	rocky ground
28	TR281384	5.0	rocky ground
29	TR281382	11.0	silty gravel + some rock
30	TR283384	4.0	rocky ground
31	TR284380	15.0	silty gravel + some rock
32	TR286377	21.0	wreck
33	TR287385	5.0	rocky ground
34	TR292378	19.0	silty gravel + some rock
35	TR295375	26.0	silty gravel
36	TR290388	2.0	rocky ground
37	TR291387	3.0	rocky ground
38	TR291386	8.0	rocky ground
39	TR293389	4.0	rocky ground
40	TR294389	5.5	rocky ground
41	TR295390	6.5	rocky ground
42	TR298392	3.5	rocky ground + sand
43	TR299391	3.0	rocky ground
44	TR304393	5.0	rocky ground
45	TR304394	3.0	rocky ground
46	TR309394	6.0	rocky ground
47	TR318400	2.0	mixed rock & pebble/gravel
48	TR359427	2.0	rocky ground
49	TR360426	10.0	silty gravel/cobble
50	TR369438	2.0	rocky ground

Table 15. Survey sites between Folkestone and South Foreland.