Marine Fauna of County Wexford, Ireland: the Fauna of Rocky Shores and Sandy Beaches

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ABSTRACT

Information accumulated during 20 years of investigations on the coast of County Wexford is summarised. Topics include shore descriptions, faunal records, transectal surveys on rocky shores and sandy beaches, cryptofaunal studies on rocky shores, and ecology, reproduction and population dynamics of many of the dominant species. Studies were mainly carried out on exposed and sheltered rocky shores in the region of Carnsore Point, Forlorn Point and Hook Head, and sandy beaches at Kilmore Quay, Carnsore, Carne, Rosslare Harbour and Rosslare Point, but some collections were made in a wide range of habitats throughout the county. A total of 484 taxa were recorded. Carnsore is the type locality for four species of oligochaete and two more are yet to be described. The fauna lacks some of the elements of west Irish coasts but is richer than on the mid-eastern coast owing to the presence of southern species. Differences in species abundance and population structure on south and east coasts are described, and possible reasons for the differences are discussed.

Key Words: marine, intertidal fauna, distribution, life histories

INTRODUCTION

In 1976, the Electricity Supply Board commissioned a baseline survey of the littoral fauna at Carnsore Point, at that time the proposed site for a nuclear power station. Prior to this survey, there were no published accounts of shore communities in Co. Wexford and few records of marine fauna. A list of Crustacea in the National Museum (O'Riordan, 1969), for example, lists only three species from Wexford localities, one of which was from the sublittoral. Southward and Crisp (1954) gave quantitative estimates of some rocky shore species (mainly barnacles and top shells) at 11 Wexford localities and Bracken and Kennedy (1967) recorded ten species of fish taken in beach seines on a number of beaches. A few other species records are contained in publications of a more general nature. Algae were recorded by Tighe (1803), Parkes and Scannell (1969), and Norton (1970).

Between March 1976 and December 1978, the area was visited monthly and we had an opportunity not only to carry out detailed studies at the Point but also to visit other shores in the area. The information collected in this period has been supplemented by records obtained during occasional visits in subsequent years and by data from more detailed studies of some of the more abundant species. A considerable amount of information has thus been accumulated. Some of the faunal records have already been published (McGrath and O'Sullivan, 1977; Healy, 1979a; O'Connor, 1980; Ó'Céidigh and McGrath, 1981; Healy and McGrath, 1982; McGrath, 1984; Healy and McGrath, 1988; O'Connor, 1988; Healy, 1996a), the ecology, reproduction and population dynamics of a few of the species have been described (Healy and O'Neill, 1984; McGrath and Ó'Foighil, 1986; McGrath, 1992; Myers and McGrath, 1993; Healy, 1996b; McGrath, 1997), and some information and species records have been published as part of studies with a wider scope (O'Connor and McGrath, 1978; Healy, 1979b; Ottway *et al.*, 1979; Wilkins and O'Regan, 1980; McGrath, 1982, 1985; McGrath *et al.*, 1988; Costello *et al.*, 1989; Healy, 1990; O'Farrell and Fives, 1990; McGrath and King 1991, 1992). Other contributions to our knowledge of the Wexford coastline during this period include records of 17 species of Halacarina (Somerfield, 1988) from Carnsore Point and Hook Head, and three species of Talitridae (Hudson and Reynolds, 1985). Algal records are given by Guiry *et al.* (1979), and Whelan and Cullinane (1979). As yet, there has been no attempt to describe the shores or their communities, or to characterise the region in terms of environmental influences.

The Wexford coastline comprises a wide range of landforms and habitats. The area is chiefly known for its birds, the inlets, lagoons and sloblands attracting large numbers of wintering waterfowl, including species of national and international importance (Merne, 1974; Sheppard, 1993), but the dune systems are also valued and have attracted the attention of geomorphologists as well as botanists. The sand and gravel barriers of the south and east coasts are the most impressive in Ireland (Ruz, 1989), while the two large lagoons, Lady's Island Lake and Tacumshin Lake, contained behind the southern barrier, are among the best examples of percolating lagoons in western Europe (Orford and Carter, 1982). In contrast, the intertidal zone presents no special features or habitats likely to contain a rich invertebrate fauna such as rapids, sea loughs and protected shores on the open coast, and the region has not, therefore, attracted collectors. Consequently, the intertidal fauna of this section of the Irish coastline is poorly known by comparison with parts of the south-west, west, and north-east where the rich faunas of regions such as Lough Hyne, Clare Island and Strangford Lough are relatively well documented. The information provided in this paper thus helps to contribute to our knowledge of the Irish marine fauna.

This paper brings together information on intertidal fauna accumulated over 20 years of investigations on the coast of Co. Wexford. It describes the main features of the Wexford coastline between Pollshone and Hook Head and provides details of rocky shore communities, chiefly in the region of Carnsore, including summary accounts of reproduction and population dynamics of most of the dominant species. A brief account of the main characteristics and faunal composition of some sandy beaches is also given, and some records for mud flats and salt marshes are listed. Non-tidal brackish waters (lagoons and artificial impoundments) are not included and accounts of these may be found in Healy *et al.* (1982), Norton and Healy

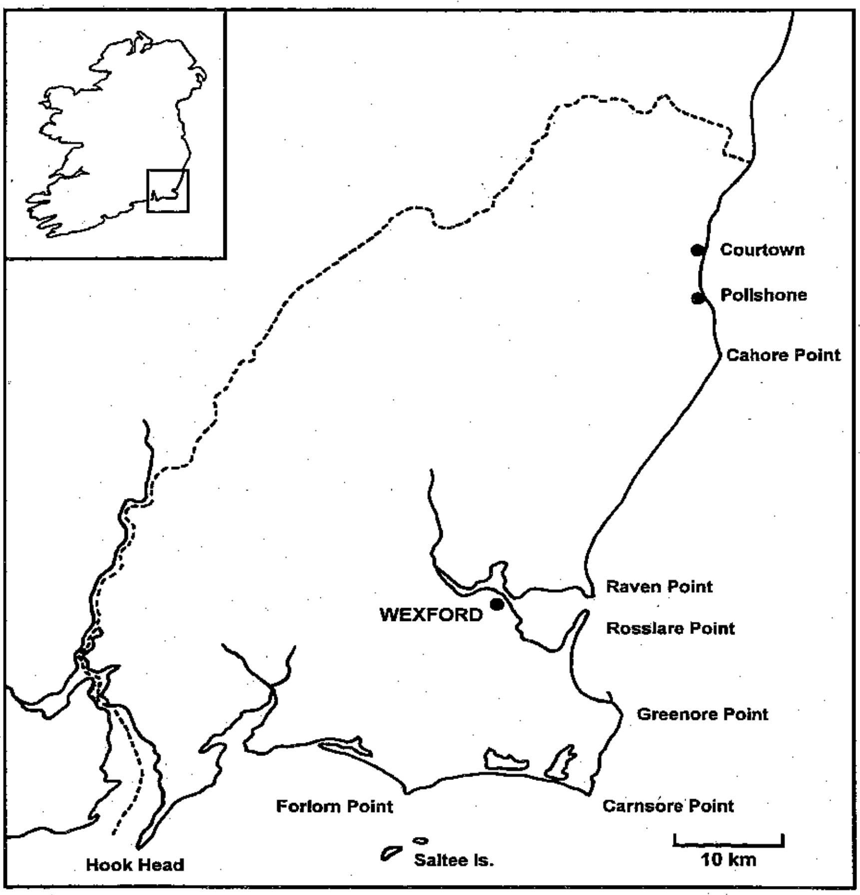

Figure 1. Co. Wexford.

(1984), Galvin (1992), Hurley (1997), and Healy (1997). Some of the observations have already been published (see above) but most of the data are derived from unpublished reports, especially Healy and McGrath (1986), student theses, and our own field and laboratory notebooks. Together they provide a description of the shores and their inhabitants, which allows comparison with similar habitats elsewhere and highlights the predominant environmental influences in the area.

THE WEXFORD COASTLINE

The coastline of Co. Wexford is dominated by barrier systems, interrupted by rocky headlands representing the resistant outcrops of SW–NE trending Palaeozoic rocks, and two major embayments, Wexford Harbour and Bannow Bay. There are few lengthy outcrops of rock and the only large islands are the two Saltee Islands lying 7 km south of Kilmore Quay (Figs. 1, 2).

Carnsore Point in the extreme south-east is a low headland of Caledonian granite displaying about 0.75 km of exposed bedrock at the Point, which gives way to boulders on the east coast (Fig. 3). Boulder shores extend northwards, interrupted by sandy beaches, to Greenore, where there are small outcrops of quartzite backed by cliffs of boulder clay. Small outcrops of conglomerates and sandstone occur along the shore near Rosslare Harbour. From Rosslare a long sand spit, bordered to the east by an exposed sandy beach, extends northwards to Rosslare Point. This stretch has been starved of sand following construction of the Rosslare Harbour Pier and continues to erode, in spite of a series of wooden groynes and several more recent attempts at shore protection (Ruz, 1989). Similar beaches form the coastline north of Raven Point but here there is some accretion in the southern section, especially at the recurved tip of the spit (Ruz, 1989). Further north, however, the shore is eroding endangering both dunes and man-made structures (Callery, 1990). Cahore Point, the main headland on the north Wexford coast, is composed of siltstones and sandstones, interspersed with shales, probably of Cambrian

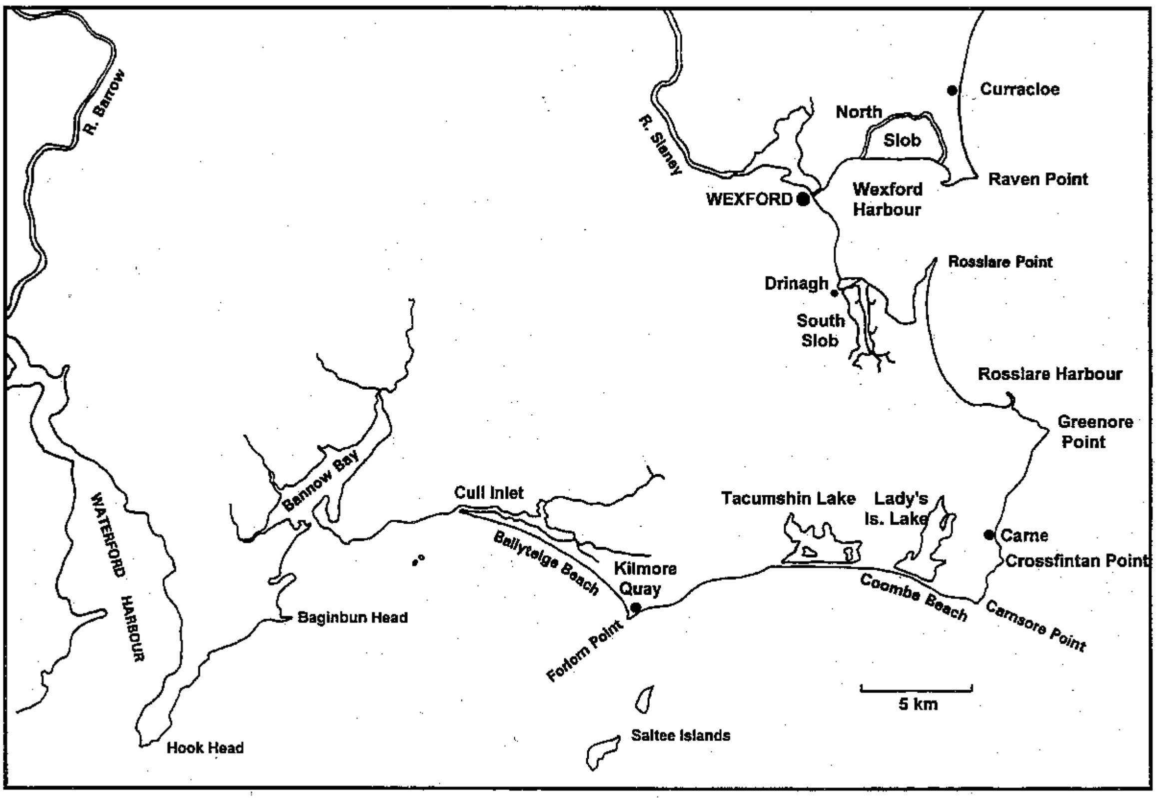

Figure 2. Principal sampling sites in south Wexford.

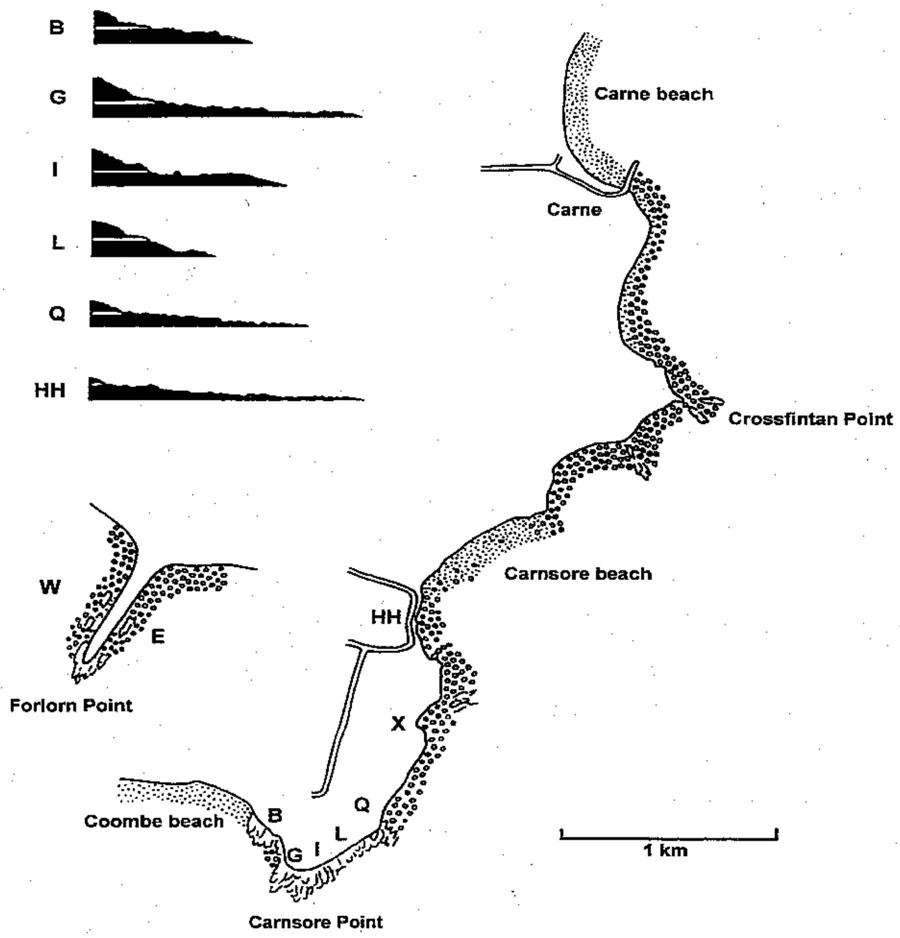

Figure 3. Principal sampling sites of rocky shore and sandy beach studies, and profiles of six rocky sites at Carnsore. Horizontal white lines on profiles indicate the approximate levels of HWS.

age (Gardiner and Brenchley, 1969), which in places rise to low cliffs. Smaller rocky headlands, with intervening beaches, occur north of Cahore at Glasscarrig, Roney Point, Pollshone and Kilmichael.

Wexford Harbour receives the River Slaney which is tidal up to a point 15 km above Wexford Bridge. There is little saline influence on the shoreline above the bridge, however, and the estuary is fringed with *Phragmites* reed beds. Large expanses of sand and mud, and small areas of salt marsh, are exposed at low tide in the Harbour. Mud flats and salt marsh were much more extensive in the past but areas of both north and south shores were reclaimed during the last century to create the sloblands. A part of the North Slob is now managed as the Wexford Wildfowl Reserve, while the remainder is rich farmland. The whole area is protected from flooding by a sea wall and a drainage system which pumps out water by way of a broad channel, including seawater derived from seepage under the sea wall. South of the Harbour, a high wall isolates most of the original salt marsh creeks, including the broad Coal Channel, and water from the low-lying South Slob is pumped into a western perimeter canal which opens into the Harbour by way of a brackish creek. There are small areas of "general salt marsh" near Drinagh in the region of the western drainage system, and a fringe of *Spartina* salt marsh on the harbour side of the Rosslare sand spit.

Most of the south coast is occupied by two major, gravel-based barrier systems, which enclose the two lagoons, Lady's Island Lake and Tacumshin Lake, and have narrowed the inlets at the Cull and

Bannow Bay (Fig. 2). The easterly system, which extends over 13 km from Carnsore Point to 3 km east of Kilmore Quay, is composed of poorly sorted sediments which at the beach face grade from medium gravel with a median grain size of 8 mm (-3 ϕ) in the east, to fine sand with a median grain size of 0.18 mm (+2.5 ϕ) near Tacumshin (Orford and Carter, 1982). The two large lagoons are both virtually land-locked but receive seawater by percolation through the barrier and by storm induced overwash (Carter and Orford, 1980). The water level in Lady's Island Lake is lowered occasionally by breaching the dune barrier (Healy *et al.*, 1982; Healy, 1997; Hurley, 1997), and drainage pipes have been installed at Tacumshin Lake.

At Kilmore Quay there is a small sandy beach, east of which lies St Patrick's Bridge, a narrow, stony shoal which extends seawards for over 1.5 km at low tide. Forlorn Point, or Crossfarnoge, just west of Kilmore Quay, is a narrow promontory composed of Precambrian gneiss and schist belonging to the Rosslare Complex (Sleeman, 1994), displaying nearly vertical bedding, the bedrock reaching to low tide level at the tip of the Point. On either side of the promontory, rocky outcrops on the upper shore give way to stones and boulders around mid-tide level and a stony shore extends eastwards to the harbour pier.

The Ballyteige barrier, which stretches from Forlorn Point to Cullenstown, consists of coarse sand and is topped by high dunes. The poorly sorted beach deposits are mainly fine sand in the east, with a median grain size of 0.14 mm (2.8 ϕ) grading to medium gravel, median grain size 11 mm (-3.5 ϕ) in the west (Orford and Carter, 1982). The low-lying land behind the dunes was once the site of a large inlet, Ballyteige Lough, but is now farmland created by a reclamation scheme similar to those of the North and South Slobs. Water is pumped westward through a system of drainage channels into the Cull Inlet, a narrow, muddy, tidal estuary representing the remains of Ballyteige Lough. The inlet is important for wintering waterfowl. From Cullenstown the shoreline as far as Bannow Bay is mainly stony with small boulders, backed by eroding boulder-clay cliffs (Lowry and Carter, 1982). Bannow Bay represents the estuary of the Owenduff and Corrock rivers and receives a few other small streams. The entrance to the bay is narrow and protected by two small sand spits. Intertidal sediments are mostly sandy, grading to mud at the north end. On the east shore there is a cockle bed (*Cerastoderma edule*) with sparse swards of *Zostera noltii*, a few outcrops of rock with fucoids and mussels, and a small salt marsh in the bay sheltered by the peninsula known as Bannow Island. In recent years, there has been some small-scale oyster culture on the east side of the bay.

The Hook Peninsula is composed of Carboniferous limestone and Devonian sandstone and its shores are mostly rocky with cliffs at the Head and at Baginbun. These are the most extensive rocky coasts in the county but the shores are largely inaccessible and, except for an expanse of pavement below the lighthouse, are too steep to be suitable for survey work.

ENVIRONMENTAL FACTORS

The environmental conditions which are likely to influence faunal distribution and abundance vary considerably over different parts of the Wexford coast. Carnsore Point in the extreme south-east lies at a point of transition on two important gradients, air temperature and wave action. A winter isotherm for mean daily air temperature passes just north of the Point delimiting a small area which is, on average, about 1°C warmer than points further north and similar to most parts of the west coast of Ireland (Rohan, 1986). Winters are undoubtedly somewhat milder, and noticeably shorter, than on other parts of the east coast, the mean date for the first air frost at Rosslare being mid-December and that of the last air-frost mid-March, giving a mean period of air-frosts of 3 months compared with 5 months in Dublin. Winter sea temperatures, on the other hand, are only slightly higher than at Dublin and are 1–2°C lower than off the west coast. Summer seawater temperatures are generally similar on east, south and west Irish coasts but it must be remembered that these values refer to offshore, deep water and that shallow inshore waters are more variable. The meteorological Station at Rosslare records the highest sunshine values for the country, thus heating by the sun of shallow waters such as rock pools or the tide flowing over sandy beaches will be more important here than elsewhere. Long periods of sunshine might also have important con-

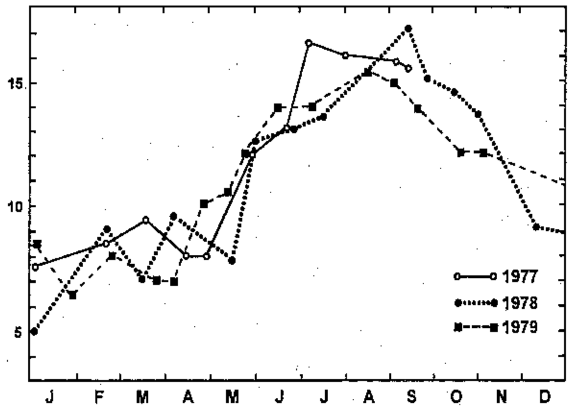

Figure 4. Water temperature at Carnsore Point during the main sampling period.

sequences for organisms exposed on rock surfaces during low tide. Evaporation, too, is higher than the Irish average in the extreme south-east and this could contribute to the stresses imposed by emersion. The only temperature measurements made during our survey were for seawater at Carnsore Point which varied between 5°C in January 1978 and 17°C in September 1978 (Fig. 4). An average annual range of 7–15°C for the period 1925–1947 was recorded by the Coningbeg Lightship situated 25 km south-west of Carnsore (Bowden, 1955).

The prevailing winds in the southern part of the study area are from the west and south-west, south-easterlies being less frequent than at points further north (Hogben and Lumb, 1967). Southern shores are dominated by Atlantic swell waves, consequently wave height, wave period and wave fetch are all greater in the southern sector of the coastline than in the east, a fact which is apparent from oceanographic maps depicting these features which show isometric lines reaching the coast in the region of Carnsore. At Carnsore Point, the sheltered conditions of the east shore compared with those of the south-east and south-west are very noticeable and are reflected in the different topography and biological communities. Wave action is much less than on the west coast of Ireland, however, even on south-west facing shores. For example, the maximum wave height (100-year prediction) at Carnsore is given as 18 m while on west coasts it is 30 m (Couper, 1983).

The mean spring tidal range is 3.6 m at Carnsore Point and points west but decreases northwards to less than 1 m at Courtown where there is distortion of the normal tide pattern with four tides a day in periods when the tidal range is small (Pugh, 1987). Daytime low water spring tides occur between 13 and 16 h GMT at Carnsore, 3–4 hours later at north Wexford localities.

The salinity of the open sea is between 34 and 35. In 1976, the salinity at high tide varied between 33.0 and 34.9 at Carnsore Point, 31.3 and 34.2 at the end of the Rosslare Harbour Pier and 33.5 and 34.8 at Kilmore Quay. The low values at Rosslare occurred in winter but it is not known whether they were due to local discharges or to a more widespread influence of the R. Slaney. This range of variation is unlikely to be significant for intertidal organisms but more subtle differences in salinity and other seawater characteristics between east and south coasts may exist because the Celtic Sea front, representing the boundary between two water masses with different characteristics, reaches the Irish coast in the region of Carnsore Point (Pingree and Griffiths, 1978). The sensitivity of many planktonic organisms to differences between water masses is well documented, but effects on intertidal fauna are largely unknown although the distribution of some shore species on the east Irish coast is suggestive of an influence of water quality on pelagic phases (Crisp, 1989; see also Discussion).

METHODS

Quantitative and semi-quantitative studies on rocky shores were carried out between June 1976 and August 1979 in the region of Carnsore Point (T 120036), and at Crossfintan Point (T 132053 and T 132055), Forlorn Point (S 962030) and Hook Head (S 732980). Further species records were obtained at these localities during casual collecting. The rocky shore at Cahore (T 224270) displays a very patchy distribution of communities and was considered unsuitable for quantitative sampling. It was visited for faunal collections only. The life cycles and population dynamics of selected rocky shore species were studied at Carnsore Point, mainly on the exposed sector. During the 1976–1978 survey, painted symbols in the splash zone, 50 m apart, were used to denote the locality of investigations. Throughout this paper, these positions are referred to by letters (A, B, C, AA, etc.) as shown in Fig. 3. Quantitative sampling of sandy beaches was conducted at five localities, and monthly sampling at two.

The intensity and frequency of collection, and levels of identification, varied between both localities and faunal groups. Failure to record a species at a given locality in Tables 1 and 3, therefore, does not mean that it was not present. For this reason, some details of sampling effort are given wherever appropriate, even for quite trivial observations.

Rock surfaces

The relative abundance and vertical distribution of species living on rock surfaces were recorded using the non-destructive, transectal method devised by Moyse and Nelson-Smith (1963) and developed by Crapp (1973) and others. The method is by now well known and in spite of its defects has been in general use, with modifications, for baseline surveys and monitoring. Details of the method used in Wexford are to be found in Crapp (1973) or Baker *et al.* (1981) and only a brief description is given here. Fifteen stations were marked at 40-cm vertical intervals, with station 1 in the *Ramalina* zone, station 9 just above MHWS and station 16 at about MLWS, i.e. 100 cm above CD (CD = IOD + 20 cm). Persistent swell made it difficult to make observations below this level. The stations were determined by means of a builder's level and staff, and heights above OD established by reference to existing on-site benchmarks. The fauna and flora were recorded at each station within a 5-m band using the abundance scales proposed by Crisp and Southward (1958) and the additional categories suggested by Lewis (cited in Crapp, 1973). The method was designed for use on shores with pavement rock extending from high to low water. No really suitable areas could be found at Carnsore Point and some compromises had to be made on all the transects surveyed, e.g. counts made on boulders instead of flat surfaces or some stations omitted. Four locations on the exposed shore at Carnsore (B, G, I and L) and one in the sheltered sector (Q) were surveyed in 1977, and one at Hook Head in 1986.

Cryptofauna of rocky shores

Species occurring cryptically in lichens, algal turf, mussel beds, laminarian holdfasts, crevices and pools were not included in the transectal surveys but samples from all these refuges were examined and some of the habitats were sampled quantitatively or semi-quantitatively at Carnsore I and Q–R by removing appropriate amounts of substrate: 100 cm^2 (1 dm^2) in the case of mussels, 6.25 cm^2 for *Lichina pygmaea* (Lightf.) C. Ag. and *Corallina officinalis* L., 200 g wet weight of *Pelvetia canaliculata* (L.) Dene and Thur. and *Fucus* spp. and 50 g wet weight of *Mastocarpus stellatus* (Stackh.) Guiry and *Himanthalia elongata* (L.) S.F. Gray. Fauna was removed from the larger algae by passing the thalli through the fingers in hand-hot water while *Lichina* and *Corallina* samples were sorted microscopically. Mats, crevices and pools were also sampled during a study of oligochaete distribution on the exposed shore at Carnsore in 1994 (Healy, 1996b).

Boulder shores

Most of the more sheltered rocky shores in SE Wexford consist of stones and boulders without extensive areas of exposed bedrock. Quantitative sampling is extremely difficult in such heterogeneous habitats and accurate estimates of faunal abundance on boulder shores are rarely attempted by survey teams. In order to obtain a record of the status of these shore communities, we carried out semi-quantitative surveys using catch per unit effort to estimate those macrofaunal species for which density determinations were difficult. Eight localities were surveyed in 1978, two at Forlorn Point (shores on either side of the promontory), four at Carnsore, including one in the exposed sector, and two in the region of Crossfintan Point. Sites were selected which had a more or less even slope, without high rocks or large pools, and observations made within a belt 10 m wide extending from the terrestrial vegetation to low water. The intertidal region was divided, arbitrarily, into three zones, an upper zone extending to the lower edge of the *Fucus spiralis* L. belt, or an equivalent point where *F. spiralis* was absent, a middle zone stretching to the upper edge of the *F. serratus* L. belt, and a lower zone consisting of the *F. serratus* belt only, i.e. not including laminarians. No attempt was made to determine true tide levels as benchmarks were not readily available in most areas and time was limited. Within each of the three zones, the percentage cover of algae and barnacles was estimated and limpets were counted by throwing a 0.25 m^2 quadrat eight times. Estimates of other species were made by counting the number of individuals collected in 5 min. The collector ranged over the area, turning over rocks when necessary and including juveniles. Specimens were later returned to the area, except for anemones which were counted in situ. The method is subjective and results depend on the ability and experience of the collector. Differences between collectors working in the same area were often found to be greater than those between counts made by the same collector in different areas, so as far as possible the same collector recorded the same species in all zones at all sites. In spite of the obvious sources of error inherent in the method, it may provide as much useful information as the use of area counts or abundance scales and is considerably quicker.

Sandy beaches

Quantitative sampling was carried out on sandy beaches at Kilmore Quay (S 968032), Carnsore (Nethertown) (T 123038), Carne (T 130065), Rosslare Harbour (T 141121) and Rosslare Point (T 102118). The beaches at Carne and Carnsore were sampled monthly. Other beaches visited once or twice only for faunal collections were Bannow Island (S 821075), Ballyteige (S 957041), Neamstown (T 980034), the Coombe beach at Carnsore (T 113038), Rosslare Strand (T 103147), Raven Point (T 104229 and T 124232), Curracloe (T 115267) and Pollshone (T 202535). Mud was sampled in the Cull Inlet (S 923078) and at Woodtown, on the south side of Wexford Harbour (T 085163), and salt marshes at Bannow Island (S 826179), Rosslare (T 094470) and Drinagh (T 059078).

Transect sampling was always carried out during spring tide periods. An upper station was selected at a point estimated to be about EHWS and stations levelled downshore as far as the current tide allowed, usually giving eight stations, occasionally ten. Initially, stations were at 40-cm vertical intervals, as on rocky shores, but when it became apparent that some species were concentrated in narrow zones which were not being adequately sampled, sub-stations at 20-cm intervals were added between stations 2 and 8. A core sample, $32\ cm^2 \times 15$ cm, was taken at each of the transect stations and grain size distribution determined using standard procedures (Buchanan, 1984). A sorting index was calculated from standard deviations as:

$$\sigma\phi = \frac{\phi84 - \phi16}{4} + \frac{\phi95 - \phi5}{6.6}$$

On this scale, sediments with values 0.35–0.5 are well sorted, 0.5–0.7 moderately well sorted, 0.7–1.0 moderately sorted, 1.0–2.0 poorly sorted, 2.0–4.0 very poorly sorted, and >4.0 extremely poorly sorted (Folk, 1974).

The degree of exposure of the beaches was assessed using the index of McLachlan (1980) which is based on a combination of the following parameters: wave action, width of the surf zone, % of very fine sand, slope, median particle diameter, depth of the reduced layer, and the presence of stable burrows.

In an initial survey of five beaches, samples of macrofauna were taken by forcing a square, flanged box core, 18 × 18 × 15 cm, into the sand and wet-sieving the contents on a 0.5 mm mesh. Monthly sampling of amphipods at Carnsore and Carne followed the same procedure but only the top 5 cm of sand were sampled and where substantial amounts of sediment >0.5 mm remained on the sieve, the fauna was extracted from it by flotation in a sugar solution of approximately SG 1.3. Meiofaunal samples (mainly for Enchytraeidae) were qualitative surface scrapes from which the fauna was extracted by repeated washing and screening of the supernatant on a 200 µm mesh. Sweeps at low water, and in intertidal pools when present, were taken with a 0.5 mm mesh, square-frame net. Larger crustaceans and fish were caught using a Riley push net (Eleftheriou and Holme, 1984) or a small beach seine.

Nomenclature of the fauna follows Hayward and Ryland (1995). Authorities of faunal species are given in Tables 1 and 3, those of algae and lichens are given at first mention in the text.

RESULTS

Description of rocky shores at Carnsore

The shore at Carnsore is composed of a reddish granite which outcrops on the south shore and at intervals on the east coast as far as Crossfintan

Point. It is a hard rock which remains rough at the surface except near low water and which presents few crevices below MHWN. The south-east and south-west shorelines, which are exposed to strong wave action, consist of irregular bedrock with a few areas of sloping pavement, interrupted by small bays containing large, smooth boulders (Fig. 3). A small earth cliff and a band of large boulders mark the top of the shore. This section of the shore varies in width between 43 and 102 m, the latter measured at the Point (G in Fig. 3). It displays the typical features of wave-exposed shores with a low cover of fucoid algae and an abundance of barnacles, limpets and mussels. On the biological exposure scale of Ballantine (1961), which grades rocky shores on a scale of 1–8, the south and south-east sector (A–M in Fig. 3), which receives the most wave action, falls within grade 3 (exposed) with site L and some promontories in grade 2 (very exposed) and the more sheltered bays in grade 4 (semi-exposed). About 350 m east of the Point (M–N), there is an abrupt change to a sheltered, boulder-dominated shore typified by a gently sloping profile reaching up to 115 m from high to low water, a substratum dominated by low rocks, stones and boulders, with some areas of exposed bedrock, and an abundance of shallow pools and wet areas. Fucoid algae were more abundant than on the exposed shore and formed distinct zones, while there were lower densities of barnacles and limpets, and mussels were almost completely absent. Most of the shore north of N may be classified as grade 5 (semi-sheltered) but there are a few headlands where mussels may be found (grade 4) and some more sheltered bays, especially north of Crossfintan Point, which fall into grade 6. The amount of sediment trapped among boulders increases northwards, the shoreline finally grading to sandy beaches with boulders.

Faunal records for rock and boulder shores

The species recorded on rock and boulder shores at Carnsore, Forlorn Point, Hook Head and Cahore Point are listed in Table 1. Some identifications may be suspect because genera were subsequently revised, e.g. *Jassa* (Conlan, 1990) and *Pontocrates* (Moore and Beare, 1993). In the case of *Nebalia*, the initial identification as *N. bipes* is probably incorrect (Dahl, 1985). Species which have been split, and for which specimens are no longer available, are listed as aggregate species, e.g. *Arenicola marina*. The reliability of the frequency designations naturally depends on the frequency of observations and other factors such as the size of the taxon and ease of identification. Species in categories "abundant", "common" or "frequent", which have a high degree of constancy, can be considered typical of the communities in which they were found and their occurrence in the habitats investigated is generally predictable. Species in categories "occasional" and "rare", on the other hand, could have been overlooked and may have been more frequent. This is particularly true of species for which identification is time consuming or requires taxonomic expertise which was not readily available. For some groups, only single collections could be identified, e.g. Porifera, Bryozoa and Tunicata.

The list of 363 taxa (357 identified to species) mainly concerns macrofauna and is by no means comprehensive. Groups undersampled include Porifera, Hydroidea, Nemertea, Gammaridae, Bryozoa and Tunicata. Among meiofaunal groups, only Oligochaeta were intensively studied and almost no microcrustaceans were identified. The most diverse groups were the Polychaeta (60 species), Amphipoda (38 species) and Proso-branchia (40 species).

The exposed shore at Carnsore Point

Description

The wave-beaten sector was characterised by three distinct supralittoral lichen zones (Fig. 5). A broad band of *Ramalina*, accompanied by *Xanthoria* and grey and brown species, just below the lower limit of flowering plants, was followed by bands of *Caloplaca* and *Verrucaria maura* Wahlenb. A few patches of *Pelvetia canaliculata* and *Fucus vesiculosus* L. f. *evesiculosus* occurred on the upper shore, especially where rocks provided some shelter, but fucoids were generally sparse, the most conspicuous organisms above MTL being *Melarhaphe neritoides*, *Littorina saxatilis* agg., barnacles and limpets, with patches of the fruticose lichen *Lichina pygmaea* and seasonal high level *Porphyra umbilicalis* (L.) J. Ag.

Mussel beds occupied the zone from about MTL to MLWN. Throughout most of the survey period, they formed two distinct zones, a patchy, upper zone of old, thick-shelled specimens, often encrusted with barnacles, and a lower zone of small,

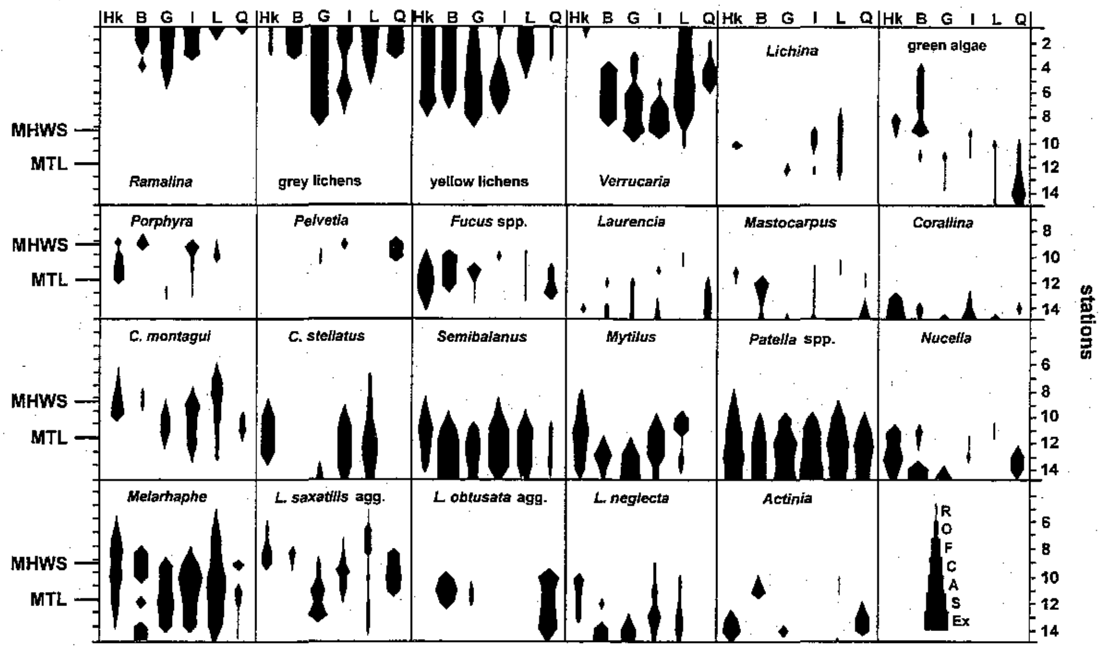

Figure 5. Vertical distribution of the dominant species at Hook Head (HK) and five sites at Carnsore (B–Q), recorded during transectal surveys in 1977 (Carnsore) and 1986 (Hook Head). Abundance categories according to Crapp (1973): Ex – extremely abundant; S – superabundant; A – abundant; C – common; F – frequent; O – occasional; R – rare.

shiny individuals, arranged in isolated rosettes, representing recent recruitment.

Rock surfaces below the mussels were either encrusted with lithothamnia or carpeted with large patches of *Corallina officinalis* turf accompanied by scattered plants of *Mastocarpus stellatus* and *Himanthalia elongata,* with *Alaria esculenta* (L.) Grev. occurring sparsely near low water. In many places, the *Corallina* extended for some distance into the sublittoral, together with *Chondrus crispus* Stackh., *Laminaria digitata* (Huds.) Lamour, *L. hyperborea* (Gunn.) Fosl. and *Saccorhiza polyschides* (Lightf.) Batt. *Fucus serratus* was common in the more sheltered areas and some *Halidrys siliquosa* (L.) Lyngb. was present in gullies. The sides of gullies and the undersides of rocks and boulders near low water were often encrusted with *Halichondria panicea* and *Hymeniacidon perleve.*

Rock surfaces

The vertical range of the species recorded in the transectal surveys, and the changes in their abundance with tide level, varied between the four sites surveyed: B, G, I and L (Fig. 5). Differences between sites are mostly explained by local variations in topography, for example the greater abundance of *F. vesiculosus* and the larger littorinids at B and G where rocks provided some shelter, and the relative scarcity of *Nucella lapillus* at I and L where nearby gullies may have been more attractive. At site L, which had the most steeply sloping rock, the lichen zones were broader than at other sites, *Pelvetia* was absent and *F. vesiculosus* rare, and the upper limits of most species were raised, especially those of lichens, barnacles, littorinids and mussels.

Limpets were abundant throughout the tidal zone, the highest densities being associated with dense barnacle cover. *Patella* species could not be distinguished in the field, except as juveniles, but collections were made at all levels and the relative proportions of *P. vulgata* and *P. ulyssiponensis* calculated (Fig. 6). *P. ulyssiponensis* was present at the lower stations at all sites and was dominant below MLWN at G and I, but only reached above MTL at I. The density in *Corallina* turf at I varied between 175 and 275 m^{-2} (mean = 237, $N = 11$)

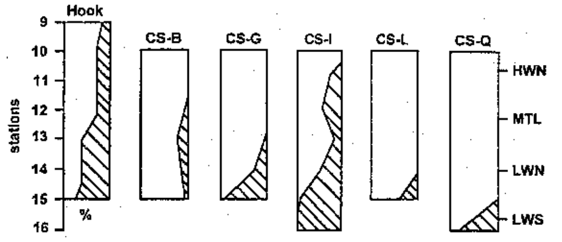

Figure 6. Proportion of *Patella ulyssiponensis* (hatched areas) in random collections of *Patella* spp. from Hook Head and five sites at Carnsore (positions shown in Fig. 3).

over a 12-month period. Examination of gut contents of *P. ulyssiponensis* from below MLWN showed that they fed almost exclusively on calcareous algae. Where the *Corallina* was dense, individuals occupied clear areas in the turf where they grazed its edges. *P. ulyssiponensis* at B were heavily infected with trematodes, the incidence of infected individuals increasing with size from 12.5% at 40–45 mm and 67% at 46–50 mm to 100% in individuals over 55 mm (see Fig. 16).

Barnacles were the dominant organisms between the upper level of *Lichina* and the mussels, with the highest mean density at I, 287 dm^{-2}, in the *Lichina* zone, falling to 79 dm^{-2} around MLWS. In most places, the upper barnacle limit was marked by a narrow band of low density *Chthamalus montagui* (about 5 dm^{-2} at I), below which *C. montagui, C. stellatus* and *Semibalanus balanoides* occurred together (Fig. 7). The lower limit of *C. montagui* occurred between MTL and LWN and *S. balanoides* was dominant on the lower shore except at L where *C. stellatus* represented 80% of the barnacle population below MTL, in some places reaching below MLWS. Approximately 2% of *S. balanoides* were parasitised by the isopod *Hemioniscus balani*.

Melarhaphe neritoides occurred in high density from the splash zone to the lower shore barnacles, in some places reaching below MLWS. It was particularly abundant, with a wide vertical range, at L. The littorinids *L. saxatilis* agg. and *L. neglecta* had variable ranges. Both *L. saxatilis* and *L. arcana* were present and both species presented a range of colour morphs including brown, yellow–brown, black, orange, cream and

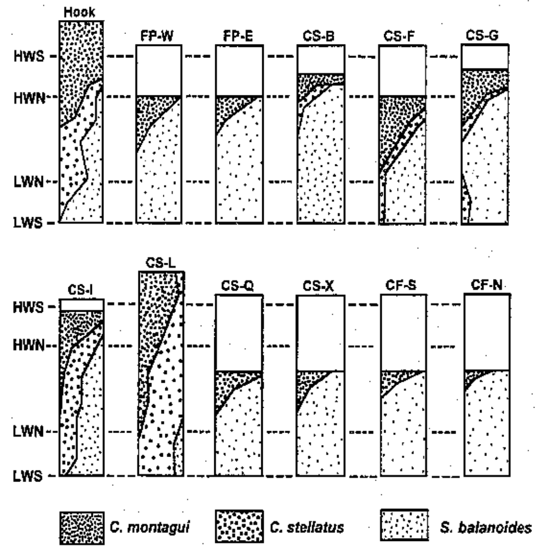

Figure 7. Variations in the proportion of three barnacle species with tide level at Hook Head, Forlorn Point (east and west shores), Carnsore (site positions as in Fig. 3), and Crossfintan Point (north and south shores).

tessellated forms. The species could not be distinguished in the field but in March 1978 it was found that an upper shore sample consisted entirely of *L. saxatilis* but 42% of a middle shore sample were *L. arcana* (Hannaford-Ellis, personal communication). As both are active species, retreating into sheltered crevices and pockets when conditions are unfavourable, differences in their vertical distribution on rock surfaces at different sites, assessed on different dates, are probably not meaningful.

Our observations on *Littorina neglecta* were based on the assumption that all specimens in the barnacle zone fitting the description given by Heller (1975) belonged to this "species". Genetic studies of *L. neglecta* and *L. rudis* from this shore (Wilkins and O'Regan, 1980) showed statistically significant differences at one locus and in fact we experienced no difficulties in distinguishing the "species", even when they occurred together among barnacles. This situation contrasts with that in NE England where the species were virtually indistinguishable (Grahame *et al.*, 1995). On the exposed shore at Carnsore, *L. neglecta* was common among barnacles where small specimens of the black form, which was dominant, looked similar to those of *M. neritoides*. At I, it extended from HWN to LWS. High densities at stations 14 and 15 at B and G (Fig. 5) corresponded with an abundance of *Nucella* at these levels and may, therefore, be correlated with the number of empty barnacles.

Mussel beds, represented by more than 50% cover, were present in a mosaic pattern between MTL and MLWN, except at L where the bed occurred above MTL. Mussels were less numerous, smaller, and generally confined to small patches at lower levels, except at G where the high density zone extended to MLWS. Mussels of the upper bed were of various sizes, reaching a maximum length of 3 cm but with a predominance of specimens less than 12 mm and included a few individuals less than 400 µm in length (see "Reproduction and population dynamics"). Electrophoretic analysis of specimens from Carnsore has shown a wide genotypic variation in the population with typical *M. edulis*, *M. galloprovincialis* and hybrids all occurring (Gosling and Wilkins, 1981). They are referred to as *M. edulis* agg. in this paper.

Nucella lapillus was mainly confined to the lower shore although young specimens were sometimes common among old mussels. The low numbers recorded at I and L (Fig. 5) are explained by the preference at these sites for nearby gullies which were not included in the transect samples. The well-documented effects of exposure on shell characteristics of dogwhelks (Crothers, 1985) are demonstrated by differences between populations on different parts of the exposed sector at Carnsore, and comparison with boulder shores. Coloured individuals, which formed 13% of the population at B and 10% at I, were less frequent in more sheltered situations and only constituted 1.4% of the population at the exposed boulder site F and were absent from the Carnsore sheltered shore, and also from Forlorn Point. There was also an increase in the shell height:aperture ratio with increasing shelter, from 1.30 at B, 1.31 at I, 1.41 at F and R, to 1.43 at Crossfintan Point and Forlorn Point. Variations in adult shell height, however, did not appear to be correlated with exposure.

In addition to the dominant species recorded during the transectal surveys, there were some smaller or less abundant species distributed patchily on rock surfaces (Table 1). These included *Littorina littorea*, *Monodonta lineata* and *Gibbula umbilicalis,* which were mainly to be found around pools. The limpet *Tectura virginia* occurred on lithothamnia. The isopod *Campecopea hirsuta* was frequent among barnacles between MHWN and MLWN, with mean densities of about 3 dm^{-2} in the *Lichina* zone and 14 dm^{-2} just above MHWN. Mites were also frequent among barnacles, including *Halolaelaps marinus, H. balticus* and *Cheiroseius necorniger,* and the collembolan *Anurida maritima* was common throughout the intertidal zone.

Cryptofauna

The supralittoral lichens provide little shelter or moisture and the only animals found were *Typhlodromus richteri* (Acari), *Xenylla xavieri* (Collembola), young forms of *Petrobius brevistylus* (Archaeognatha), and *Milnesium tardigradum* (Tardigrada), all recorded from among the erect *Ramalina.*

The most important refuges on the upper shore were *Pelvetia* and *Lichina* although neither species exceeded 10% cover. Densities of the dominant faunal species in *Pelvetia* clumps, sampled in August and September 1976, (ind. per 200 g, $N = 4$) were the amphipod *Hyale nilssoni* agg. (21) (both *Hyale nilssoni* and *H. stebbingi* were present on this shore but were not distinguished during the first year of our survey), juvenile *Ligia oceanica* (32.5), *Melarhaphe neritoides* (14.3), and *Littorina saxatilis* agg. (12.3). *Lichina pygmaea,* which was present as scattered patches not exceeding 1 cm in height, provided important cover between the *Pelvetia* zone and the mussel bed for small animals, especially *Lasaea rubra, Melarhaphe neritoides* and the isopod *Campecopea hirsuta,* while sediment trapped in the turf created a substrate for the oligochaetes *Lumbricillus semifuscus* and *Marionina macgrathi* – this is the type locality for the latter species (Healy, 1996a) – and also for harpacticoids and mites, including *Arctoseius ibericus* for which this is a new Irish record. An unidentified tipulid larva (Diptera) was confined to this habitat but other species were also present in empty barnacles and crevices. Samples taken in January–April 1977 gave the following densities (ind. dm^{-2}, $N = 3$): L. rubra 5328, *M. neritoides* 1173, *C. hirsuta* 128 and *H. nilssoni* agg. 43. In the only two samples of *F. vesiculosus* analysed, *H. nilssoni* agg. was the dominant taxon (109 per 200 g) followed by *Littorina obtusata* agg. (24.5 per 200 g), all males of which were *L. obtusata.*

Mussels provided good protection for cryptofauna between MTL and MLWN and 24 species were identified. The byssus threads of the upper mussels trapped sediment and detritus, forming a stable habitat for species with poor mobility and high moisture requirements such as the oligochaetes *Lumbricillus semifuscus, Inermidrilus georgei* and another undescribed species of *Inermidrilus, Clunio marinus* (Chironomidae), *Hydrogamasus littoralis* (Acari), *Idotea pelagica* (Isopoda), *Parasinelobus chevreuxi* (Tanaidacea), young individuals of *Nucella lapillus* and several species of polychaetes and nemerteans (Table 1). The mean density of *I. pelagica* in mussels at G was estimated at 77 dm^{-2} (Healy and O'Neill, 1984). Apart from crevices, this was the only habitat on the exposed rocky shore available to the larger worms such as *Cirratulus cirratus, Lineus longissimus* and *Nereis pelagica.* Turnstones, oystercatchers and gulls, which were often to be seen feeding on the mussel beds, may take these as well as the mussels themselves. A negative correlation between the densities of *C. cirratus* and oligochaetes was observed (Healy, 1996b) suggesting that the sticky secretions of the former may inhibit small worms. Lower zone mussels were short-lived and their infauna poorly developed.

Corallina officinalis and associated filamentous red algae, which formed a dense turf 1–2 cm in height around MLWS, contained the richest fauna of any cryptofaunal habitat examined with a total of 65 species (Table 1). The dominant species were the sponge *Scypha compressa*, the polychaetes *Pholoe minuta, Syllis gracilis, Spirorbis corallinae* and *Fabricia sabella*, the oligochaetes *Grania pusilla* and *Marionina ulstrupae*, amphipods, particularly *Hyale nilssoni* agg. and small molluscs *Rissoa parva, Skeneopsis planorbis, Turtonia minuta, Lasaea rubra* and *Littorina mariae*. Egg capsules of *Turtonia* were sometimes abundant. This is the type locality and typical habitat of the oligochaetes *Marionina ulstrupae* (Healy, 1996a) and *Grania mira* (Locke and Coates, 1998). Sample analysis was time consuming and density was determined from 3–5 samples for a few selected species only. The bivalve *Turtonia minuta* was estimated at 160 dm^{-2} in June 1976 and 1472 dm^{-2} in September 1976, the sipunculid *Nephasoma minuta* at about 3 dm^{-2}, and amphipods, including *Hyale nilssoni, H. stebbingi* and *H. pontica*, at 13–26 dm^{-2}. Density estimates for *Grania* spp. and *Marionina* spp. in samples from January to July 1977 ($N = 13$) averaged 517 and 132 dm^{-2}, respectively, but higher densities of 3504 dm^{-2} for *Grania* and 7040 dm^{-2} for *Marionina* were recorded in September–October 1994 (Healy, 1996b). The richness of the fauna was in large part due to the sediment trapped by the algae, often to a depth of more than 1 cm in the turf, and an abundance of sandy tubes constructed by amphipods and polychaetes which creates additional refuges. The presence of young stages of several species suggests that *Corallina* may play an important role in trapping the settling juveniles of molluscs such as *Mytilus* and *Littorina littorea*, thus acting as a nursery from which colonisation of intertidal rocks can take place.

Mastocarpus stellatus, which occurred mainly as scattered groups of plants among *Corallina* and mussels, harboured several mobile species which may leave the weed and swim freely when it is submerged, as well as more sedentary species. A total of 23 species was recorded, the best represented groups being small gastropods (seven species), small bivalves (four species), coelenterates (four species) and amphipods (five species). The most important taxa, estimated in the period January–August 1977 (ind. per 100 g, $N = 9$) were *Idotea granulosa* (68.1), *Lacuna vincta* (32.4), *Hyale* spp. (10.8), other amphipods, mainly Jassidae (15.0), and *Rissoa parva* (5.6). The relative importance of herbivorous gastropods varied seasonally, *Lacuna pallidula* being most important in June–August (mean density 12 per 100 g) and *Lacuna vincta* in August–September (21 per 100 g). *Helcion pellucidum* first appeared in low numbers in April and numbers then increased until June and decreased during July–September (McGrath, 1992). *Littorina mariae* and *Rissoa parva* occurred irregularly (or perhaps patchily).

The annual receptacles (thongs) of *Himanthalia* offered little shelter although 18 species were recorded. However, only *Idotea granulosa, I. pelagica, Lacuna vincta, Tricolia pullus* and *Turtonia minuta* occurred in 50% or more of samples collected between April and July 1978. *Helcion pellucidum* occurred seasonally, juveniles first appearing in June, increasing until August when they were about 6 months old. Their grazing activities appeared to accelerate destruction of the thongs which disappeared during the following winter–spring (McGrath, 1992). The following species were recorded from perennial buttons: *Scypha compressa, Leucoselenia botryoides, Plumularia setacea, Ampithoe rubricata, Parajassa pelagica, Helcion pellucidum, Rissoa parva, Lacuna pallidula, Mytilus edulis, Alcyonidium polyoum* and *Electra pilosa.*

Holdfasts of *Laminaria digitata,* which contained shelly material and some sediment, were examined chiefly for polychaetes of which eight species were recorded (O'Connor, 1980), crustaceans (six species), and molluscs (ten species). The most abundant species were polychaetes *Brania pusilla, Nereis pelagica, Pholoe minuta, Platynereis dumerili,* amphipods *Hyale nilssoni* agg., *Stenothoe monoculoides* and the isopod *Idotea granulosa. Apletodon dentatus,* the small-headed cling fish, was frequent on *Laminaria* and especially in the hollow bases of *Saccorhiza,* and one specimen of *Liparis montagui,* Montagu's sea snail, was also recorded from a *Saccorhiza* holdfast (Dunne, 1981; O'Farrell and Fives, 1990).

The only other species of alga examined for its fauna was the densely branching *Cladostephus verticillatus* which harboured large numbers of the small gastropod *Rissoa parva.*

The cryptofauna of barnacles was mainly represented by small gastropods (*Littorina saxatilis* agg., *L. neglecta* and *M. neritoides*), *Campecopea hirsuta, Anurida maritima,* and mites (*Halolaelaps marinus, H. balticus* and *Cheiroseius necorniger*), all of which occurred in empty shells. In some places, barnacles grew taller, reaching 16 mm in height in and below the mussel zone at G. A more diverse fauna lived among and within these, especially when algae grew on their surfaces and the skeletal plates were perforated by endolithic algae, lichens or sponges. Dominant taxa were oligochaetes, mites, chironomid larvae, *Lasaea rubra, Fabricia sabella,* juvenile tanaids and *Idotea,* and small amphipods. Oligochaetes were often common in the grooves between the skeletal plates and even inside internal canals of the plates (Healy, 1996b). One specimen of the tardigrade *Echiniscoides sigismundi* was taken; the species is commensal on barnacles (Crisp and Hobart, 1954).

The Carnsore granite does not present many crevices of a size suitable for harbouring small animals except above HWN but a few were opened between the splash zone and LWN. Supralittoral species included the pseudoscorpion *Neobisium maritimum* and the centipede *Strigamia maritima.* Among the 44 species recorded intertidally were some unique to this habitat, i.e. obligate crevice species (Kensler and Crisp, 1965), e.g. *Hyale perieri* and the pulmonate gastropods *Leucophytia bidentata* and *Otina ovata.* The most abundant species in all zones were *Lumbricillus semifuscus, Lasaea rubra* and *Anurida maritima,* the latter often accompanied by orange egg masses. The small enchytraeid *Marionina macgrathi* and an undescribed enchytraeid were frequent in surface cracks and under granite flakes (Healy, 1996b).

Movable boulders on the exposed shore were scarce and only present near low water where a resident fauna on their undersides was restricted by the strong wave action. Among the more interesting species recorded were the decapods *Galathea strigosa, Thoralus cranchi* and *Athanas nitescens. Diplosoma listerianum* (Tunicata) formed extensive sheets under some boulders; *Dendrodoa grossularia,* on the other hand, was relatively scarce. A large boulder measuring over 1 m across, wrenched from its position on the upper middle shore and overturned during a winter storm, was encrusted with *Verruca stroemia.*

Pools

Pools were present throughout the exposed sector but were most numerous near the Point (G). They were of three main types: *Enteromorpha* pools above HWN, which had widely fluctuating salinity and water levels, sometimes drying out completely in summer; deep pools (more than 20 cm depth) on the middle and lower shore; and shallow, coralline pools on the lower half of the shore.

Tigriopus brevicornis (copepod), larvae of *Halocladius fucicola* (chironomid), *Littorina saxatilis, Melarhaphe neritoides* and juvenile *Carcinus maenas* were common in *Enteromorpha* pools throughout the year while some insects were only seen occasionally, for example *Octhebius subinteger, Myrmecophora brevipes* and unidentified

Halticinae (Coleoptera) and syrphid larvae (Diptera). Infrequent species included *Neomysis integer* and *Jaera nordmanni.*

Many of the deep pools contained abundant algae, most frequently *F. serratus, Halidrys siliquosa, Laminaria digitata* and *Chondrus crispus,* and most had a fringe of *Corallina. Codium* sp. and *Cystoseira* sp. were present in a few pools. The fauna was rich but many species were erratic in their appearance. Common species included *Calliopius laeviusculus, Stenothoe monoculoides, Littorina littorea, Rissoa parva* (mainly the variety *interrupta), Asterina gibbosa* and *Amphipholis squamata.* The small opisthobranch *Hermaea dendritica* was common on *Codium* in 1977 but was not found on subsequent visits. Similarly, *Ancula cristata* and *Aplysia undata* were plentiful in some years but absent in others, while *Jorunna tomentosa* and *Eubranchus farrani* were taken only once. This is the only known Irish locality for the amphipod, *Microdeutopus gryllotalpa* (Costello *et al.*, 1989). Apart from the common blenny, *Lipophrys pholis,* and the sea scorpion, *Taurulus bubalis,* fish were mainly recorded as juveniles in the period July–September (Healy and McGrath, 1982). Juvenile blennies were especially common in coralline pools in July and August. One 4- to 5-year-old male *Lipophrys* contained 63 young individuals of the leech *Oceanobdella blennii* in its branchial chamber. The rare Montagu's blenny, *Coryphoblennius galerita,* was taken on two occasions (O'Farrell and Fives, 1990).

Coralline pools were encrusted with lithothamnia and contained scattered tufts and patches of *Corallina.* Characteristic species of this habitat were *Polydora ciliata, Spirorbis corallinae* (Polychaeta), *Runcina coronata, Limapontia capitata, L. senestra* (Opisthobranchia), *Skeneopsis planorbis, Littorina neglecta, Melarhaphe neritoides, Tectura virginea* and *Patella ulyssiponensis,* with juveniles of *P. vulgata* and *P. ulyssiponensis* present seasonally. One specimen of the crab *Pirimela denticulatus* was taken in November 1976.

Dynamics of the exposed shore community

Observations made during the 1976–1978 survey period and on subsequent visits have provided some insight into the dynamic nature of the exposed rocky shore community at Carnsore Point. The two-zone pattern of the mussel beds appears to be the result of differences in both recruitment and mortality. Recruitment in the lower zone was heavier and growth more rapid than on the middle shore but most lower shore individuals did not survive their first year of life. Between July 1976 and July 1977, the percentage cover of mussels in the lower zone fell from *c.* 50% to <5% but had increased to almost 100% in 1978. Numbers fluctuated in subsequent years and mussels were almost entirely absent from this zone in 1994. The causes of mortality are not known but predation by *Nucella,* which was abundant on the lower shore, is one likely factor. *Asterias* were infrequent and numbers always low in the intertidal zone. Throughout most of the survey period, the upper zone remained more or less stable but patches of naked byssus threads appeared occasionally indicating that clumps of mussels had been removed, perhaps as a result of storms after an initial, weakening attack by feeding birds or other predators. Both settlement success and survival of all age groups varied from year to year. In 1977, there was a blanket settlement of mussels between MTL and MLWS which survived into 1978. By 1979 the mosaic pattern of the upper zone had become re-established and the mussels of the new settlement were indistinguishable from the older ones. The mosaic persisted during the following years but when the shore was visited in August 1986 the entire upper mussel bed at I had disappeared, possibly due to severe storms during the previous winter, and the only mussels present were small specimens of a recent settlement occurring as small patches and rosettes, mainly in the lower zone. The same changes were observed at Hook Head. The beds were restored to their former state at Carnsore by 1990.

Settlement of *Semibalanus,* although variable from year to year, appeared to be regular and no failures were recorded. Recruitment of the two *Chthamalus* spp., on the other hand, was erratic. Both 1976 and 1977 were good years for both species but in 1978 settlement was poor with spat numbers not exceeding 2.2 dm^{-2} and in 1979 it was very poor although it is known that spawning at Carnsore occurred at the usual time. A consequence of the poor settlement in 1978 was a higher density of *Semibalanus* in 1979. There were no marked changes in the cover of algae or lichens or in the abundance of *Patella* species during the observation period.

The sheltered shore at Carnsore point

Description

The upper shore tended to be gravelly and wet and even where rocks were present, lichen zones were poorly developed. At Q–R, there was a low outcrop of bedrock on the upper half of the shore, and here distinct zones of *P. canaliculata, F. spiralis, Ascophyllum nodosum* (L.) Le Jol. (with some *F. vesiculosus*) and *F. serratus* were apparent (Fig. 5). The zones became less distinct northwards where increasing amounts of sand and gravel between the boulders indicated lesser wave action. Where the cover of fucoid algae was less extensive, *Verrucaria mucosa* was common on rock surfaces. Limpets were larger but less abundant than on the exposed shore and barnacles were largely confined to the tops of rocks. Red algae were common on the lower shore among *F. serratus*, particularly *M. stellatus, C. officinalis* and lithothamnia. *Himanthalia* and *Alaria* were absent. A kelp bed, composed almost entirely of *L. digitata*, was present throughout much of the sheltered sector but diminished in width from Q northwards. Pools between Carnsore R and the beach at Nethertown contained fucoids and were mostly shallow, becoming larger, with sandy bottoms, towards the north.

Rock surfaces

The section Q–R on the east side of Carnsore Point is mainly composed of impacted boulders but also contains a stretch of sloping bedrock where a transectal survey was carried out. The bedrock gives way to boulders below MTL, however, and in this region estimates had to be made on isolated boulder tops. By comparison with the exposed shore, algal cover, particularly of fucoids, was much greater, *Littorina littorea, L. obtusata* agg., *Gibbula umbilicalis* and *Monodonta lineata* were more numerous, and barnacles, limpets and mussels, *Melarhaphe neritoides* and *Littorina neglecta* were all less abundant (Fig. 5, Table 1). Semi-quantitative estimates of the dominant species occurring on and among boulders in this area are given under "Boulder Shores".

The sublittoral fringe

The most distinctive feature of this shore was the extent of the kelp bed. On good tides, a belt of *Laminaria digitata* reaching 30 m in width could be explored and contained a number of movable rocks which were well encrusted with epifauna. The small anemones *Actinothoe sphyrodeta* and *Bunodactis verrucosa* were common and small numbers of *Lamellaria perspicua, Berthella plumula, Aeolidia papillosa* (opisthobranchs), *Trivia monacha* and *Galathea squamifera* could usually be found. *Candelabrum cocksi* was seen occasionally on the underside of rocks and *Haliclystus auricula* was common on algae in summer. *Calliostoma zizyphinum* was frequent but rarely extended into the intertidal zone. Among the rarer species taken were the opisthobranchs *Lamellaria latens, Catriona aurantia* and *Aeolidiella alderi*. Hand net sweeps among the kelp yielded occasional specimens of *Hippolyte varians* and *Antedon bifida*. Species obtained from rock washings are mentioned under "Cryptofauna".

Cryptofauna

Fucoid algae harboured more species than those on the exposed shore. *Hyale nilssoni* agg., *Littorina obtusata* and *Idotea granulosa* were the dominant species on *Fucus vesiculosus* and sessile species were rare, while *Idotea granulosa, Gibbula cineraria* and *Littorina mariae* were dominant on *F. serratus* which also had a rich sessile fauna, the most frequent species being *Sertularia pumila, Spirorbis spirorbis, Electra pilosa, Flustrellidra hispida* and *Botryllus schlosseri*.

Corallina samples analysed from Q–R yielded 31 identified species compared with 63 from exposed shore samples. Samples contained fewer species of polychaetes and molluscs but hydroids and pycnogonids were more important (Table 1). *Idotea granulosa* and *Littorina mariae* were always abundant but *Lacuna* spp. were only present in July. No *Mastocarpus* samples were fully analysed and only 14 species were identified but it was apparent that they contained higher densities of *Idotea granulosa, Littorina mariae, Helcion pellucidum* and *Lacuna* spp. than other algae on this shore. In samples of *Mastocarpus* taken during the same period as those on the exposed shore, i.e. January–August 1977, mean densities for the most abundant species (ind. per 100 g, $N = 30$) were *Idotea granulosa* 34, *Lacuna vincta* 10, *Rissoa parva* 9.6 and *Helcion pellucidum* 3.2. *Littorina mariae* was not counted in all samples but reached over 500 per 100 g in one sample. A mean density of 200 per 100 g of *I. granulosa* was recorded at a similar site just south of Carnsore beach (Healy and O'Neill, 1984). The gastropods occurred seasonally, as on the exposed shore, both *R.. parva* and *L. mariae* increasing in spring to reach a maximum in May, *H. pellucidum* was present from April with maximum numbers of 33 per 100 g in June, and *L. vincta* was only present in August.

Holdfasts of *L. digitata* contained a rich fauna with 34 species of polychaetes, including the first Irish records of *Pionosyllis divaricata* and *Sphaerosyllis ovigera* (O'Connor, 1980). The most abundant polychaetes were *Amphiglena mediterranea, Pholoe minuta, Syllis gracilis, Brania pusilla, B. clavata, Exogone gemmifera, Platynereis dumerili, Nereis pelagica* and *Pomatocerus triqueter*. Crustacea were also more diverse than on the exposed shore with 18 species, including 11 Amphipoda, the most frequent being *Elasmopus rapax, Stenothoe monoculoides* and *Apherusa jurinei*. Sessile species were well represented with *Dynamena pumila* and *Actinia equina* being especially common. In all, 83 species were recorded from holdfasts on the sheltered shore at Q–R compared with 37 from the exposed shore at I (Table 1).

Stones in wet patches on the upper shore often had large numbers of *Procerodes littoralis, Jaera albifrons* and *J. nordmanni* on their undersides. The undersides of stones and boulders on the middle and lower shore tended to be muddy, restricting the diversity of sessile fauna. *Porcellana platycheles* and *Dynamena pumila* were common on the lower shore while *Sphaeroma serratum* and *Nerophis lumbriciformis* were present in low numbers and one specimen of *Acasta spongites* was found in the *Ascophyllum* zone. Stone washings in the laminarian zone yielded many amphipods, especially *Calliopius laeviusculus, Elasmopus rapax, Hyale nilssoni* agg., *Lembos websteri* and *Podocerus variegatus*, rissoids, including *Rissoa parva, Onoba semicostata, Manzonia crassa, Alvania semistriata* and *Cingulopsis fulgida*, a few *Eualus occultus* and one live specimen of the gastropod *Graphis albida*.

Pools

Palaemon elegans was present throughout the year in high shore pools but infrequent in January–February, reaching highest densities in July–September. *Palaemon serratus* was rare. *Hippolyte varians* was frequent in sandy-bottomed pools south of Carnsore beach. The most frequently occurring fish were *Lipophrys pholis, Pholis gunnellus, Gobiusculus flavescens, Chelon labrosus* and *Crenilabrus melops*. Fish occurring in pools on the sheltered shore, but absent from the exposed sector, included *Pollachius virens, Ctenolabrus rupestris, Lepadogaster lepadogaster* and *Gasterosteus aculeatus*. All specimens examined of the latter species harboured the gill chamber parasite *Thersitina gasterostei*.

Dense blooms of the red, phagotrophic dinoflagellate *Oxyrrhis marina* Dujardin occurred in several upper shore pools at Z during the summer of 1977 and in May–June 1978. The pools contained much decaying seaweed, mainly laminarian pieces with some *Fucus* and red algae. Cell densities reached 360,000 cm^{-3} giving the water a pink-mauve colour. The blooms exhibited diurnal rhythms of vertical migration and cell division (Ottway, personal communication).

The rocky shore at Forlorn Point

The promontory of Forlorn Point lies in a wave-exposed sector of the coast but the nature of its shores, consisting chiefly of stones and small, movable boulders, indicates that wave energy in the area is dissipated by offshore topography. The bedrock forms a central ridge, reaching to low water only at the southern tip of the peninsula. A list of 126 species (Table 1) includes records from both the rocky outcrops and from the stony shores on either side of the promontory. The shore is notable for the presence of the anemone *Cereus pedunculatus* which was common in fissured rock, and for the abundance and variety of hydroids, including *Laomedea flexuosa, Diphasia rosacea, Sertularella polyzonias, Kirchenpaueria pinnata* and *Aglaeophenia pluma*. This was the only intertidal locality in Wexford where the echinoderms *Psammechinus miliaris, Leptosynapta inhaerens* and *Pawsonia saxicola* were found. Other species taken here but not at Carnsore were *Nebalia* sp. and the polychaetes *Halosydna gelatinosa* and *Gattyana cirrosa*, all from under stones at low water. The Cornish cling fish, *Lepadogaster lepadogaster*, was frequent on the east shore. The relative abundance of the dominant species on east and west shores is reported under "Boulder Shores".

The rocky shore at Hook Head

Just below the Hook Lighthouse, the rock extends as an almost unbroken pavement to low water, affording the best accessible example of a very exposed rocky shore (grade 2) in the county and an unrivalled opportunity for quantitative studies. Unfortunately, the site was too far from Carnsore to be visited regularly but some collections were made in 1977 and a transectal survey was carried out in May 1986. Differences between this shore and the exposed sector at Carnsore are largely accounted for by a greater exposure to wave action with a resultant absence of fucoids and boulders. A total of 30 species in Table 1 includes a few species collected on nearby boulder shores as well as those from rock pavement.

The rock is a dark, crinoid limestone, rich in fossils, which presents a smooth, wave-scoured surface in the region extending from the lower level of flowering plants to HWN, but is deeply pitted on the middle and lower shore. Lichen zones were poorly developed, except for *Caloplaca,* and the *Verrucaria* zone was barely distinguishable in the area of the transect (Fig. 5). *Pelvetia* and *Lichina* were absent in the region of the transect and the smooth rock provided few refuges for littorinids which were rare above the barnacle limit. *Chthamalus montagui* formed a zone from station 6 (about 50 cm above MHWS) to station 10 at about MHWN where the species overlapped the distributions of *C. stellatus* and *S. balanoides,* which were the main organisms above the mussels (Fig. 5). The mussel zone occupied roughly the same position on the shore as at Carnsore I (Fig. 5) and, as at the latter site, was represented by small specimens only in 1986 although an upper band of older mussels had been present in 1977. The large population of *Nucella lapillus* in this zone included a high proportion of coloured individuals, especially purple ones. A dense turf of *Corallina,* with scattered plants of *Mastocarpus stellatus, Himanthalia elongata, Alaria esculenta* (more frequent than at Carnsore) and *Laminaria digitata,* covered the lower shore. Neither *C. stellatus* nor *S. balanoides* were as dense on the lower shore as at Carnsore, probably owing to competition for space with *Corallina* and the abundance of *Nucella. Melarhaphe neritoides* was also infrequent below MTL. *Patella vulgata* and *P. ulysiponensis* both reached higher levels than at Carnsore and the latter was dominant on the lower half of the shore (Fig. 6). *Littorina littorea* was rare, no *Monodonta lineata* were seen, and *Gibbula umbilicalis* was confined to wet depressions on the upper shore.

The rocky shore at Cahore Point

This is probably the most exposed headland on the east coast of the county. However, the small tidal range and vertical bedding of the rock make it difficult to delimit tidal zones, and do not allow discernment of a clearly defined zonation of communities, so no attempt was made to survey it using the method employed at Carnsore and Hook.

The splash zone is broad, in places forming cliffs, but only *Caloplaca* formed a well-defined lichen zone, *Verrucaria* being difficult to distinguish on the black rock. Large-sized *M. neritoides* and small, highly polymorphic *Littorina saxatilis* agg. were abundant on the upper shore, extending patchily into the splash zone. *L. saxatilis* agg. was common on vertical rock faces throughout most of the intertidal zone. The jagged rock profile of the eulittoral creates sheltered areas where species characteristic of less exposed sites can survive and most algae and fauna were patchily distributed. In 1977, a *Chthamalus montagui* zone was not distinguishable and the species was scarce. In 1996, a small population of *Elminius modestus,* not found in 1977, was present in the zone normally occupied by *C. montagui,* but individuals were widely spaced and the population may not be capable of reproducing. Most surfaces on the upper and middle shore were blanketed with dense growths of *Cladophora* or *Porphyra* (spring observations) leaving only a few patches of fucoids and barnacles. Middle shore barnacle patches, mainly on vertical rock faces, consisted of both *C. stellatus* and *S. balanoides,* the latter being heavily infected with *Hemioniscus balani.* Mussels were mostly confined to crevices and gullies. Fucoid algae were present but zones were poorly defined except for the lower shore where the typical assemblage of *F. serratus, M. stellatus, C. officinalis* and *L. digitata* was present. A patchy kelp bed, which was not sampled, appeared to consist mainly of *Laminaria hyperborea.*

Faunal studies on boulder shores in SE Wexford

All boulder shores were relatively sheltered in comparison with the sites surveyed using the transectal method. The eight shores surveyed varied in width from 70 m at Carnsore Q and F and the east shore of Forlorn Point to 110 m at the north side of Crossfintan Point and Carnsore HH (Figs. 8a and 8b). Comparison of algal zonation and faunal abundance between the shores reveals differences between the south and east coasts which are probably explained by differences in exposure to wave action with consequent variation in the amount of sediment which is deposited (Table 2, Fig. 9).

Supralittoral lichen zones were much narrower than on more exposed shores and were sometimes absent. Algal zonation was essentially the same on all shores but some zones were poorly developed and algal cover was rarely greater than 50% except in the lower zone. *Pelvetia canaliculata* formed a distinct band at Carnsore Q–R but was rare at other eastern sites. The absence of this species and of *F. spiralis* at some sites may have been due to smothering by seasonal accumulations of tidal debris on the upper shore which were sometimes substantial. On some shores, *F. vesiculosus* was the dominant algal species of the middle shore, e.g. at Forlorn Point, while *Ascophyllum nodosum* was the more abundant on others, e.g. at Carnsore. At Crossfintan Point and Carnsore Q–R the algal cover of the middle zone was less than 10% and here the lichen *Verrucaria mucosa* was usually conspicuous.

Faunal species characteristic of shelter such as *Littorina littorea, Gibbula umbilicalis* and *Monodonta lineata*, were common on all boulder shores. The latter two species were particularly numerous on the Forlorn Point shores which were also the only localities where young individuals were at all frequent. Both *G. umbilicalis* and *M. lineata* decreased in numbers north of Carnsore. The exposed shore species *Patella ulyssiponensis, Melarhaphe neritoides, Littorina neglecta* and *Chthamalus stellatus* were scarce everywhere except at Carnsore F, the most exposed site. *Chthamalus montagui*, however, continued to form a distinct zone even at the most sheltered site examined, and often extended below the *F. spiralis* belt into the middle zone where it overlapped with *S. balanoides* (Fig. 7). *Littorina saxatilis* agg. on east coast shores were larger than on the south coast and were generally whitish in colour. *Littorina mariae* constituted 100% of flat winkles from the lower zone at Carnsore F and Q but only 70% at Carnsore HH and only *L. obtusata* was found at Crossfintan Point N. Adult *Nucella lapillus* were confined to barnacle-covered rocks and north of Carnsore R the population was mainly concentrated on the lower shore. *Gibbula umbilicalis* and *P. vulgata* also became less frequent on the upper shore north of Carnsore.

For the most part, collecting on boulder shores was confined to the dominant fauna and there is only one record of a rare species, a single specimen of *Caridion steveni* taken from the shore south of Crossfintan Point which was the first record of the adult of this species in Irish waters (Ó'Céidigh and McGrath, 1981). The west shore of Forlorn Point was the only intertidal locality for *Psammechinus miliaris* although the species is found sublittorally (Keegan *et al.*, 1987; O'Connor, 1988), and unidentified anomiids were common here but not recorded elsewhere.

Reproduction and population dynamics of dominant rocky shore species

The reproductive cycle and population dynamics of selected species at Carnsore were investigated in different ways and for various lengths of time. The species were chosen initially according to their perceived importance as key organisms structuring the shore community or their likely usefulness as indicators of environmental change such as a rise in water temperature resulting from the discharge of cooling water. Species near the edge of their geographic range were considered to be especially useful for the latter purpose. Some of these, and other species, became the subject of more intensive studies for purely scientific reasons. In the following accounts, particular attention is given to the timing of breeding and settlement or recruitment periods, and variations in recruitment success. Breeding, in this context, starts with copulation or release of gametes. Comparisons with localities elsewhere in western Europe can then lead to a better understanding of the limiting factors which determine geographic ranges, and explanations for the different timetables of events observed at different points within the species ranges. It must be borne in mind, however,

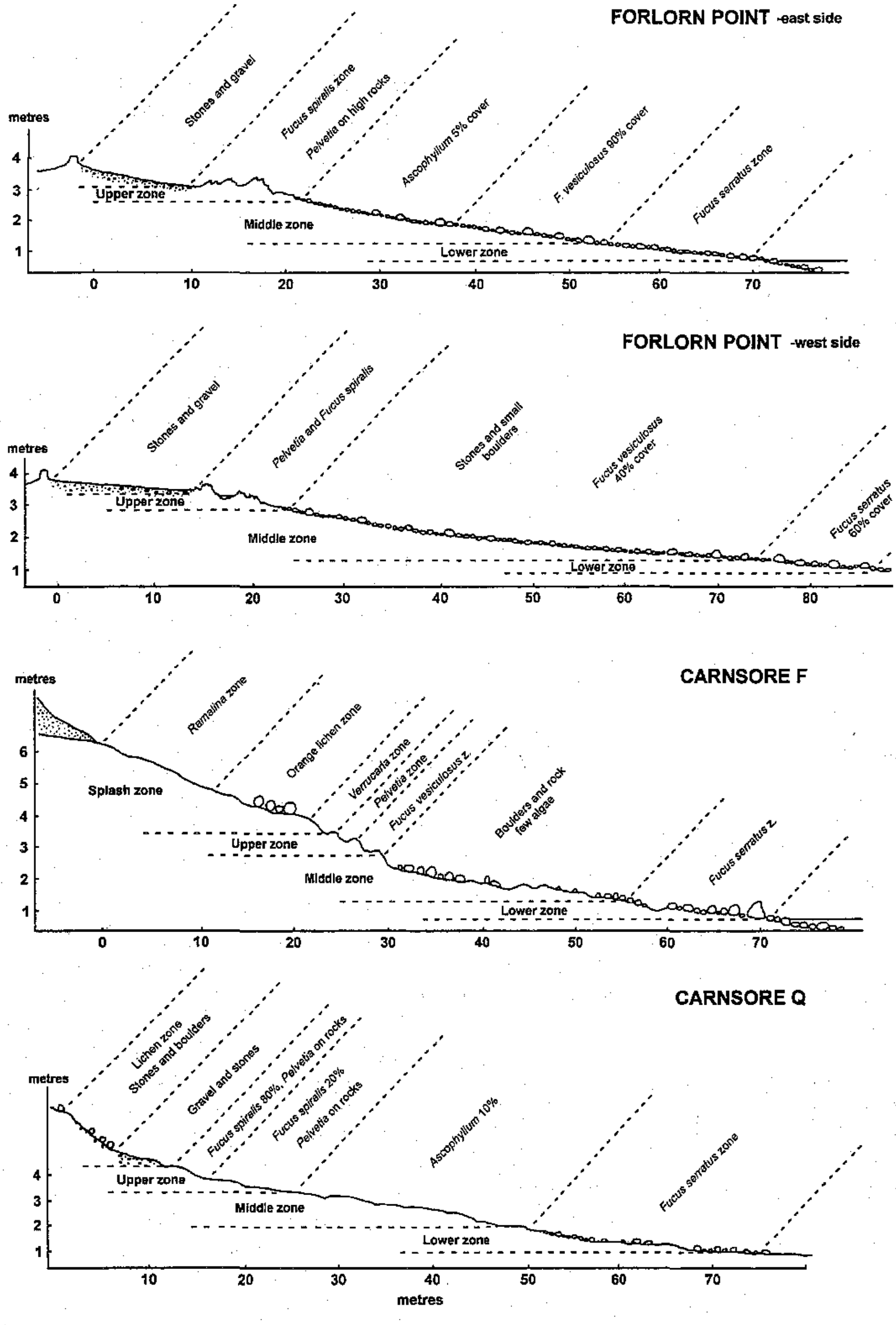

Figure 8a. Profiles, substrate and algal zonation on boulder shores at Forlorn Point and Carnsore.

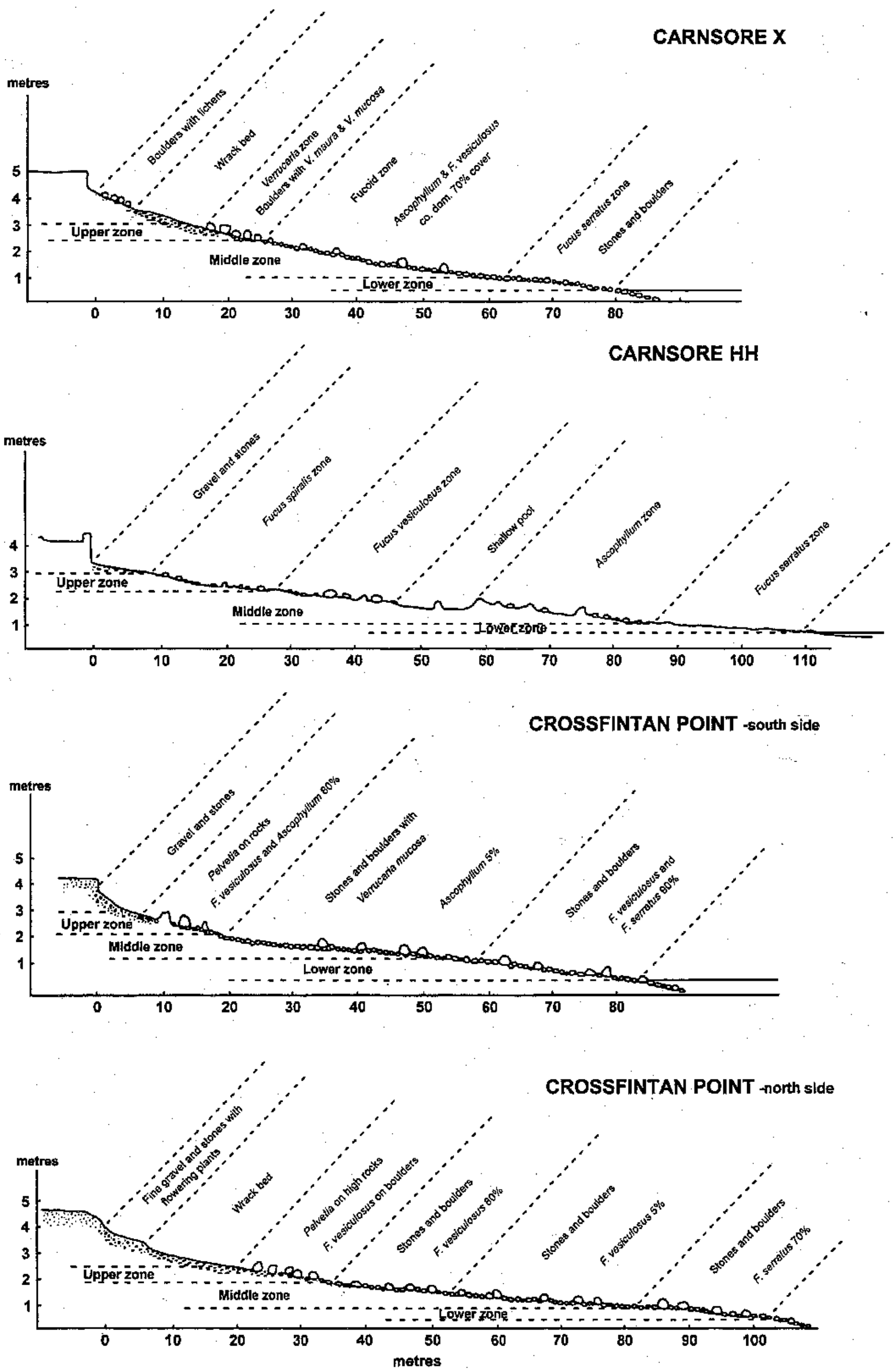

Figure 8b. Profiles, substrate and algal zonation on boulder shores at Carnsore and Crossfintan Point.

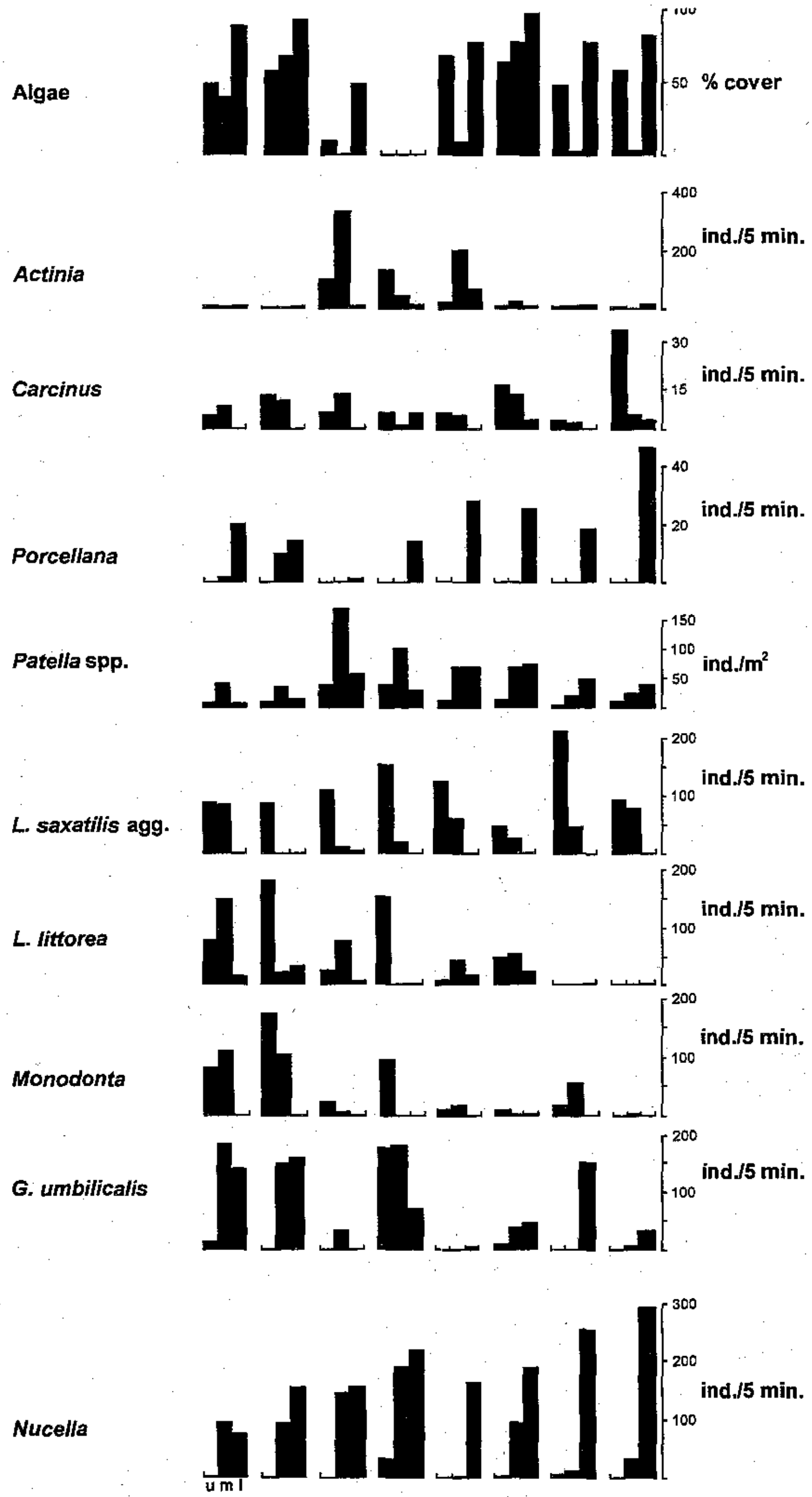

Figure 9. Relative abundance of the dominant species in upper, middle and lower zones on the eight boulder shores described in Fig. 8 and Table 2.

that sampling frequency was at most 2-weekly and usually only monthly so that precise dates for the onset and duration of breeding or recruitment cannot usually be determined. Moreover, observations were usually limited to a single annual cycle which may not have been typical for the population.

In the following accounts, summaries only are provided for published investigations while more details are given where the information is unpublished. Observations on *Chthamalus montagui* and *C. stellatus* are described in more detail than for other species because there have been few published accounts of reproduction in these species since they were separated in 1976.

Semibalanus balanoides

Observations. Brooding was first observed in mid November in both 1976 and 1977. The spawning period was more variable and nauplii could be released from early March to early April.

Settlement was first reported on 29 April 1977, 10 April 1978 and 29 March 1979. Weekly counts of cyprids and spat were made in marked areas at six tide levels at G in 1977, the areas being scrubbed after each count. Heavy settlement continued at a more or less steady rate from 1 May to 27 May and at a slower rate until 15 June. The total number recorded during the observation period was 1,880 dm^{-2} just below HWN, increasing downshore to 19,400 dm^{-2} just above LWN. The maximum density of adults on this part of the shore was 500 dm^{-2}. No settlement was detected above MHWN.

Spat survival was monitored in areas cleared of adults at four tide levels at I from 1977 to 1978. Mortality in the first 2 weeks after settlement was 44% just below HWN, 85% at MTL and 69% near LWN. The new cohort reached stability by the end of November after which there was no significant change in density. Settlement was somewhat lower in 1978, especially on the middle and upper shore, but survival was better. This was a year when *Chthamalus* settlement was poor. No settlement failures of *S. balanoides* were observed during the period of our observations.

Discussion. Copulation in *S. balanoides* occurs within the same narrow period each year at a given location. It is believed to be determined by long exposure to a local temperature regime and may be cued by a photoperiod (Crisp and Clegg, 1960). A latitudinal gradient in the date of onset of breeding is correlated with falling seawater temperature and is later towards the south (Crisp, 1959; Barnes, 1963). The true date for Carnsore is probably somewhat earlier than our recorded observations although the seawater temperature in the area does not fall to 10°C, believed to be the critical temperature for fertilisation (Crisp, 1959; Barnes and Barnes, 1976), until December. However, the average daily maximum air temperature falls to 10°C around mid November. Breeding starts on 1 December in the Plymouth area (Crisp, 1959) and within 1 or 2 days of 23 October in Galway Bay (King *et al.*, 1993). A date in the first half of November at Carnsore, therefore, appears likely. Times of larval release and settlement of *Semibalanus* are variable from year to year at all localities and are probably associated with local climate and aspects of the spring diatom increase, but a trend towards later release from SW England–Scotland–NE England–Arctic indicates a relationship with temperature. Recruitment failure has been recorded from NE England but probably does not occur on Irish coasts. There appears to be no consistency in settlement success on different parts of the British coast (Hawkins and Hartnoll, 1982; Kendal *et al.*, 1985) which suggests that local conditions rather than broad climatic trends are responsible for the variations.

Chthamalus montagui and *C. stellatus*

Observations. The description of *Chthamalus montagui* (Southward, 1976) was published late in the first year of our study. Our observations on breeding for 1976 included both species and are, therefore, not useful. The following observations on breeding are based on collections of around 100 barnacles of both species taken monthly from their preferred zones at I from May to October in 1977 and 1978. Isolated individuals were avoided although the species are known to self-fertilise.

Brooding of both species was first observed on 5 June in 1977 but in 1978 some *C. stellatus* were brooding on 6 May while brooding was not observed in *C. montagui* until the end of June. Three stages of brood development were recorded: stage 1 in which no embryonic development was obvious, corresponding to stages 1–8 of Crisp (1954),

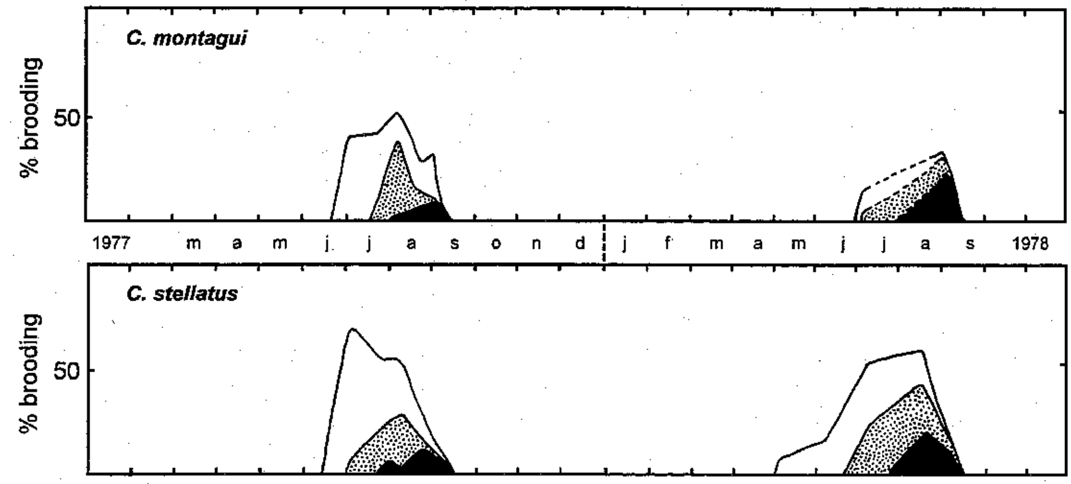

Figure 10. Brooding periods of *Chthamalus montagui* and *C. stellatus* at Carnsore I in two successive years determined from monthly samples of 100 individuals of each species. Clear areas – eggs without visible sign of embryonic development; stippled areas – embryos with limb buds; black areas – embryos with limbs and eyes well developed.

stage 2 in which embryos had limb buds (stages 9–11 of Crisp), and stage 3 in which limbs and eyes appeared to be fully formed (stages 12–13 of Crisp) (Fig. 9). The greater proportion of stage 2 embryos in *C. stellatus* in July 1977, compared with *C. montagui,* suggests that breeding may have started somewhat earlier in *C. stellatus* in that year also. In *C. montagui,* the maximum proportion of the population brooding at any time never exceeded 50% and by the time larvae were ready for release at the beginning of September, no more than 15% carried broods in 1977 and only 20% in 1978 (Fig. 10). In *C. stellatus,* the maximum proportion breeding was 70%. Late stage embryos and larvae were present in both species from the end of July, therefore the decline in the proportion of ovigerous individuals was due to either brood mortality or, more likely, early spawning by a section of the population. The highest proportion of late embryos was recorded at the end of August to the beginning of September in both years and the main spawning period was early September, practically all individuals being spent by the end of September. Small collections made in subsequent months showed that a few individuals were brooding in winter.

Chthamalus montagui spat could not be distinguished from those of *C. stellatus* until they reached a length of 0.7 mm (aperture 0.4 mm) at about 1 month old on the lower shore, and possibly up to 5 months old on the upper shore. Settlement of *Chthamalus* began in late September in 1977 and continued irregularly until April 1978. Any larvae released before the end of August either did not survive to settlement, or their planktonic development was slow, or they settled elsewhere. Settlement appeared to be intermittent after December with pulses in February and April (Fig. 11). Subsequent identification of spat indicated that both species were settling throughout the period September–April. Settlement of both species was poor in 1978, the estimated density of spat at MTL in October 1978 being only 2.2 dm^{-2}, and in 1979 it was very poor. Good settlement was recorded in late October 1976 but the fate of the spat was not monitored.

While the failure to distinguish the species until they were at least 1 month old makes it impossible to compare numbers of the two species settling at different shore levels directly, the much higher spat densities on the lower and middle shore (Fig. 11), and the predominance of *C. stellatus* at these levels among identifiable spat, indicate a much heavier settlement of this species than for *C. montagui,* particularly on the lower shore. The proportion of *C. montagui* among 0^+ *Chthamalus* increased throughout the first year of life above MTL, demonstrating a much better tolerance of

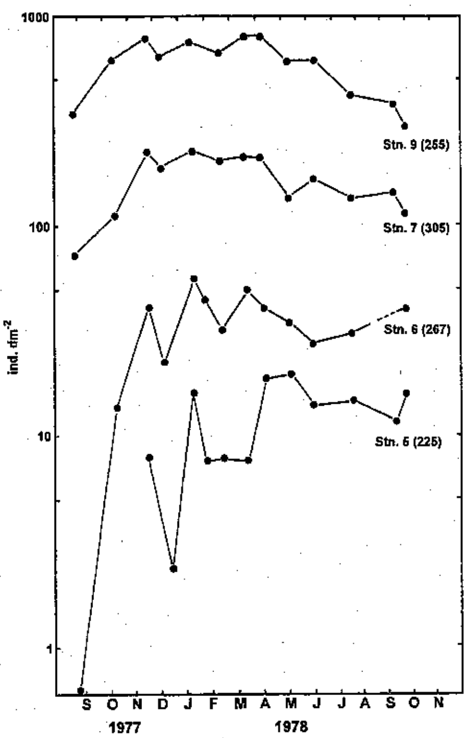

Figure 11. Settlement and survival of *Chthamalus* spat at four levels on the exposed shore at Carnsore site 1. Numbers in brackets are adult densities.

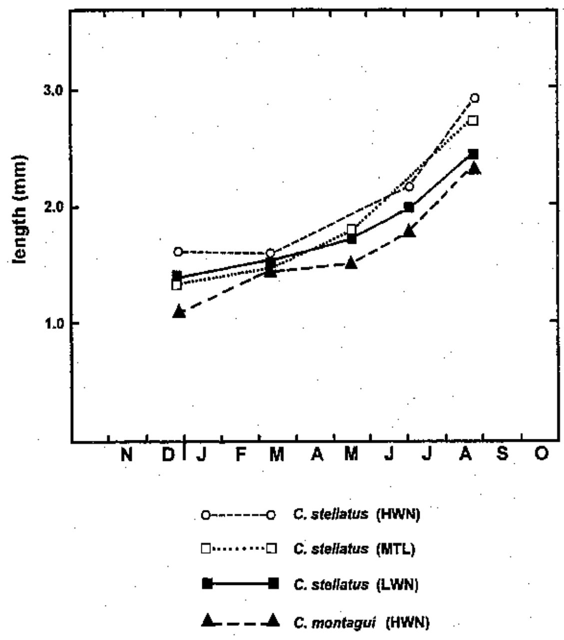

Figure 12. Growth of *Chthamalus stellatus* and *C. montagui* spat at different levels on the exposed shore at Carnsore site I in 1977–1978. Measurements are total length.

high level conditions by this species than *C. stellatus,* but numbers of *C. montagui* were always low on the lower shore. It is not possible from the data available to determine whether settlement of *C. montagui* was poor on the lower shore or whether spat suffered high mortality during their first month. The growth rate of *C. montagui* spat at HWN was faster than that of *C. stellatus* at the same level in winter but slower from March to July (Fig. 12). A significant mortality of *Chthamalus* spat occurred at all levels between 28 December and 14 January (Fig. 10), probably due to frost or unusually low water temperature (Fig. 4), and again between mid February and early March, the mortalities being offset in each case by further spatfalls. The density of 0^+*C. montagui* in July 1978 (ind. dm^{-2}) was estimated to be 12.3 at MHWS, 7.0 at MHWN, 14 at MTL and 0 at MLWN. Densities of adults at the same levels in June 1979 (ind. dm^{-2}) were 217, 147, 62 and 4, respectively. The low recruitment rate, coupled with evidence of frequent settlement failure, indicates both long life and low mortality for *C. montagui* adults on this shore. The densities of 0^+ *C. stellatus* (ind. dm^{-2}) in July 1978 were estimated to be 1.7 at MHWS, 200 at MHWN, 162 at MTL and 606 at MLWN. Densities of adult *C. stellatus* at the same levels in June 1979 were 8, 110, 243 and 215 ind. dm^{-2}, respectively. Spat mortality was evidently more severe on the lower shore.

Penes of *C. stellatus* were recognisable from August in the year after settlement at a rostro–carinal length of 3.0 mm or more, but no brooding was observed. Some individuals may reproduce in their first year, but because of the long settlement period, the age at maturity could not be determined. Maturation of 0^+*C. montagui* was not seen.

Discussion. The considerable literature which preceded the splitting of *C. stellatus* (Southward, 1976) is of little use for comparison with the present data and there have been relatively few studies of reproduction, settlement and juvenile survival in the last two decades. However, attention is drawn to the papers of O'Riordan *et al.* (1991, 1992, 1995) which describe investigations of these processes in the two species in south-west Ireland. It is generally agreed that there is little difference in the physiological adaptations or breeding and settlement periods of the two species. Both are southern species and have similar geographic distributions although *C. stellatus* extends further south and is more common in the Mediterranean (Crisp *et al.*, 1981). The somewhat earlier start of breeding in *C. stellatus* at Carnsore, also reported by Southward (1976), may have been due to the different levels on the shore from which samples for the two species were taken. Crisp (1950) observed that *Chthamalus* starts to breed earlier at lower than at higher levels, but this could be explained by the presence of two species occupying different tide levels. Both species are known to produce successive broods, except near their northern limits (Lewis *et al.*, 1982; Burrows *et al.*, 1992). In SW Ireland, a small percentage of both species produced viable broods in winter and it was observed that gonads never totally degenerated so that breeding was possible throughout the year (O'Riordan *et al.*, 1992). It thus appears likely that the winter–spring settlements described here for 1977–1978 were the result of autumn or winter broods which, because of lower temperatures, would have taken longer to develop, and the planktonic phase longer to complete, than for those produced in summer. Unfortunately, few observations on brooding were made after October.

The onset of breeding in *Chthamalus* is believed to coincide with a rise in temperature above 10°C (Burrows *et al.*, 1992; O'Riordan *et al.*, 1995) which would occur at Carnsore (water temperature) towards the end of May. The observed start in late May–June is thus probably typical for the region. In Scotland, breeding is confined to summer (Barnes, 1972; Crisp *et al.*, 1981) but both species start breeding earlier and have longer breeding seasons on continental coasts than in Britain (Kendall and Bedford, 1987), thus winter breeding at Carnsore and SW Ireland, and a small amount of breeding throughout the year at Anglesey (Patel and Crisp, 1960), may be viewed as characteristic of southerly populations. Brood development in *C. montagui*, from oviposition to larval release, can be completed in 3 weeks at 15°C (a little more in *C. stellatus*) (Burrows *et al.*, 1992) or even 2 weeks (Patel and Crisp, 1960, species not known), allowing production of two or even three broods in a summer. However, the data from Carnsore suggest that only a proportion of the population released early broods and that the larvae may not have survived to settlement. More frequent sampling would be needed to verify this.

The main settlement period for Britain and Ireland is September–October but later settlements have been recorded (e.g. O'Riordan *et al.*, 1992). The apparent failure of early broods to settle before late September at Carnsore, and the settlement failures of 1978 and 1979, are suggestive of environmental stresses affecting species near the limits of their range. *Cthamalus stellatus* does, in fact, become infrequent on the east coast north of Carnsore and *C. montagui* becomes confined to a narrow zone above *Semibalanus* (see also Southward and Crisp, 1954). Poor recruitment and recruitment failures are reported for Scotland (Lewis *et al.*, 1982) and for N. Wales (Bennell, 1981).

Idotea granulosa

Reproduction and population dynamics were studied on the sheltered shore in 1978–1979 by analysing monthly samples of *Mastocarpus* from boulders near low water. The main breeding season was January–August with a peak in March, but there was some breeding throughout the year. Juveniles (all individuals which could not be sexed) were present in all months except March and October. Some females are believed to have produced broods when only a few months old. Breeding individuals appeared to die off in May–June to be replaced by a new generation, some of which matured and produced young in late summer. (For more details see Healy and O'Neill, 1984.) The isopod brood parasite *Clypeoniscus hanseni* was present in four females.

Idotea granulosa is a northern species, reaching its southern limit in northern France. Some continuous breeding has been recorded from Yorkshire (Irwin-Packington, 1934) and the Isle of Man (Bruce *et al.*, 1963; Salemaa; 1986) but at these localities the peak of reproductive activity was in summer. A peak in early spring had not previously been reported.

Idotea pelagica

Reproduction and population dynamics were studied in the exposed shore mussel bed at G in 1978–1979. Breeding was less well synchronised in the population than in *I. granulosa,* the main period of breeding lasting from December to July and less than 10% of females brooding between August and November. Juveniles (all individuals which could not be sexed) formed at least 30% of the population in all months except October 1979. Analysis of female size frequency, and the incidence of full and empty marsupia, indicated two generations of breeding females, the first releasing young in December–January which reached maturity in March–May and released a second generation in May–June. Some females of both generations could have produced second broods. (For more details see Healy and O'Neill, 1984.) *Clypeoniscus hanseni* was present in one female.

The species has a wider distribution than the previous one, extending south to Biscay. It is reported as breeding in most months in the Isle of Man (Bruce *et al.*, 1963) but breeding was confined to summer in NE England (Sheader, 1977).

Palaemon elegans

The number collected in timed hand net sweeps in the same pool on the upper shore at Carnsore X from July 1976 to February 1978 varied between 0 and 16 min^{-1} from October to May and from 45 to 176 min^{-1} from early June to early September. Ovigerous females measuring 33–52 mm carapace length were present in upper sheltered shore pools from May (1978) or July (1977) until the beginning of August, and juveniles from 4 mm, modal size 9–12 mm, were abundant in July and August.

Porcellana platycheles

Females became ovigerous from 4 mm carapace width. Breeding in 1977 started in late March and by the first week of April 73% of females over 6 mm were ovigerous. The proportion of berried individuals among adult females rose to 95% in early June when younger females measuring 4 mm became ovigerous. The proportion of females carrying eggs had fallen to 10% in the last week of July. Only one ovigerous female was taken in winter (in November). In 1978 the timing of events was similar but only 29% of females were ovigerous in the first week of April and the proportion never rose above 50%. The breeding season is, therefore, well defined with a main spawning period in late March–early April and a well synchronised release of larvae in June–July, but in some years a proportion of females may not succeed in breeding. Heavy settlement occurred in mid–late August.

The breeding season at Carnsore is similar to that recorded at Plymouth (Lebour, 1943) and S. Wales (Smaldon, 1972) where females were gravid from March or April to August. However, the peak occurrence of gravid females was somewhat earlier at Carnsore, i.e. March–April compared with April–June in S. Wales. In the Adriatic, brooding was mainly recorded in February–June but some ovigerous females occurred in all months and two or even three broods may be produced in a year (Stevcic, 1988).

Patella vulgata

Observations. The maximum shell length of exposed shore specimens was 55 mm (at B) and on the sheltered shore 63.6 mm (at R). The well documented differences in the size structure of high density, exposed shore populations, compared with low density populations on sheltered shores, are demonstrated by collections from barnacle covered rocks at I and rocks with algae at R (Fig. 13). The smallest recognisable males at I were 8.4 mm, the smallest females 16.1 mm, males outnumbering females by 3:1 in the adult population. The species thus appears to be a protandrous hermaphrodite as proposed by Blackmore (1969).

Data on reproduction are only available for the exposed shore population at I in the period September 1978–April 1979. Developmental stages of male and female gonads were classified according to the gonad index devised by Orton *et al.* (1956). The rates of development and times of gamete release were similar in both sexes. Gonads were already ripening in September when 30% were ready to spawn (Fig. 14). The main period of gamete release was in October when 80% of mature individuals were in spawning condition and are believed to have spawned soon after. There was some redevelopment of gonads in January but no further spawning stages were observed. By April, 80% of males and 95% of females had regressed gonads.

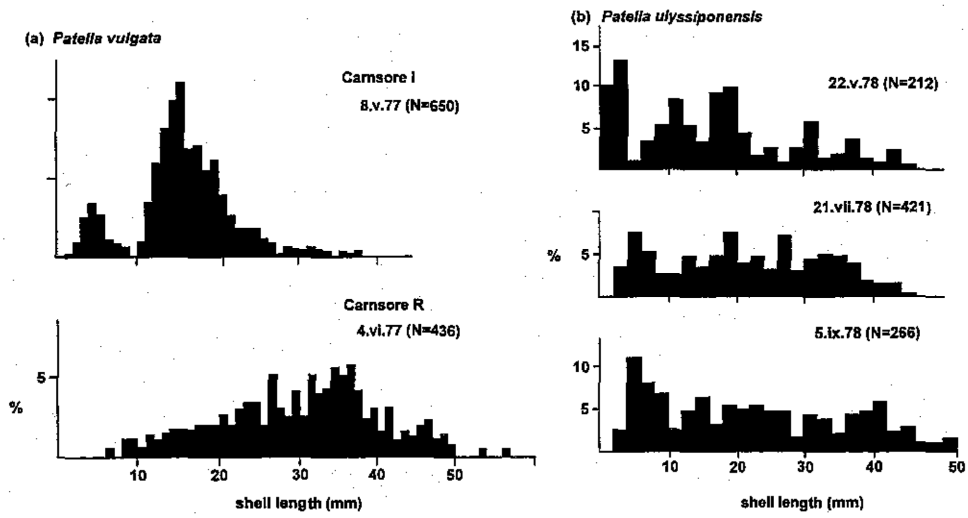

Figure 13. (a) Size distribution of *Patella vulgata* from exposed (site I) and sheltered (site R) sections of the shore at Carnsore. (b) Size distribution of *Patella ulyssiponensis* collected in three different months from the *Corallina* zone at Carnsore I, showing recruitment and growth of spat.

Juveniles first appeared on open rock at I on the lower shore and in pools throughout the intertidal zone, the smallest spat being most easily observed on crustose lithothamnia and on the shells of adult limpets, especially *P. ulyssiponensis* in *Corallina* turf. Spat of the 1978 spawning appeared in small numbers on the lower shore in November when they measured 0.7–1.1 mm shell length (Fig. 15). Numbers of spat then increased but remained low until April when numerous juveniles measuring 1–2 mm appeared. The modal size of this cohort had increased to 3–4 mm by August. Individuals of the 1977 spawning, first observed in May 1978 at a modal size of 2–3 mm (as in May 1979), had grown to 5–6 mm by September. As males mature from 8 to 9 mm, they probably do not breed until the end of their second year and females would not mature until their third year. On the sheltered shore, recruits were observed somewhat earlier and their occurrence appeared to be less spasmodic. The first spat here were recorded in 1978 at around LWN from the beginning of September and at HWN from October to February. In 1979, recruits were present at both levels in November and more had appeared by January.

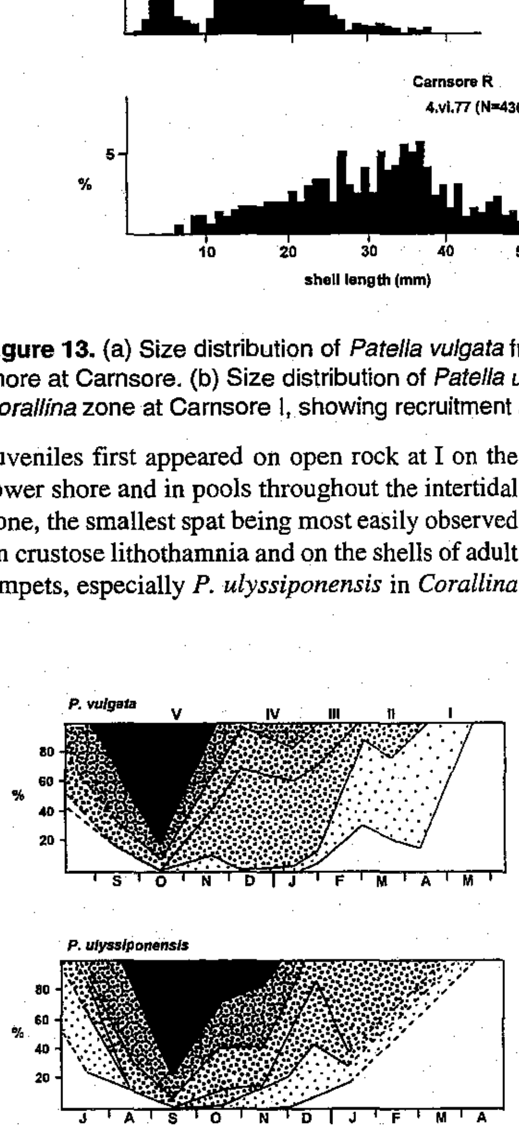

Figure 14. Female gonad development and spawning in *Patella* species in 1977–1978. Roman numerals indicate developmental stages as defined by Orton *et al.* (1956). Individuals at stage V (black areas) are spawning or ready to spawn.

Discussion. The timing, duration and synchronisation of breeding and settlement of *Patella* species on European coasts vary along a N–S gradient (Bowman and Lewis, 1986). In Norway, spawning occurs from August to October (Kolstad, 1959) while in Britain it usually starts in October. It has been observed that spawning of *P. vulgata* takes place when the water temperature first falls

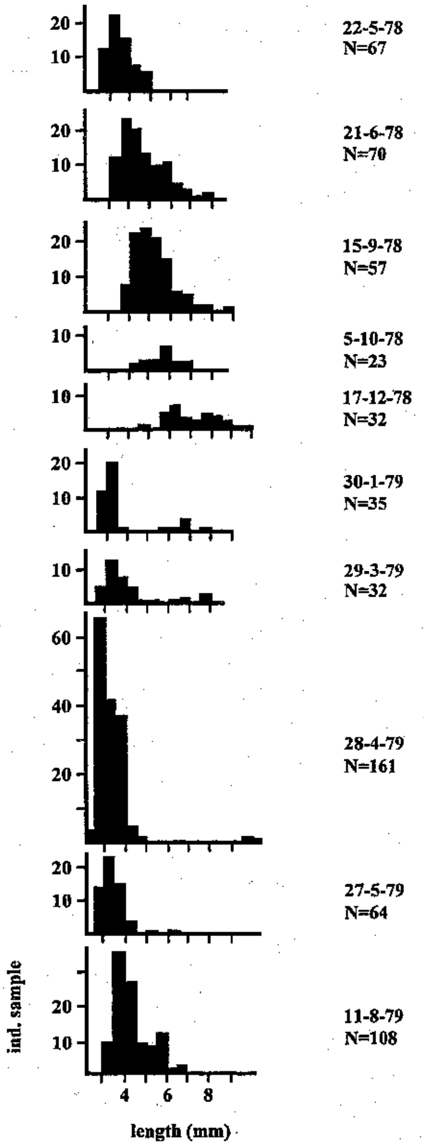

Figure 15. Length frequency of *Patella vulgata* spat from the *Corallina* zone at Carnsore I showing recruitment periods, changing density and growth rates. All samples but one were collected from randomly selected areas of 1 m^2 which were different on each occasion. The sample for May 1979 was taken from several small areas owing to wave surges.

below 12°C and coincides with an Atlantic swell (Bowman and Lewis, 1986). The narrow temperature "window" would normally occur at Carnsore in October (Fig. 4) which was the main spawning period in 1978. There was no evidence of subsequent spawnings, a characteristic of southern populations (Bowman and Lewis, 1986), although some redevelopment of gonads occurred. A protracted recruitment period, peaking up to 12 months after its recorded start, is normal for the species in British waters (Bowman and Lewis, 1977).

Patella ulyssiponensis (syn. *P. aspera*)
Observations. Reproduction and population dynamics were studied on the lower exposed shore at I from May 1978 to April 1979. The smallest recognisable males measured 13 mm and the smallest females 18 mm. Males formed the bulk of the population under 35 mm while females predominated at 37 mm and from 44 to 48 mm (Fig. 16), indicating that *P. ulyssiponensis*, like *P. vulgata*, is probably a protandrous hermaphrodite on this shore. All individuals measuring 50 mm or more were heavily parasitised by trematodes and their sex could not be determined.

Spawning and resting periods (determined according to the gonad index of Orton *et al.*, 1956) were similar to those of *P. vulgata* but *P. ulyssiponensis* commenced breeding around one month earlier (Fig. 14). About 20% of gonads were ripe on 20 August, 80% in September and 30% in October, while in November 10% of males and 20% of females were still in spawning condition. There was some redevelopment of both sexes in January but no ripe gonads were found after November.

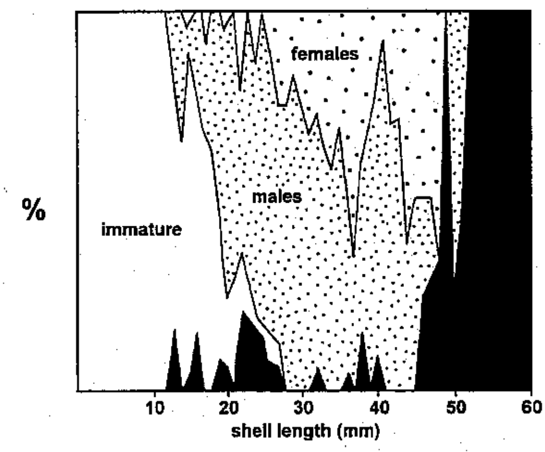

Figure 16. *Patella ulyssiponensis.* Sex ratio in random collections from the exposed shore at Carnsore B showing changing ratio with increase in size. Black areas indicate parasitised individuals for which sex could not be determined.

Spat appeared in the *Corallina* zone, and in coralline pools on the lower shore, from 1.0 mm shell length. The onset of recruitment was not observed in 1978 but occurred after February and was well advanced by May (Fig. 13). In 1979, 1- to 2-mm spat were present in April. By the end of their first year they measured 6–12 mm and by the end of their second year the modal size of the cohort was 16–17 mm. As the smallest females were 18 mm, female breeding probably does not start until individuals are in their third year. The growth rates are similar to those observed in Bantry Bay (Thompson, 1979). The size structure of the population (Fig. 13) indicates regular recruitment at this site.

Discussion. Patella ulyssiponensis is a southern species, reaching its northern limit in southern Norway where breeding has been recorded between July and September (Kolstad, 1959). The onset of spawning is progressively later in Britain along an anti-clockwise gradient from August in NE England, September in Scotland and Wales (as at Carnsore) to November in SW England (Bowman and Lewis, 1986), while in S. Portuguese populations, a succession of spawnings from August to March/April were observed (Guerra and Gaudèncio, 1986). In Britain, both the timing of spat appearance onto the lower shore, which can occur from early autumn to the following spring, and recruitment success, are very variable with occasional failures in northern regions (Bowman and Lewis, 1986). The apparent delayed recruitment at Carnsore, which was observed in two successive years, appears to be unusual for this latitude. Portuguese populations also recruited from March/April but numbers continued to build up in late summer and autumn (Guerra and Gaudèncio, 1986).

Helcion pellucidum

The reproductive cycle was not investigated at Carnsore but the species breeds throughout the year with a peak in spring in Britain (Graham and Fretter, 1947). The following account is a summary of a detailed investigation of recruitment and growth on the Carnsore exposed shore at I (McGrath, 1992).

Recently settled juveniles with attached larval shells were first recorded on lithothamnia-covered rocks, and in coralline pools on the lower shore, in February 1978 at a maximum shell length of 0.66 mm. Recruitment continued until April but the densities on lithothamnia fell. Low numbers of 0^+ appeared on *Mastocarpus* from April or May, increasing until June as they recruited from lithothamnia, but decreased steadily during July–September and only low numbers were present from September to March. The decrease was explained by migration to the growing annual receptacles of *Himanthalia.* The limpets also appeared on *Laminaria* in May where they were almost exclusively found on the frond tips.

Settlement on crustose red algae had not previously been recorded. Recruitment to *Laminaria* in May was also reported in Britain (Graham and Fretter, 1947) but did not occur until July in W. Norway (Vahl, 1971).

Gibbula umbilicalis

Observations. Comparison of size distributions for populations at Carnsore Q–R in May 1977 and Kilmore Quay in April 1996 (Fig. 17) reveal differences in population structure and adult size which suggest that local environmental factors influence both settlement success and growth rates and that settlement success varies from year to year. At Carnsore Q–R, large individuals >12 mm, modal diameter 16–18 mm, dominated the population and juveniles were difficult to find, the smallest collected being 4–5 mm when they may already have been several months old. A few small nurseries could be found in spring in coarse sediment of shallow pools of the upper middle shore but numbers were always low. The 1^+ 1975 cohort was small, representing no more than 10% of the population in May 1977, and the 1976 cohort was even smaller. A similar population structure was found in April 1996. Growth ring analysis, which was successful for 60% of the population, did not indicate any absence of recent year classes. Settlement on both Carnsore shores appears to be generally low and the populations are presumably maintained by low mortality and long life. In contrast, the size distribution of the population at Kilmore Quay, where the density was similar to that at Carnsore Q–R, was bimodal with a good representation of juveniles, a weaker 1^+ class, and a smaller adult modal diameter of 13–15 mm, suggesting faster growth and a shorter life span. The abundance of stones on this shore, many of them flat, may create a more suitable habitat for juveniles than exists at Carnsore, but even here settlement is evidently low in some years.

Both sexes started to breed at a shell diameter of 10–11 mm (May sample). Changes in reproductive condition were followed on the sheltered shore using the gonad index proposed by Williams (1964). In April 1977, when the first sample was analysed, the majority were at stage III with gonads partly developed and these had developed to stage IV by May. The spawning stage (V) was not observed but was probably reached in June–July. Spawning appeared to be serial and poorly synchronised in the population. Only a small proportion of the August sample appeared to have begun to spawn and by mid November most still had well-developed gonads although the number of oocytes had decreased. The gonads regressed in December–January but at no time during the year of observation were completely spent individuals found and it was always possible to separate the sexes. These observations suggest a period of oocyte maturation in spring–early summer followed by intermittent spawning until all or most of the oocytes were discharged, but it is also possible that oogenesis continued during the spawning period.

Discussion. The latitudinal trend in the timing of reproduction, from the most northerly populations in N. Scotland to S. Portugal, is for a lengthening of the breeding period so that although animals in spawning condition usually appear first in July/August throughout the range, spawning is completed in 1–4 months in Britain. It lasts until November/December in Northern Spain and until October/November in Portugal (Lewis, 1986). Spawning can occur earlier in the year, however, e.g. from March in northern France (Pelseneer, 1934), while in south European populations, some spawning was recorded throughout the year with no clearly defined resting period (Bode *et al.*, 1986; Gaudèncio and Guerra, 1986). The prolonged spawning period of the Carnsore population, and the absence of a resting period, indicate environmental affinities with localities at Plymouth (Underwood, 1972) and N. Spain (Bode *et al.*, 1986), at least for 1977/1978. In mid Wales, spawning appears to be better synchronised, taking 3 or 4 months according to Williams (1964) and Underwood (1972). Garwood and Kendall (1985), however, observed completion of breeding in 1 month in W. Wales, believing the longer periods reported by other workers to be accounted

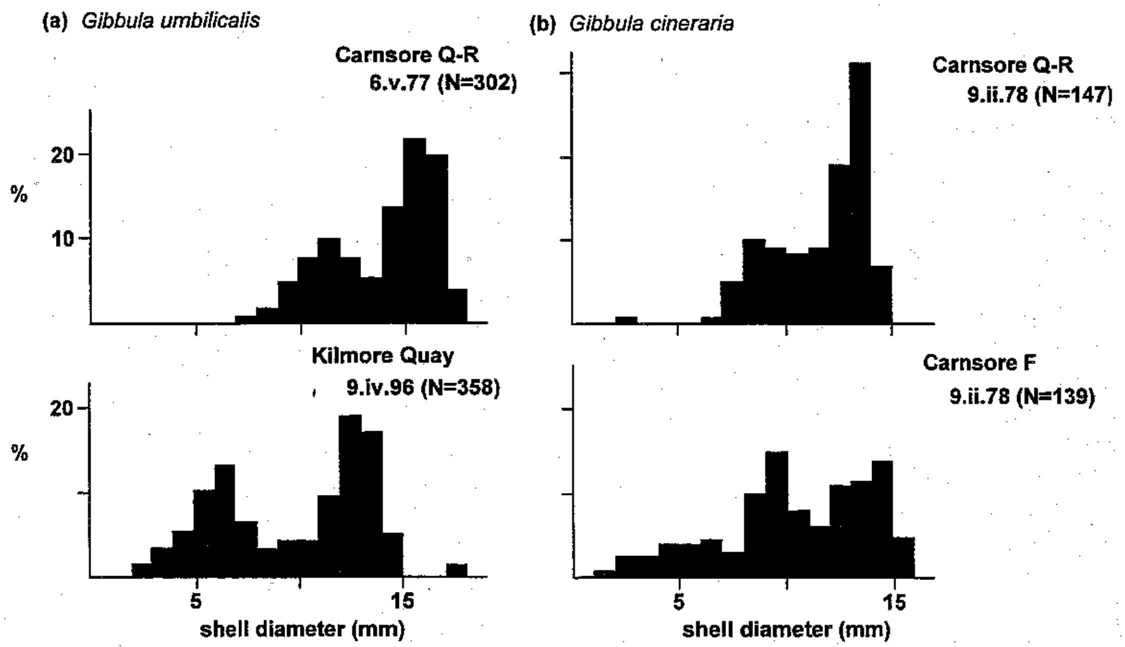

Figure 17. Population structure of winter–spring samples of *Gibbula* species at different sites. (a) *G. umbilicalis* from the Carnsore sheltered shore and Kilmore Quay; (b) *G. cineraria* from exposed and sheltered shores at Carnsore.

for by different methodologies and interpretation of results. The conclusions reached here may be suspect for the same reasons.

Failure to find juveniles is a common experience (Kendall and Lewis, 1986, Lewis, 1986) and even in southern populations, juveniles are poorly represented. The consistently poor representation of 0^+ and 1^+ age groups on the Carnsore shores suggests that recruitment was genuinely low in several successive years and may be normal for this population because appropriate conditions for juveniles are scarce. The frequency of poor recruitment has been shown to increase from south to north on the British west coast and from west to east on the north Channel coast, with 6 consecutive years of failure (1978–1983) being recorded in Scotland (Kendall and Lewis, 1986). The trend was reflected in the size frequency distributions for the different localities which were unimodal with a modal size of 15–19 mm (shell diameter) in Scotland and bimodal in Wales and SW England. The Carnsore population at station R thus resembles more southerly ones in its long breeding season but the population structure indicates a recruitment rate more characteristic of a species at or near the northern (or eastern) limit of its range while the Kilmore Quay population structure is more similar to those in W. Wales.

Gibbula cineraria

Size frequency distributions of quarterly collections at Carnsore were generally bimodal and indicated regular, if variable, recruitment (Fig. 17). The maximum size was 17 mm shell diameter. Juveniles 2 mm or less were most frequent in February, and most numerous at F.

No attempt was made to study the reproductive cycle in this species. Occasional gonad squashes at different times of year showed no apparent change in the proportion of oocytes or sperm. Histological preparations of gonads from a population at Plymouth showed no seasonal changes in the appearance of the tissues and no specimens were found to be completely spent or completely ripe (Underwood, 1972).

Monodonta lineata

Observations. Observations on breeding and population dynamics were made at Q–R where the mean density on the upper middle shore in May 1977 was 5.9 m^{-2}. The population was dominated by large, old animals with a modal shell height of 23–26 mm (diameter 23–24 mm) and a maximum height of 30 mm (Fig. 18). Exposed shore individuals, concentrated around pools and on rocks with fucoid algae near HWN, were larger, 25% measuring more that 29 mm and one reaching 33.7 mm. Juveniles and 1-year olds, which, unlike adults, are cryptic in habit, were even harder to find than those of *G. umbilicalis*, in spite of careful searching throughout the tidal zone. Individuals 12–17 mm, estimated to be 2 years old, were also poorly represented. The 0–3 age groups together constituted less than 9% of specimens collected. A higher proportion of the 1^+ group was found at Kilmore Quay in 1977 where older individuals were somewhat smaller than at Carnsore with a modal height of 18–23 mm but juveniles were rare (Fig. 18). In 1996, however, juveniles were common under stones but the 1^+ class was poorly represented while at Carnsore the population structure remained unchanged. These observations suggest that recruitment at Carnsore is consistently low and individuals slow-growing and long-lived, while at Kilmore Quay recruitment is more successful but variable and growth rates are faster. Winter growth checks on specimens from Carnsore suggested a life span reaching 15–20 years (Coll, 1979).

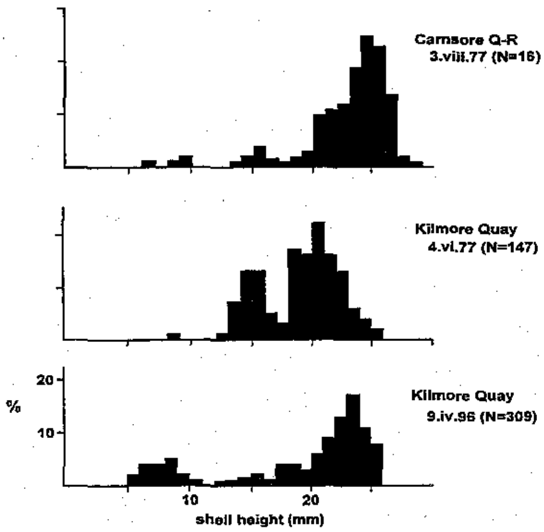

Figure 18. *Monodonta lineata.* Comparison between population structure at Carnsore Q–R and Kilmore Quay in 1977, and the very different population structure at Kilmore Quay in 1996 showing recent successful recruitment.

Ripe gonads, corresponding to stage IV of Desai (1966), were present during May–August but some oocytes and active sperm could be found throughout the year. Settlement times could not be determined.

Discussion. Monodonta is a southern species and its reproductive cycle, and the latitudinal gradients in breeding and recruitment, are similar to those of *G. umbilicalis*. However, *Monodonta* does not extend as far north, reaching its northern limits in Donegal on the west Irish coast and Anglesey in west Britain. On the east Irish coast north of Rosslare, it is only present in an area of south Co. Down, having apparently disappeared from its former locality at Skerries reported by Southward and Crisp (1954). The south Wexford localities, therefore, correspond to a range limit although the precise environmental reasons are not clear (see general Discussion).

In spite of the low representation of young age groups in Carnsore samples, the population appears to be thriving and the density at Q–R in 1996 was similar to that recorded in 1977. The fact that significant numbers of juveniles were found only on the stony shore of Kilmore Quay suggests that recruitment may be limited by habitat (but see general Discussion). Hardly any juveniles were found at the regular sampling site (Q–R) at Carnsore but in this area there were few movable rocks or stones, the usual habitat for young animals (Williamson and Kendall, 1981; Kendall, 1987) and suitable habitats may have existed on nearby parts of the shore. Adults are known to undergo extensive migrations (Desai, 1966) and do not necessarily occupy the same regions as immature animals. At other localities near the geographic limits of the species in W. Wales, SW Britain and Britanny, young age groups were better represented and years of poor or failed recruitment were unusual (Williamson and Kendall, 1981). Other authors have recorded recruitment failures in W. Wales, however, and recruitment in this region, as at Carnsore, is probably always low by comparison with that of most gastropods.

The predominance of older age groups in the Carnsore population may owe as much to long life as to low recruitment. Modal and maximum sizes are among the largest recorded for the species and specimens on the exposed shore were exceptionally large. The modal size of 22–26 mm shell height (23–24 mm diameter) is within the range recorded by Kendall (1987) for populations in Wales, S. England and N. France, but considerably larger than that of populations analysed by other authors in N. Somerset (Crothers, 1994) and W. Wales (Desai, 1966) where the modal height was only 15–17 mm, suggesting shorter life spans at these localities. Estimated life spans range from 4 to 5 years on the Biscay coast of France (Gaillard, 1965), from 10 to 15 years in N. Spain and N. Brittany, 10 years in mid Wales and 17 years near the northern limits in Britain (Lewis *et al.*, 1982), while at Carnsore individuals may live for up to 20 years. As size is related to longevity, the exceptional size of the exposed shore specimens suggests that they may live even longer and that long life, implying slow growth, may be characteristic of wave exposed populations. Large animals were also present on the shores of Skokholm Island, W. Wales (Stanbury, 1974).

Summer breeding is recorded for *Monodonta* throughout its range, the length of the breeding period increasing southwards as for *G. umbilicalis* (Lewis, 1986). The presence of oocytes and ripe sperm in almost all months is explained by a slow rate of gametogenesis with gradual accumulation of gametes, which seems to be typical for the species throughout its range from N. Spain (Bode *et al.*, 1986) to Plymouth (Underwood, 1972) and Wales (Garwood and Kendall, 1985).

Littorina littorea

Observations. Population densities were low on the exposed shore except in weedy, sheltered places above MTL, around the edges of mid- and upper-shore pools, and among boulders at F. Open rock samples were dominated by juveniles and no adults were found at the B and L transect positions where fucoids were rare. The sheltered shore population, which was subject to low intensity, commercial harvesting, was dominated by older age groups in spring 1977 but strong recruitment in that year resulted in a population dominated by the 1^+ class in late 1978 (Fig. 19).

Individuals at Q–R reached maturity at 17–18 mm shell height. Monthly examination of gonads in 1978–1979, and occasional checks in 1977, showed that nearly all adults were in spawning condition in January and February and all were

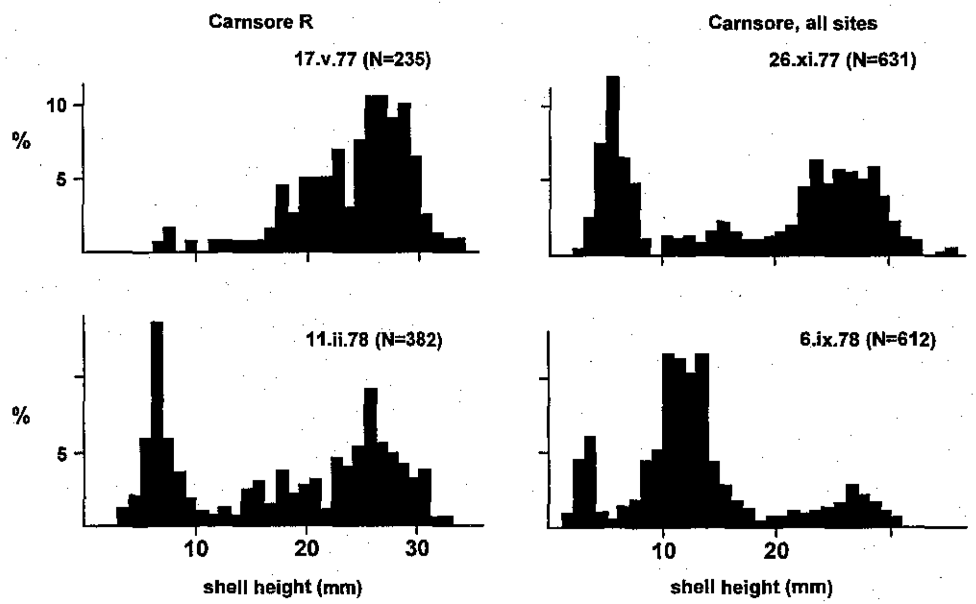

Figure 19. *Littorina littorea.* Differences in recruitment between 1977 and 1978 shown by comparing size distribution at Carnsore R and all sites at Carnsore combined.

spent by May. In 1977 there was a second spawning by about 50% of the population in August. The species was not examined in summer in subsequent years and it is not known whether summer spawning is a regular occurrence at the locality. Eggs were most numerous in inshore plankton in February (P. White, pers. comm.) which was probably the peak spawning period.

Juveniles were first seen in the lower zone of the exposed shore at I in July in both 1977 and 1978. A density of 160 m^{-2} was estimated on 3 August 1977 on rock below LWN. Two weeks later, some had reached pools throughout the tidal zone and by mid September they had spread to rocks in all zones with a mean density of 104 m^{-2} at LWN and 16 m^{-2} above HWN. The mean density for the entire shore (HWS–LWS) remained approximately the same from 3 August to 15 September which suggests that either no further recruitment to the intertidal occurred after the beginning of August, or that any new recruits to the lower shore suffered mortality. By November, the juvenile density had fallen to 14 m^{-2} at HWN and 22 m^{-2} at LWN. A comparison of size frequency distributions for the whole population on this shore (Fig. 12) shows that recruitment was more successful in 1977 than in 1978. Although there was good recruitment to open rock on the exposed shore, mortality in this habitat appears to have been high.

Quarterly collections from three levels on boulder shores at F, R and HH from May 1977 to February 1978, showed similar size distributions at the different sites and demonstrated the strength of the 1977 recruitment. The similarity between the population structure at the exposed boulder site F and that of the more sheltered east shore sites suggests that it is local habitat type rather than the degree of exposure of the shore as a whole that determines survival and growth. In May, the population was divisible into three classes, a small 0 group, 5–11 mm, representing the 1976 settlement which appears to have been poor, a smaller 1975 class measuring 12–17 mm, and a larger class, 18–37 mm, probably representing several indistinguishable year groups. A new, large cohort, measuring 1–6 mm, had joined the population by August and by November these had grown to a modal size of 7–8 mm. The proportion of 0^+ in samples increased on the mid and lower shore from August to February but the size structure of the cohort showed that the increase was not due to further settlement but to either local migration or improved sampling efficiency.

Discussion. Breeding in southern Britain and Ireland usually takes place from January to June but there can be wide variations from year to year which do not appear to be correlated with sea or air temperatures (Fish, 1972). The occurrence of a second spawning in summer can even vary over short distances, e.g. two localities in Co. Galway (O'Sullivan, 1977). The general pattern of events at Carnsore seems to be typical for S. Britain and Ireland, i.e. a main breeding season in January–March with a section of the population spawning again in summer, and settlement in mid summer followed by upward migration on the shore.

Littorina neglecta

The population on the lower middle shore at I in June 1978 (Fig. 11) was dominated by immature individuals with a modal size (shell height) of 1.6–1.8 mm and brooding individuals at this time constituted less than 10% of the population. The minimum brooding size of females was 2.3 mm. The length of the breeding season is not known but brooding females were observed in May and August and all females >2.8 mm were brooding in September.

Melarhaphe neritoides

Observations. Length frequency analysis of collections made on open rock below the *Verrucaria* zone between October 1977 and December 1978 showed three periods of settlement: November 1977, June 1978 and December 1978. The mean density of new recruits measuring 0.4–0.7 mm shell height was 26 dm^{-2} in December 1977. Settlement did not occur on open rock in the *Verrucaria* zone but spat were common in pools with a mean density of 38 dm^{-2}. The population density at the sampling station in *Lichina* was 288 dm^{-2}. Analysis of population structure in summer 1978 showed that settlement appears to have occurred throughout the eulittoral zone and that the growth of recruits was most rapid on the lower shore. The largest adult snails were to be found in the high shore lichen zones. Size then decreased down shore to about half way through the species' range, then increased again. Further details are given in Myers and McGrath (1993) and McGrath (1997).

Discussion. The maximum settlement observed in this study is an order of magnitude higher than that reported for Plymouth (Fretter and Manly, 1977) but lower than that recorded at a Cork locality (Myers and McGrath, 1993). Settlement at both Irish localities occurred each year but varied from year to year in timing and extent. Growth rates at Carnsore were lower than those estimated in Cork and in N. Wales (Hughes and Roberts, 1980), and Brittany (Daguzan, 1976).

Nucella lapillus

Observations. The population on the exposed shore at I occupied two distinct habitats: the mussel bed, where immature specimens were frequent, and lower shore rocks and gullies, where most individuals were adults and where most spawning occurred. At sheltered shore sites, adults were present from MHWN to LWS throughout the year but size distribution of monthly samples at Q–R indicated some downshore migration in winter–spring. A fall in the proportion of adults (specimens with worn shell lips indicating cessation of growth) between November 1977 and January 1978 in all zones, with a mean decrease from 44% to 20%, suggested widespread mortality.

Maturation in the sheltered shore population occurred at a minimum size of 18 mm shell height. A few clusters of egg capsules could usually be found in the lower zone of the sheltered shore and some spawning probably occurs all the year round. The main spawning period was March–July; spawn was present in all zones at Q–R in April–May 1977. On the exposed shore, some individuals spawned in coralline pools in areas where crevices or boulders were unavailable.

On the sheltered shore, juveniles were found under stones and boulders, chiefly on the lower shore where they probably feed on spirorbids. Nearly 50% of young individuals had spirorbids on their shells. On the exposed shore, juveniles were present in crevices, pools, *Corallina* and *Laurencia* turf, and especially among mussels. Monthly analysis of population structure at Q–R from September 1976 to March 1978 showed that juveniles moved onto the upper and vertical surfaces of rocks and boulders at a length of 8–10 mm. They were especially common on rocks in the lower zone in September. Size frequency indicated regular but variable recruitment with strong year classes for 1976 and 1977.

Discussion. Spawning in *Nucella* takes place at a minimum water temperature of 9°C and a rise through 9–10°C is said to stimulate spawning (Largen, 1967). The sea temperature at Carnsore usually falls below 9°C between December and March (Fig. 4) but occasional rises as, for example, in March 1977 and February 1978, may be enough to stimulate spawning in a few individuals, especially if the air temperatures are higher. In Yorkshire, there was a main spawning period in April–May and a second spawning in August (Feare, 1970a) but at Milford Haven, S. Wales (Crothers, 1966) and Plymouth (Moore, 1938) some spawning takes place all the year round. If the pattern of spawning observed at Carnsore, i.e. a main breeding season from March to July and some spawning throughout the year, is typical for the region, then it resembles that observed throughout the Irish Sea and Channel localities. Segregation of age groups, reported for an exposed shore population in Yorkshire (Feare, 1970b), was not clearly defined at Q–R and may be a characteristic of exposed shore populations which spend long periods in non-feeding aggregations (Feare, 1970a).

Mytilus edulis agg.

Observations. Length frequency analysis of monthly collections from both upper and lower mussel zones indicated strong recruitment in the period May–July in 1977 (Fig. 20) and also in

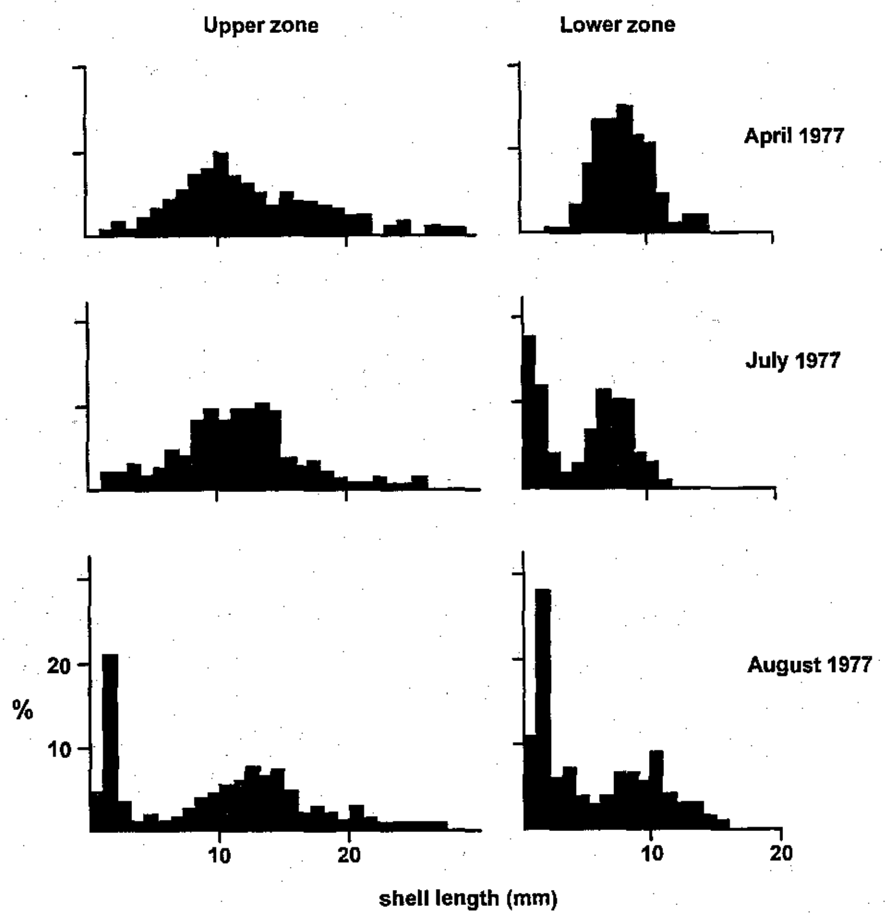

Figure 20. *Mytilus*. Size distribution of mussels from upper and lower zones at Carnsore I in three months of 1977 showing differences in the population structure and the timing of recruitment in the two zones.

1978. Recruitment began in the lower zone in May at a shell length of 1–3 mm and recruits increased in number until July. By September, the new cohort dominated the lower shore population. The onset of recruitment into the upper zone was more difficult to detect but was apparent by late summer in both 1977 and 1978. Recruitment was particularly strong at Carnsore, and also at Hook Head, in 1977, resulting in blanket coverage of the lower shore, but was less successful in 1978 and appears to have failed almost completely in some years.

At the time of the Carnsore Point investigation, it was considered that, prior to colonising the adult beds, mussels went though two pelagic phases. Settlement from the plankton occurred on filamentous substrates such as algae and hydroids, followed by a period of growth before arriving on the adult beds (see McGrath and King, 1991 for a review). Recruitment to the adult beds involved a second pelagic phase termed byssus drifting or byssopelagic migration. Thus, mussels less than 500 μm would not be found in the adult beds. However, later, McGrath *et al.* (1988) showed that mussels settled directly on adult beds without the second phase of growth and migration in Galway Bay, and McGrath and King (1991) showed that this occurred widely on the lower shore of exposed coasts. In the 1977–1978 study at Carnsore Point, mussels of settlement size were not searched for and so may have been overlooked. Thus, no comment can be made on settlement patterns. McGrath and King (1991) found no individuals of direct settlement size in their study at Carnsore Point.

Discussion. All Irish populations studied to date display spring and summer spawning peaks but spawning can extend over a considerable part of the year (Seed and Brown, 1975; King *et al.*, 1989). In some parts of Britain, in contrast, populations may spawn only in a restricted period, in spring or spring and summer (Seed, 1976; Lowe *et al.*, 1982).

Lasaea rubra

Population dynamics and reproduction of the population in *Lichina pygmaea* at I during the period August 1976–July 1978 have been described (McGrath and Ó'Foighil, 1986). The mean density in *Lichina* was 4608 dm^{-2}. Probability analysis of length frequency suggested the presence of 2–3 major year classes with few individuals entering their fourth year. Brooding was observed in the dense population inhabiting *Lichina* from May to August 1977, with a peak in July. Juveniles first appeared in the population in July at 0.5–0.7 mm. By August, juveniles comprised 49% of the population and the 0^+ class remained distinct throughout the year. The class reached 1.2 mm in 12 months but there was little growth in winter.

The brooding period at Carnsore (May–October) is similar to that described for Plymouth (May–November) and the time of juvenile release and size at maturity are the same (Oldfield, 1963). A similar recruitment period was recorded in Co. Down, Ireland (Seed and O'Connor, 1980).

Depositing shores

Depositing shores dominate the Wexford coastline offering a wide range of habitats from the fine muds and salt marshes of Wexford Harbour, Bannow Bay and the Cull Inlet, through sandy beaches to the coarse sands and gravels bordering the south and east coast barriers. Some casual collecting was done in representative examples of each of the habitats (see "Methods" and Fig. 1 for sampling localities), but quantitative sampling along transects, and more intensive sampling of fauna at low water, were only carried out at five beaches: Rosslare Point, Rosslare Harbour, Carne, Carnsore (Nethertown), and Kilmore Quay, and monthly sampling was only attempted at Carne and Carnsore.

Faunal records

Table 3 lists all species recorded from beaches, mud flats and salt marshes, including supralittoral driftline fauna, species taken by sweeping, beach-seining or push-netting at low water, and strandings. Among the 196 species listed, 121 were not taken on rocky shores. Levels of identification varied considerably, generally according to the size of the organisms. Records of Copepoda and Acari, for example, are for one or two collections only, the former from Kilmore Quay, the latter from Carnsore and the Drinagh salt marsh. Some records of fish are taken from the unpublished work of Mansoor (1982) which compared

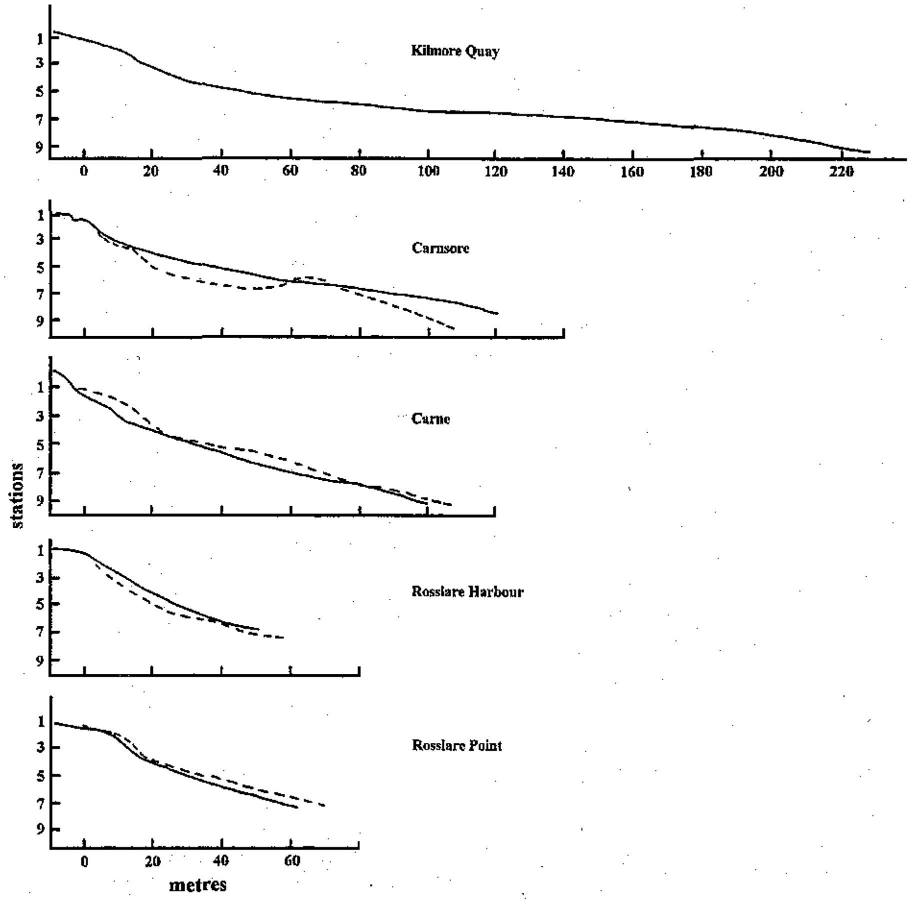

Figure 21. Seasonal variation in topography of the five sandy beaches surveyed. For Kilmore Quay, only a September profile was available; for other sites, the solid line shows the profile in winter–spring, and the broken line that in July–August. Stations 3 and 5 are approximately HWN and LWN, respectively.

juvenile flatfish occurrence at a number of beaches on the east coast.

Sandy beaches

The five beaches at which transectal studies were carried out form a series which reflects increasing exposure from Kilmore Quay, protected by the harbour walls and offshore shoals, to the unprotected point of the Rosslare spit. Differences in the degree of exposure are seen in the width of the beaches (Fig. 21), and median grain size (Table 4), as well as their faunal communities (Table 3). The critical median grain size of 232 µm, which in Scotland separates sheltered beaches characterised by a rich, burrowing fauna, including many polychaetes and bivalves, from exposed beaches dominated by swimming crustaceans (Eleftheriou and Nicholson, 1975), is not applicable to the Wexford localities. Examination of Table 3 shows that Kilmore Quay, with a median grain size of 136 µm, has a typical sheltered shore fauna but that Carnsore and Carne, with median grain sizes of 147 µm and 200 µm, respectively, lacked bivalves, or they were extremely rare, and their faunas are typical of more exposed beaches.

The lack of a consistent relationship between slope, particle size and exposure led McLachlan (1980) to devise an exposure index based on a range of physical and biological parameters (see Methods). An attempt has been made to apply this scheme to the five Wexford beaches. However, scores for some parameters could only be approximations because they were based on only a few observations of characteristics which varied seasonally or unpredictably such as wave action, width of the surf zone, and median particle diameter. The author recommends using data from the middle shore but on beaches where deposits are poorly sorted and frequently mobile, an average for a wider section of the beach was considered more appropriate. The following ratings are conservative:

	Score (max. 20)	Beach type
Kilmore Quay	6	very sheltered
Carnsore	7	sheltered
Carne	9	sheltered
Rosslare Harbour	13	exposed
Rosslare Point	13	exposed

Some beach type ratings are lower than those adopted by most authors in western Europe who would consider Carne and Carnsore to be exposed. Subdivisions of the categories might be appropriate at a local level.

The beach deposits also showed differences in the degree of sorting, which tended to be poorer at the more exposed localities. However, the sorting indices in Table 4 can only be taken as rough guides to the differences between the beaches because sorting changes according to the amount of wave action and values calculated for the same position on a beach before and after storms or, in different seasons, can be quite different. On all the beaches studied, there were laminations of coarse material which appeared at the surface occasionally following scouring of the surface sand, giving a poorly sorted surface layer. At such times, there could be wide differences in sorting between different parts of the same beach (e.g. Rosslare Harbour, Fig. 22). An example of the way grain sizes at a given point on a beach can change rapidly is shown by grain size distributions for 3 successive months at Carnsore where the sorting index for the

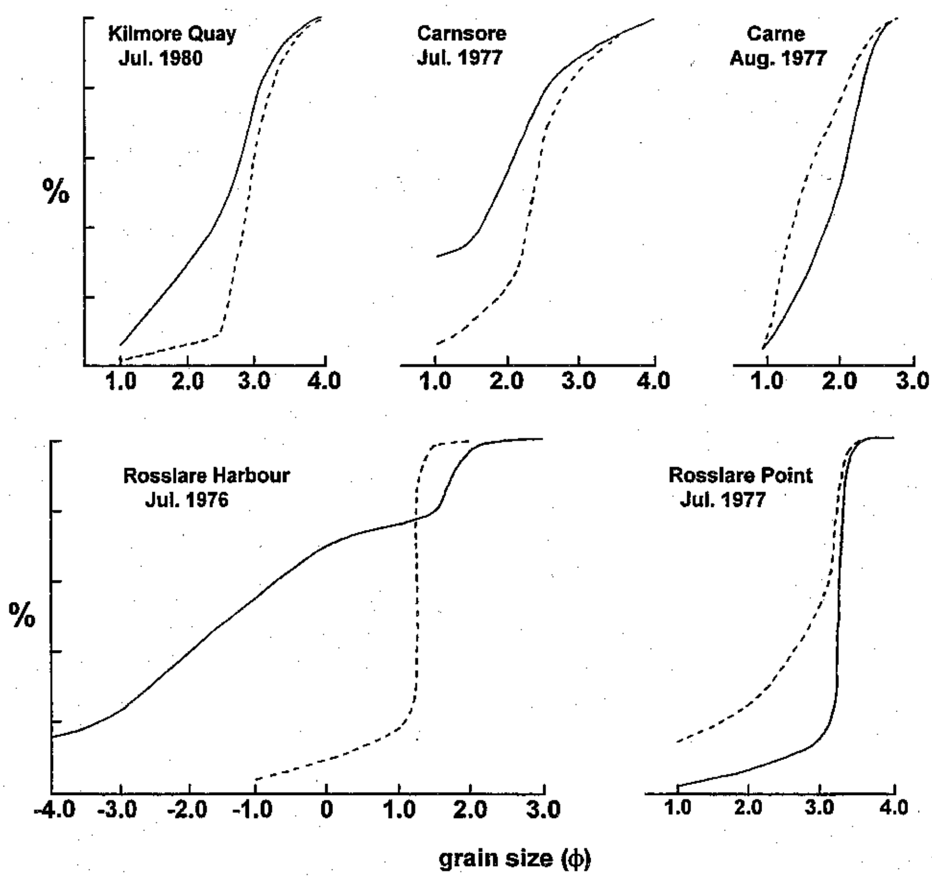

Figure 22. Grain size distribution at five beaches in SE Wexford. Solid lines – samples from around HWN; broken lines – samples from around LWN.

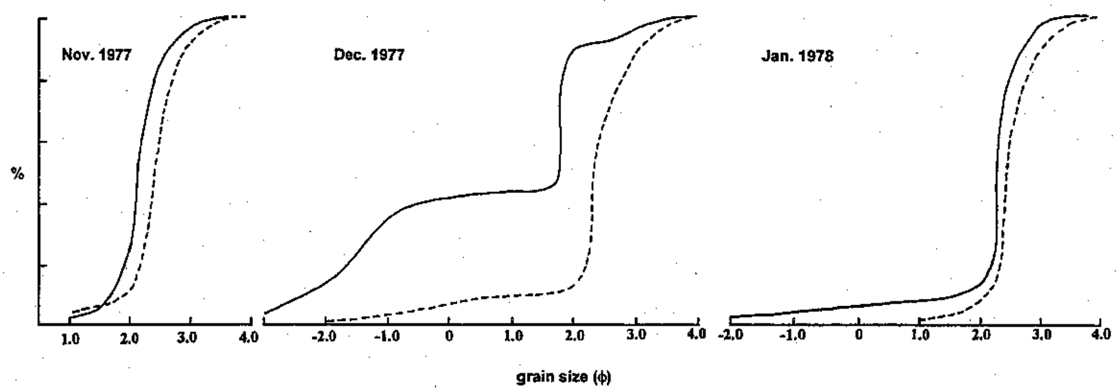

Figure 23. Variation in grain size distribution in three successive months at Carnsore. Solid line – around HWN; broken line – around LWN.

top 15 cm of sediment at station 3 (roughly HWN) changed from 0.41 (well sorted) in November 1977 to 2.01 (poorly sorted) in December and 0.51 (moderately well sorted) in January 1978 (Fig. 23). Single analyses, therefore, can be meaningless when it comes to assessing the effects of sorting on fauna unless both sorting and faunal parameters are studied at the same time. The presence of coarse material also tended to disrupt the redox potential discontinuity (RPD) by improving drainage, and a distinct RPD was only apparent in sand without gravel.

Beach profiles underwent seasonal changes as a result of cut and fill processes, the low, spilling breakers in summer depositing sand on the middle shore which built up into banks, and the steeper, plunging breakers associated with winter storms scouring the sediment away to give evenly sloping beaches (Bird, 1984). The terminology used in descriptions of beach topography follows McLachlan (1983) where the term berm is reserved for the ridge above HWS, the intertidal banks are called bars and the depressions troughs. The classic summer and winter profiles were most apparent on the more exposed beaches where a bar developed just below MTL during prolonged calm weather in summer, with a trough above it which became progressively deeper, sometimes forming pools or even longshore channels. The scouring of the bar in winter was evident at Carnsore where the summer sand level on mid-shore rocks, marked by a blackening of the rock, was up to 30 cm lower in winter. The displacement of such large quantities of sand tended to expose deep layers of gravel (Carnsore), gravel and stones (Rosslare Harbour and Rosslare Point), shell debris (Rosslare Harbour), or even peat (Carne and Carnsore).

Extreme variation in sampling frequency and intensity make it difficult to compare faunal assemblages in the five beaches reliably, but it is apparent that the infauna was more diverse at Kilmore Quay, the only beach where bivalves were common, and that pelagic Crustacea were especially well represented at Carnsore, possibly because the adjoining boulder shores provided abundant, floating organic debris. The high densities of sand-dwelling Amphipoda recorded at Carne and Carnsore (see accounts below) are characteristic of exposed beaches and were much lower at Kilmore Quay. Increasing exposure was also reflected in the changing proportions of amphipod species from Kilmore Quay to Rosslare Point with *Pontocrates* becoming relatively more frequent on the more exposed beaches. Counts of *Arenicola* casts, which theoretically can give an indication of the amount of organic matter in the sand, varied widely from month to month and could not be used to assess differences in organic content between beaches. All but the most exposed beaches are nursery grounds in summer for juvenile flatfish, mainly plaice but with sole, brill and turbot becoming more frequent with increasing exposure (Mansoor, 1982). Shrimp (*Crangon crangon*) were also common on all the beaches sampled, especially in summer (Healy and McGrath, 1988).

Kilmore Quay beach

This small beach, lying just east of the old harbour wall, stretches approximately 75 m eastwards before giving way to boulders associated with St. Patrick's Bridge, and was the most sheltered of those investigated. It lies immediately below the village of Kilmore Quay and at the time of the surveys was protected by a low harbour wall to the west (now replaced by a much larger pier) and by the St. Patrick's Bridge shoal to the east which projects seawards in a south-westerly direction. HWS, marked in summer by a small amount of tidal debris, lies close to a sea wall. Evidence of the sheltered conditions was seen in the long gentle profile, reaching to more than 200 m at LWS, a median grain size of 136 μm (very fine–fine sand) and moderately well sorted sediments with a modal grain size of 2.5–3.0 ϕ on the upper half of the beach and 3.0–3.5 ϕ on the lower half. The silt–clay fraction was negligible (dry sieving), however, even towards low water. The RPD was at 50 cm on the upper shore but was close to the surface at MTL and on the lower shore. In contrast to the more exposed beaches, there was no significant difference between summer and winter profiles and conditions appeared to be dissipative.

Fauna. Two transects were sampled in October and November 1976, and one in summer 1980. The fauna was typical of sheltered beaches with a predominance of polychaetes and bivalves and a relative scarcity of amphipods below MHWN. A dense talitrid zone (only *Talitrus saltator* was identified) at HWS was followed by zones of *Lumbricillus viridis* and *Marionina subterranea*, the latter replacing *M. preclitellochaeta* which was dominant at this level on exposed beaches. Two peaks of *Bathyporeia* could be distinguished, but numbers were low in comparison with exposed beaches (see amphipod studies). In 1980, when a 1-mm sieve was used, *B. pilosa* reached a peak density of 48 m^{-2} at around HWN, and a mixed population of *B. pelagica* and *B. guilliamsoniana* a peak of 50 m^{-2} at around LWN. *B. guilliamsoniana* was infrequent on other beaches. *Pontocrates altamarinus* was present but *Haustorius arenarius* was not recorded. Polychaetes were common, especially *Capitella capitata* (maximum density 29 m^{-2} near HWN), *Scoloplos armiger* (maximum density 103 m^{-2} just below MTL), and *Pygospio elegans* (maximum density 57 m^{-2} near LWS) (these estimates for 1980). Among the 19 polychaete species recorded (Table 3) are some possible accidentals which may have originated among nearby rocks.

The most numerous bivalves were *Angulus tenuis* and *Fabulina fabula*. In October 1976, both were present from about MTL but *A. tenuis* reached a peak density of 165 m^{-2} at around LWN and *F. fabula* a peak density of 136 m^{-2} at LWS. Only one adult *Cerastoderma edule* was found but spat were common. *Macoma baltica* was present in low numbers on the upper beach and a few specimens of *Mysella bidentata* were taken near LWS. Few low water sweeps were taken at this locality and there are no records of fish.

In July 1976, a red tide caused mortality of *Arenicola* and some other species on this and other south coast beaches (for details see Ottway *et al.*, 1979). Faunal estimates for subsequent months may not, therefore, be representative.

Carnsore beach

Description. The beach lies between two boulder fields, one at the north end of the Carnsore sheltered shore, the other extending south from Crossfintan Point. Scattered rocks and boulders are present on the beach and the algae growing on them, and on adjacent shores, contribute to the rather high organic content of the sand, seen in the intensity of the sulphide layer and its proximity to the surface on the lower shore. A thick wrack bed forms seasonally at the south end of the beach where there is easy access for vehicles and where it is harvested for fertiliser. The beach is approximately 400 m long and its maximum width, from HWS to the lowest level observed when sampling, was 140 m.

At the top of the beach is a grassy bank, and below it a line of stones and boulders in which tidal debris collects which corresponds approximately to HWS. At most times the beach surface was composed of a medium sand (mean Md 147 μm), but there were laminations of gravel (grain sizes 1–8 mm) and small amounts of peat which appeared seasonally on the upper shore at the surface, chiefly in summer, and at such times samples could be very poorly sorted ($\sigma\phi$ 2.0 or more). Observations made in 1978 indicated that a significant component of gravel near the surface on the upper half of the beach persisted throughout most of that year. In summer, a bar formed just below MTL and a moist trough above it which became progressively deeper from June to August. From September, the beach flattened out and the bar and trough disappeared, although gravel appeared at the surface periodically. The same cycle of seasonal change was observed in the 3 years of our observations.

Fauna. Monthly sampling along a transect was carried out from January 1977 to January 1978 (see "Observations on some amphipods of sandy beaches" for details). The infaunal assemblage of the sand was typical of an exposed beach with a predominance of amphipods, relatively few polychaetes, and a complete absence of bivalves. A talitrid zone was only recognisable on the beach proper in certain months, mainly in summer; at other times the sand at HWS had eroded away and the sea washed over the boulders during spring tides and even broke over the grassy bank so that talitrids retreated into the boulders or grass. One specimen of the centipede, *Necrophloeophagus longicornis* was taken in the talitrid zone. Enchytraeidae were abundant near the high water mark with *Lumbricillus viridis* forming a distinct zone just below HWS and *Marionina preclitellochaeta* a narrow, low density zone just below it. Two species of *Bathyporeia* were dominant between HWN and LWN, *B. pilosa* being mainly concentrated on the upper and middle shore and *B. pelagica* on the lower shore, but with the two distributions overlapping (see amphipod studies). *Haustorius arenarius* occurred mainly in the middle zone, while *Bathyporeia guilliamsoniana* and *Pontocrates altamarinus* were occasionally found in sand near low water, and cumaceans were frequent when particulate organic matter was mixed with the sand.

The fauna taken in sweeps at low water was notable for the abundance and variety of mysids. Twelve species were taken here, seven in one sample. The influence of neighbouring rocky shores was seen in the frequency of *Lipophrys pholis* in samples and in the occasional presence of gastropods such as *Lacuna vincta* and *Gibbula cineraria. Pleurobranchus pileus* and *Sepiola atlantica* were frequent in late summer. Species recorded here but not on other beaches included *Hippolyte varians, Praunus inermis, Praunus flexuosus, Buglossidium luteum* and *Pleuronectes flesus.*

Carne beach

Description. The beach extends for approximately 800 m northwards from the Carne harbour wall to a boulder field at a small headland. It is backed by high, steep-fronted dunes which showed some evidence of erosion. The sand surface was generally clean and any algal debris mainly collected at the south end of the beach. Transectal and other studies were carried out at a point about half way along the beach.

The medium sand (mean Md 200 μm) was well sorted (about $\sigma\phi$ 0.45 at all levels) (Fig. 22) with few stones or laminations of gravel, although some underlying peat was occasionally exposed. The modal grain size changed little during the 13 months of our survey and was generally 1–1.5 ϕ, falling to 1.5–2.0 ϕ on the upper shore in October. In winter, the beach was steeper than at Carnsore so that station 8 was only 80 m or less from the dune face. In summer, the width of the beach increased to 140 m and at the same time a small bar developed between HWS and HWN and a larger one below MTL. A moist trough formed at or just below MTL which gradually deepened and by August there were sometimes shallow pools at this level. The organic carbon content of the sand, estimated by the wet oxidation method of Walkley-Black, was <0.07% throughout most of the beach, but reached 0.09% near the harbour pier.

Fauna. Monthly sampling along a transect was carried out from January 1977 to January 1978 in parallel with sampling at Carnsore and using the same methods (see "Observations on some amphipods of sandy beaches" for details). Amphipoda formed the bulk of the infauna, as at Carnsore, but numbers were somewhat lower, possibly because there was less organic matter. A talitrid zone containing both *Talitrus saltator* and *Talorchestia deshayesi* could usually be distinguished on the beach but high tides and waves sometimes caused the talitrids to retreat into the dunes. Dipteran larvae were frequent here and could sometimes be seen moving on the sand surface. The oligochaete zone was represented by *Marionina preclitellochaeta* only. *Bathyporeia pilosa* and *B. pelagica* were the dominant amphipods below HWN, the latter more abundant in the samples analysed than at Carnsore. *Pontocrates altamarinus* also appeared to be more frequent here and occurred to a higher level on the shore (station 5). The most frequent polychaetes were *Megalocerus fuliginosus* and *Capitella capitata* but numbers of both were low. One specimen of *Angulus tenuis* was found.

Mysids were the dominant group taken in sweeps and push-net samples at low water with *Siriella armata, Schistomysis parkeri* and *S. spiritus* particularly abundant, but several of the species taken at Carnsore were not recorded at Carne (Table 3). Fewer species of Cumacea were also recorded here. Juvenile plaice appeared in May and *Pleurobranchus pileus* and *Sepiola atlantica* in late summer, as at Carnsore. Species not recorded on other beaches include *Limanda limanda, Ampithoe gammaroides* and *Urothoe brevicornis.* A single specimen of the broadnosed pipefish *Syngnathus typhle* was taken in 1980 (Douglas, 1989).

Rosslare Harbour beach

Description. The area sampled lies just east of the car ferry pier, at the west end of a beach which stretches, with increasing amounts of rock, to Greenore Point. The high water mark was situated below a bank of low dunes. In both summer and winter there were moderate amounts of fucoid debris, probably derived from the harbour pier, which had become buried in the sand at HWS to form a raised strandline. The beach was narrow, only about 50 m from the strandline to MLWS, with a tidal range at medium springs of only 2.6 m. In July 1976, the upper part of the beach was rather steep, flattening out below MTL, but in March 1977 the entire beach sloped evenly.

A feature of this beach was the large amount of stones, gravel and shell debris (chiefly mussels) which occurred patchily at or near the surface on both sampling occasions. The upper part of the beach was very gravelly with small stones on the surface and there were beds of shells near the high water mark and also, in March, near low water. Well-sorted, medium sand (mean Md 315 μm) was present only on the lower parts of the beach, samples from the upper and middle regions being poorly sorted ($\sigma\phi$ 2.3) with a mean Md of about 400 μm. Obviously, grain size distributions here would have varied according to the part of the beach sampled, season, recent storms, etc. and values for most of the beach might not be representative of long-term trends. The curves in Fig. 22 were constructed from samples which avoided the coarsest material.

Fauna. Quantitative sampling at 40-cm vertical intervals along a transect was attempted in July 1976 but the samples were not fully analysed. Talitrids were very abundant at station 1, near the strandline, and also at station 2. Below this zone was a narrow band of *Lumbricillus viridis* and below it a dense zone of *Marionina preclitellochaeta. Bathyporeia pelagica, Pontocrates arenarius* and polychaetes (*Arenicola* and unidentified species) formed the bulk of the fauna on the middle and lower shore. Sweeps at low water yielded four species of Cumacea and five species of Amphipoda but only four species of mysids. No beach-seining was done here and there are no records of fish. Species taken at this locality which were not recorded on other beaches were *Pseudocuma longicornis* and *Perioculodes longimanus.*

Rosslare Point beach

Description. The section of beach sampled was situated about 500 m from the tip of the Rosslare spit and was chosen because there were no wet hollows. The area was backed by low dunes and there were no rocks in the vicinity. Fragments of *Ruppia* sp. and *Zostera marina* L. on the beach indicated a possible influence of water from Wexford harbour. In August 1976, there was a damp trough below the strandline and a small bar above HWN, below which the beach sloped evenly to low water at about 80 m from the high water mark. The depression and bar were not present in March 1977 when the beach displayed a flatter winter profile.

The upper shore sand was coarse (mean Md 270 μm) and well sorted ($\sigma\phi$ 0.30), but the middle and lower shore were stony, with coarse, shelly sand, becoming moderately sorted ($\sigma\phi$ 0.83) towards low water where the mean Md was 400 μm.

Fauna. A transect was sampled at 40-cm vertical intervals in March 1977. A broad talitrid zone encompassed station 1 near the strandline, and also station 2 as at Rosslare Harbour. Enchytraeids were uncommon, however, and did not form a distinct zone. The macrofaunal density from HWN to LW was low, reaching a peak density of 309 m^{-2} at around MTL. *Bathyporeia* were less frequent than on other beaches and the dominant species were *Haustorius arenarius, Pontocrates altamarinus* and *Eurydice pulchra.* There were a few unidentified polychaetes and only one specimen of *Angulus tenuis* was found. No *Arenicola* casts were seen. Shells of *Donax vittatus* were frequent but no live individuals were found. Sweeps at low water did not yield any species not present at other beach localities.

Coombe beach

The gravel beach which fronts the Coombe barrier was sampled qualitatively at its eastern end where thick beds of decomposing kelp accumulated. It consisted of a steep intertidal zone composed of sand and gravel, about 30 m in width, and a gently sloping back shore, much of it shingle, of about the same width. The profile of the latter underwent extensive seasonal change, and also more permanent changes resulting from gravel extraction in the area. The sand at the top of the beach was lowered by at least 1.6 m during 2 years of our observations while Carter and Orford (1980) estimated that the shoreline retreated by up to 8 m over a 1.5 km stretch between 1978 and 1980. The rotting algae at the high water mark and on the back shore provided food for large populations of dipteran larvae, which were in turn consumed by birds, and numerous beetles and enchytraeids. *Enchytraeus albidus* and *Lumbricillus rivalis* were abundant among relatively fresh material but the greatest enchytraeid diversity was to be found in gravel mixed with drier, more decomposed algae from which nine species were identified, including *Marionina arenaria* for which this is the type locality (Healy, 1979b). Unidentified copepods and beetles were also common within the gravel. *Talitrus saltator and Talorchestia deshayesi* were abundant in the sandier regions. *Idotea baltica* was sometimes very abundant on algae floating at the edge of the sea, and appeared to attract flocks of feeding gulls.

Bannow Bay

The east shore of Bannow Bay contained the only bed of marine cockles (*Cerastoderma edule*) known to us outside Wexford Harbour, and also the only sward of *Zostera noltii*. *Abra tenuis* and *Retusa obtusa* were taken from among *Zostera.* A mussel bed on the east shore of Bannow Bay was remarkable for the abundance of *Elminius modestus* on the shells; this is the only known locality in Co. Wexford where the species was common.

Other beaches

One live specimen of *Spisula solida* was found in the coarse sand of Ballyteige beach, just west of Forlorn Point, and *Idotea baltica, Eurydice pulchra* and *Gammarus locusta* were common here in net sweeps. Sweeps at Pollshone contained six species including *Gammarellus angulosus* and *Bathyporeia elegans*. *Eurydice pulchra* was common in sweeps at Raven Point and some live *Cerastoderma edule* were found. The presence of numerous cockle shells on other beaches, e.g. the west side of the Rosslare spit, suggests that the species is common in Wexford Harbour. Wooden groynes on Rosslare Strand were riddled with burrows of the gribble *Limnoria lignorum* and a few live specimens were obtained.

Mud flats and salt marshes

The only mud flats sampled were in the Cull inlet where *Corophium volutator, Hediste diversicolor* and *Hydrobia ulvae* were common and at Woodtown on the south shore of Wexford harbour where *H. ulvae* and *Macoma baltica* were recorded.

A small area of salt marsh at Bannow Island contained numerous *Alderia modesta* and *Limapontia depressa* in March 1977 and *Paragnathia formica* was present in a creek bank.

The salt marsh near Drinagh, which is a remnant of the former extensive marshes drained to form the South Slob, consisted of a "general salt marsh" sward and drainage creeks. *Phytia myosotis* was common among the vegetation, and *Paragnathia formica* in the banks of creeks. The mites *Oolaelaps sellnicki* and *Arctoseius ibericus,* taken from the marsh surface, were new Irish records.

An area of poorly developed salt marsh, grading to mud flats, on the south side of Wexford Harbour yielded *Alderia modesta, Lekanesphaera rugicauda* and *Leptocheirus pilosus.* Together with the channels of the North Slob, this is the only known Irish locality for the latter species.

Strandings

Stranded fauna included *Rhizostoma octopus* and *Aurelia aurita* at Carnsore, *Chrysaora hysoscella* at Carne, *Limnoria lignorum* in driftwood at Carne and *Limnoria quadripunctata* on Coombe beach, *Eledone cirrhosa* at Curracloe, *Lepas anatifera* and *Lepas pectinatus* on Coombe beach, and *Lepas anatifera* alone at Carnsore. In October 1977, large numbers of *Velella velella*, including both right- and left-handed individuals, were washed ashore at several points around Carnsore Point, and on the Carnsore and Carne beaches (McGrath, 1985).

Observations on some amphipods of sandy beaches

Methods

Monthly samples were taken along transects at Carnsore and Carne, at the same position on each occasion, from January 1977 to January 1978. Sampling stations were at 20-cm vertical intervals except for 1–2, 7–8 and 8–9 which were 40 cm apart. Stations were fixed on each occasion by levelling against a temporary benchmark, on a rock at Carnsore, the harbour pier at Carne. Station 1 at Carnsore was situated just below the strandline boulders at the start of the project but in some months had shifted above them as the sand eroded away and it was only possible to take sand samples at this station on a few occasions. Samples were taken from the same vertical level on each occasion but not necessarily from the same position. On both beaches, MHWN was in the region of station 3, MTL at around station 5, and MLWN near station 7. Preliminary sampling to establish vertical distribution of the fauna indicated that *Bathyporeia* spp. were concentrated in the top few centimetres. Six 1944 $cm^2 \times 5$ cm samples were taken at each station.

Results

Bathyporeia spp. at Carne and Carnsore

No attempt was made to distinguish the two species in monthly transect samples. Identification of exploratory collections made at Carnsore in May 1976 indicated that *Bathyporeia pilosa* alone was present on the upper shore but that both *B. pilosa* and *B. pelagica* occurred on the middle and lower shore, the proportion of the latter increasing towards low water. Both species became infrequent below station 7. At Carne, in contrast, *B. pilosa* was confined to the upper shore and *B. pelagica* was more abundant than at Carnsore, reaching its highest density at around MTL and extending upshore in low numbers to station 4. *Pontocrates altamarinus* also appeared to be more frequent here than at Carnsore. Partial replacement of *B. pilosa* by *B. pelagica* with increasing exposure, and also an increasing importance of *Pontocrates* spp. demonstrated by the different proportions recorded at Carnsore, Carne, Rosslare Harbour and Rosslare Point, indicate that the few samples analysed gave a true picture of the differences between the Carne and Carnsore beaches. However, it cannot be assumed that the proportions and relative distributions of the two species were the same, and remained unchanged, throughout the study period.

At Carne, the mean density of *Bathyporeia* spp. from stations 2 to 8 fluctuated seasonally reaching its highest, 1266 m^{-2}, in June and its lowest, 237 m^{-2}, in September (Fig. 24). Peak densities occurred between stations 3 and 6A, the highest recorded being 6,670 m^{-2} at station 5 in June (Fig. 25). The population increased slowly from January to April suggesting either a low level of breeding and juvenile release or, possibly, recolonisation from an offshore section of the population. A major increase in overall density occurred in June, to be followed by a gradual decrease in subsequent months. There were indications in February–April, and in January 1978, of two populations, one centred above and the other below MTL, which may have belonged to different species, but from May to December, only one peak was evident, situated below MTL. During May–August, highest densities occurred in the moist trough region, the population moving upshore in September when the beach profile flattened out.

At Carnsore, densities of *Bathyporeia* were somewhat higher than at Carne, the mean density from stations 2 to 8 varying between 431 m^{-2} in June and 2950 m^{-2} in November (Fig. 24). Peak densities occurred between stations 3A and 6, the highest recorded being 7860 m^{-2} at station 5 in September (Fig. 25). The pattern of seasonal change in density and distribution shows a number of differences when compared with that at Carne. Changes in mean density point to a later main breeding period in late summer but comparison with seasonal trends at Carne suggests that breeding may have started earlier but was offset by mortality caused by environmental changes. At

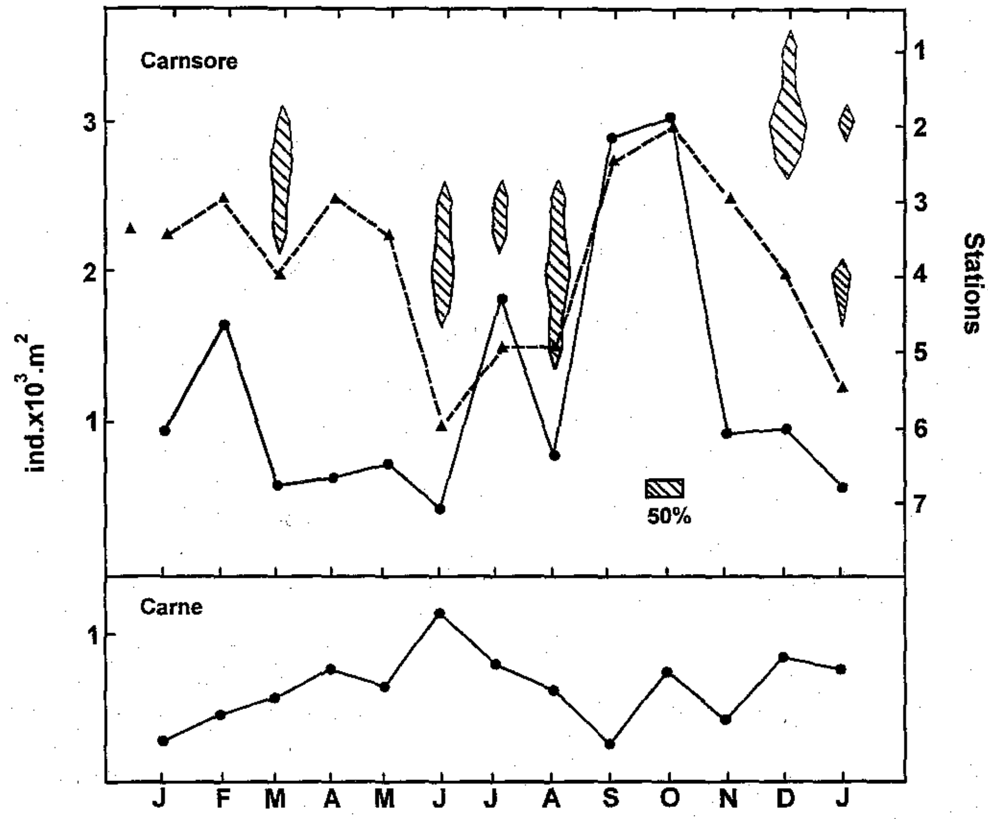

Figure 24. Seasonal changes in total density of *Bathyporeia* species at Carnsore and Carne in 1977–1978 (mean of stations 2–8), and the incidence of coarse sediment at Carnsore. Solid line – density of *Bathyporeia;* broken line – upper limit of density >500 m^{-2}; hatched areas – proportion of particles > 500 µm. No coarse sediment was present in Carne samples.

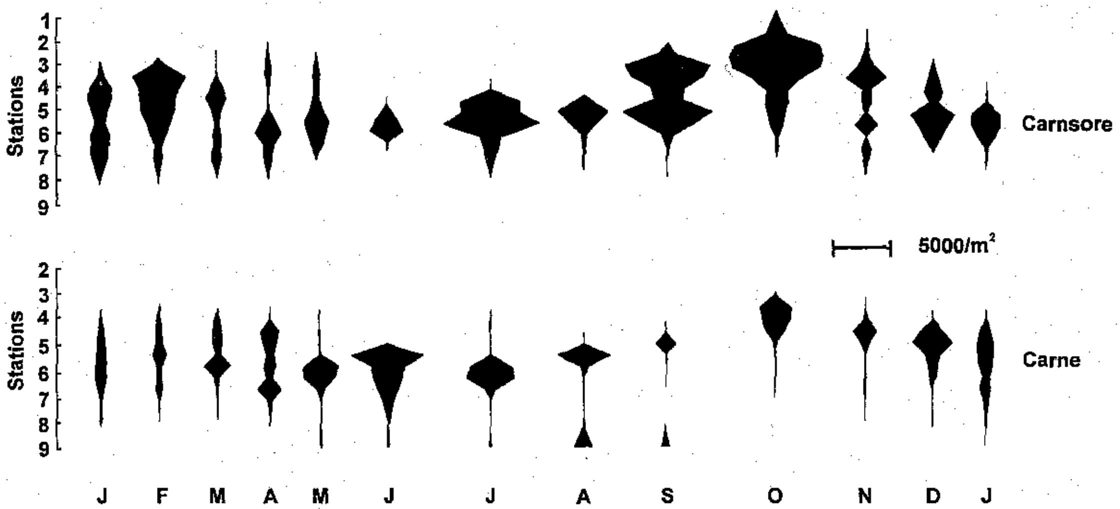

Figure 25. Seasonal changes in the distribution and density of *Bathyporeia* species on Carne and Carnsore beaches in 1977–1978.

a time when the population density at Carne reached its peak, it fell to its lowest level at Carnsore (Fig. 24). Decreases in population density on this beach in April, June and August, and again at the end of the year, occurred above MTL and coincided with changes in the nature of the surface sediment of stations 2–4A as gravel beds were exposed. The proportion of particles 500 μm or more at station 4, for example, increased from 8.5% in May to 43% in June, 18.5% in July and 51% in August, falling again to 15% in September (Fig. 24). Examination of the bar which developed between stations 5 and 6 did not reveal a higher density of *Bathyporeia* than at the stations above or below it, so the loss of individuals was unlikely to have been due to migration and probably occurred on the beach as a whole. Throughout June–August, the remaining population was concentrated in the moist trough between stations 5 and 6, as at Carne, a part of the population extending upshore in September.

Haustorius arenarius

Early sampling showed that, unlike *Bathyporeia* spp., *Haustorius* was not confined to the surface layer of sand but occurred commonly below 10 cm. Density estimates are for the top 5 cm only and are only available for Carnsore where the species had a narrower range than *Bathyporeia* spp., especially in the early part of the year when its upper limit was at station 4A, shifting to 5 or 5A in June–July. Only one specimen was taken in August but relatively large numbers appeared from September when the species invaded the upper shore. The seasonal trends in distribution and population density thus appear to be similar to those of *Bathyporeia pilosa* at this site but there could have been changes in depth distribution which were not observed.

Discussion

Bathyporeia pilosa occurs in moderately exposed beaches and has been recorded on European coasts from the Baltic to Arcachon in W. France; *B. pelagica* has a narrower range and is restricted to Britain and Ireland and northern France (Salvat, 1967). The two species have similar reproductive cycles (Fish and Preece, 1970) but somewhat different ecological distributions. *Bathyporeia pilosa* is more tolerant of high temperatures and desiccation than *B. pelagica* (Preece, 1971). Latitudinal trends in breeding and zonation are chiefly explained by differences in temperature and moisture content of the upper beach deposits. In the northern part of its range, e.g. at Millport, W. Scotland, *B. pilosa* was confined to a narrow zone on the upper shore (Watkin, 1939), but in W. Wales, there were distinct high and low shore populations (Fish and Preece, 1970) while at Wissant in N. France the population was centred around MTL and at Arcachon, W. France, it occurred only on the lower half of the shore (Salvat, 1967). Populations of *B. pelagica* were generally concentrated below MTL at the localities investigated although the population extended above MTL in W. Wales. The distributions of the Carne and Carnsore populations of *Bathyporeia* thus show similarities with those in both W. Wales and N. France.

Bathyporeia spp. are "sand-lickers", depending for food on microorganisms whose growth is promoted by moisture. It is not surprising, therefore, that temperature and moisture limit their distributions. Salvat (1967) noted that although *B. pilosa* could live at higher levels on the shore than other members of the genus, it was principally found in the zones of resurgence and saturation where the moisture content was highest. At Carne and Carnsore, the populations appeared to shift downshore in summer, and peak densities then occurred in or near the moist trough which developed near MTL. A lowering of the upper limit of distribution in summer to levels where emersion times were shorter was also reported in W. Wales (Fish and Preece, 1970).

The effects on *Bathyporeia* of substrate displacement and different grain sizes are not well documented. The species are essentially swimmers with limited powers of burrowing and are confined to the surface layer. They would, therefore, be displaced with their substrate by strong wave action. Normally, they re-establish themselves by rapid swimming as the tide ebbs (Nicolaisen and Kanneworff, 1969) but they are probably unsuccessful at this in rough seas because they are passively swept away in currents greater than 2.5 cm s^{-1} (Khayallah and Jones, 1980). It is not known whether the loss of fine sand from the upper beach at Carnsore, which occurred spasmodically in both summer and winter, was a gradual process or a result of unusually strong wave action. If gradual, as seems likely in summer since it occurred in three successive years, the decreases in *Bathyporeia* populations could have been due to a failure to survive in the exposed coarse sediment rather than passive removal from the beach by the action of waves or currents.

Bathyporeia pilosa breeds continuously in summer, females being capable of releasing young 15 days after oviposition (Watkin, 1939) and producing three or four broods in a season (Powell and Moore, 1991); it is thus capable of rapid population increases. In the Clyde, a breeding population in late April–late September was found to consist of several cohorts, some producing three or four broods in the season (Powell and Moore, 1991). In W. Wales (Fish and Preece, 1970) and N. France (Salvat, 1967), a spring generation gave rise to a second generation in late summer, and at some localities there were two corresponding peaks in density, while in the Baltic three generations have been recorded (Köhn and Sammour, 1990). The absence of observations on breeding at Carne and Carnsore makes any interpretation of seasonal density trends unreliable. The onset and rate of breeding in spring, for example, cannot be determined with any confidence from an increase in density because *Bathyporeia* may move actively or passively offshore in winter (Nicolaisen and Kanneworff, 1983), and their return in spring might coincide with an increase in breeding activity. Comparison of the breeding seasons of a number of populations of *B. pilosa* led Powell and Moore (1991) to conclude that latitude alone cannot predict the life cycle. The different periods of population increase at Carne and Carnsore support this view and demonstrate the strong influence exerted by local conditions.

The concentration of *Haustorius arenarius* at and above MTL was also reported in the Clyde and Yorkshire (Colman and Segrove, 1955) but the species occurred at LW in Devon and Cornwall (Crawford, 1937).

DISCUSSION

A total of 484 taxa (482 species) is recorded, constituting one of the most comprehensive lists of intertidal fauna for the Irish coast. A large proportion are new county records and nine were new Irish records, details of which have been published (with the exception of two species of mites). Some macrofaunal groups were undersampled and require further study, notably Porifera, Nemertea, Gammaridae, Paguridae, Bryozoa and Tunicata. The poor representation of echinoderms, however, is not due to undercollecting but appears to be a feature of the area. Meiofaunal groups were generally ignored, except for Oligochaeta and a few collections of Acari. Mesostigmatid mites were abundant in some intertidal habitats and their ecology merits further study. Carnsore Point is the type locality for four species of Enchytraeidae (Healy 1979b, 1996a; Locke and Coates, 1998), and at least two further oligochaete species on the exposed rocky shore await description, underlining the need for more taxonomic studies, even in these well-studied habitats.

A bias towards habitats on the more exposed open coasts has meant that few collections or observations were made in muddy areas such as Wexford Harbour, the Cull Inlet and Bannow Bay. Only the south-east was sampled intensively and localities on more northerly and south-west coasts received only one or two short visits. The west side of the Hook peninsula in particular has been ignored and deserves investigation.

An assessment of species diversity on the Wexford shores, and comparisons with other parts of the Irish coast, are difficult because there have been few comparable studies elsewhere in Ireland. The fauna of the Wexford rocky shores is certainly richer than that of the Dublin area (authors' observations) but comprises few species which might be considered rare or unusual for the country when compared with, say, the shores of Strangford Lough (Williams, 1954). For example, 167 species of molluscs have been recorded intertidally in Strangford Lough (Nunn, 1994) compared with 84 species in SE Wexford. A lower intensity of collecting only partly explains the smaller number of Wexford records for this group. Comparable areas on south and west coasts with which comparisons might be made (Cork Harbour, Lough Hyne, Galway Bay) contain Lusitanian and western species which are not present in Wexford and are generally considered to be richer. The total number of amphipod species recorded for Carnsore Point (all records, including the sublittoral), is 84, compared with 155 for Galway

Bay and 122 for Dublin Bay (Costello *et al.*, 1989). Not all groups are poorly represented (or recorded) in Wexford however. O'Connor (1980) noted that the polychaete list of 51 species (subsequently raised to 75 by further collecting) was the second largest for the intertidal in the country (after Blacksod Bay) although collections were of a general nature and polychaetes were not specifically sought.

The rocky shore at Carnsore Point represents a transition zone where conditions and communities characteristic of south and west coasts of Ireland meet those more typical of south Irish Sea coasts. The characteristic exposed shore community, with its scarcity of fucoid algae and abundance of mussels and other indicators of wave exposure on British and Irish coasts such as *Chthamalus stellatus, Melarhaphe neritoides, Littorina neglecta* and *Patella ulyssiponensis,* is not to be found anywhere on the east coast south of Co. Down, except in a diminished form on a few headlands. The indicator species listed above, where they exist on the east coast, are much less abundant and their vertical range is much reduced. Southward and Crisp (1954) did not record *Chthamalus* (species not distinguished) below MTL at any locality on the east coast of Ireland between the Giant's Causeway in Co. Antrim and Crossfintan Point in Co. Wexford, although it was commonly found on the lower shore on western and southern coasts. In our survey, the range of *C. montagui* was small and *C. stellatus* scarce at all Wexford localities north of Carnsore M (see Boulder Shores). Similarly, *Melarhaphe neritoides* was generally confined to the splash zone and upper shore on the east Wexford coast. This is its usual range in Britain but the species appears to have a wider range on Irish coasts and has been recorded down to MTL in Co. Cork (Crapp, 1973) and to LWN in Co. Galway (Ryland and Nelson-Smith, 1975). At Carnsore, its range is even wider for, as well as being abundant in the splash zone, it maintains high densities among lower shore barnacles.

Many of the species characteristic of exposed shores in Ireland, including those listed above, are southern species for which the present records fill a gap in the distribution data. South-east Wexford marks the eastern limit of a number of southern species which are common further west, e.g. *Bunodactis verrucosa, Campecopea hirsuta, Cumopsis fagei, Schistomysis parkeri, Monodonta lineata, Gibbula umbilicalis* and *Coryphoblennius galerita,* and algae such as *Cystoseira* spp., all of which are absent or rare north of Rosslare. These and other southern species such as *Actinothoe sphyrodeta, Candelabrum cocksi* and *Hyale perieri* contribute to the high diversity of Wexford shores when compared with shores in the Dublin area. Some other western species do not reach into Wexford, for example *Sabellaria alveolata,* which is abundant at localities on the west coast of Waterford Harbour (authors' observation), and *Paracentrotus lividus* which does not extend east of Cork Harbour.

While differences between communities of southern and eastern rocky shores at Carnsore are apparently associated with variations in wave exposure, and possibly water and/or air temperatures, these may not be the predominant factors limiting species distribution. Crisp (1989) has demonstrated a close correspondence between the distribution of species such as *Chthamalus stellatus, Monodonta lineata* and *Sabellaria alveolata* and the location of tidal fronts in the Irish and Celtic seas. Many of the species which become rare or are absent north of Rosslare reappear, in fact, in south Co. Down in the region of the North Irish Sea front. The reasons proposed by Crisp to explain the correspondence between species distributions and water masses are higher summer surface temperatures in the stratified water of the north-east and western regions which might favour southern species, and differences in nutrient cycling between stratified and mixed waters.

Although the ways in which stratified water favours southern intertidal species are not yet understood, the differences in water quality between stratified and mixed waters, and the particular properties of tidal front waters, appear more likely influences on species distributions than shore topography, which some authors have attempted to correlate with observed geographic ranges. For example, *Monodonta lineata,* which is typically found on sheltered boulder shores, decreases in abundance from Forlorn Point to Crossfintan Point although shores at the two extremes of this gradient are physically similar, and there is evidence that recruitment in the eastern sector is lower and potential life spans longer. The species is absent north of Rosslare although apparently suitable boulder shores are widespread, especially in Co. Dublin, but a substantial population exists at St. John's Point, Co. Down. Higher density and a greater proportion of juveniles on the stony shore of Forlorn Point may be explained by a favourable habitat but the suggestion that absence of the species between S. Wexford and Co. Down may be due to a lack of suitable habitat (Southward and Crisp, 1954; Kendall, 1987) is not wholly convincing for three reasons: (1) differences in relative abundance at E. Wexford localities are not obviously correlated with habitat type; (2) the species was formerly present at localities on the mid-east coast (Fisher, 1935; Stelfox, 1936; Southward and Crisp, 1954) but these populations now appear to be extinct (author's observations), and periods of decline and increase are recorded in Milford Haven (Little *et al.*, 1986); and (3) in SW England, the species has been extending its range eastwards in the past 50 years and its population structure in the new localities indicates that conditions for its recruitment are good (Crothers, 1994). Factors associated with local climate, water quality or current patterns, therefore, appear more likely to limit distribution than physical characteristics of the shore. *Gibbula umbilicalis*, which has similar habitat requirements and reproductive biology to *Monodonta*, appears to be limited in the same way. On the east Irish coast, it becomes infrequent north of Carnsore, occurs at low density in the Dublin area, and is common in south Co. Down.

The physical characteristics and faunal communities of the sandy beaches in the area did not always show the same contrasts between the exposed south and the more sheltered east coasts, being more influenced by local conditions such as the presence of dissipating reefs or shoals and the nature of the local sediment. The species recorded at Kilmore Quay and Bannow Bay were typical of sheltered beaches and those of the four east coast sites, which are unprotected, were typical of exposed beaches, while the sediments fronting the south coast barrier systems were too coarse and mobile to support any significant resident fauna below the high water mark. The relationship between species richness and the degree of exposure to wave action is a universal feature of sandy beaches which is independent of latitude, as is the changing proportion of polychaetes and crustaceans with exposure (Dexter, 1992). Exposed beaches similar to those at Rosslare occur extensively from Raven Point to Cahore and northwards, at intervals, along the whole east Irish coast. Their characteristic fauna, including *Bathyporeia* spp., *Haustorius arenarius, Pontocrates* spp., *Psetta maxima* and *Scophthalmus rhombus,* mostly has a wide distribution on European coasts. Accounts of the fauna of sandy beaches in other parts of Ireland include Donegal (Rees, 1939), Co. Down (Seed and Lowry, 1973), Sherkin Island, Co. Cork (Rees, 1980) and Dublin Bay (Wilson, 1982).

Life history data have been collected for most of the common rocky shore species and this information may be of value for comparison with other geographic regions. In many cases, however, the data are limited to a single annual cycle which could have been atypical due to unusual environmental conditions. One such possible influence is the bloom of *Gyrodinium aureolum* which affected the south coast from Carnsore to Kilmore Quay in the summer of 1977 (Ottway *et al.*, 1979). Although no effects on rocky shore species were observed, a similar bloom in SW Ireland in 1979 was seen to affect a number of rocky shore species and to cause a reduction in the densities of several molluscs (Cross and Southgate, 1980). Any planktonic larvae present in an area at the time of a bloom might be particularly vulnerable.

In spite of relatively small differences in sea temperature between Wexford and more northerly Irish Sea coasts, some species at Carnsore exhibit population structures and life history traits different from those recorded on the west coast of Britain. Many of these are species at or near their geographic limits which may be subject to both adult mortality during adverse climatic conditions and poor recruitment. British populations of many southern species are known to have been depleted by the severe winter of 1962–1963 although no population extinctions were reported (Crisp, 1964). Even the low recruitment rates of many *Monodonta* and *Gibbula umbilicalis* populations were apparently adequate to offset adult mortalities. In Britanny, however, a population of *Monodonta* was entirely extinguished during the same cold winter and the species did not become re-established until 1975 (Daguzan, 1991). In general, geographic limits and the structure of marginal populations appear to be determined more by recruitment rates than by adult survival (Lewis *et al.*, 1982). Populations of species near the northern limits of their range are characterised by large individual sizes, potentially long life spans, short reproductive periods in summer, and frequent recruitment failures (Orton, 1920; Lewis *et al.*, 1982). Examples at Carnsore are *Chthamalus* spp., *Patella ulyssiponensis, Monodonta lineata* and *Gibbula umbilicalis,* all of which were seen to display at least some of these characteristics. Populations near the southern limit of a species range are characterised by smaller individual size and a shorter life span, longer, less well synchronised reproductive periods with some breeding in winter, and few, if any, recruitment failures. Examples at Carnsore are *Littorina littorea* which is a winter breeder, and *Idotea* spp. and *Gibbula cineraria* which were seen to breed to some extent in winter. In these species, winter breeding and a long breeding season, sometimes with the production of more than one brood per female and breeding in late summer by a second generation, indicate a capacity for continuous growth throughout the year, made possible by favourable temperatures. Species which are well within their range may display life cycle traits which vary along a climatic gradient (*Semibalanus balanoides, Patella vulgata*), or these tendencies may be overridden by local influences (*Bathyporeia* spp.).

In terms of marine fauna, this survey has not revealed any areas of exceptional richness or significant populations of species which might be considered rare or endangered. The chief interest of the region lies in the wide range of shore community types, in areas which remain largely natural, situated in a region of transition between south and east coasts. As some of our investigations have shown, both communities and populations display changing characteristics along a gradient from south to east Wexford coasts. The prevailing influences which bring about these changes are not well understood and deserve further investigation.

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Table 1. Species recorded on rocky shores in County Wexford. Abundance categories: A – Abundant, adults generally found in hundreds, present all the year round, likely to be typical of the community everywhere; C – Common, adults generally collected in tens, present all the year round; F – Frequent, common seasonally *or* small numbers throughout the year; O – Occasional, one specimen on several occasions *or* a few specimens on a few occasions *or* large numbers unpredictably; R – Rare, single specimens only *or* a few specimens on one occasion

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Porifera																							
Amphilectus fucorum (Esper)														R									
Aphroceras ensata (Bowerbank)														R									
Clathrina coriacea (Montagu)														O									
Halichondria panicea (Pallas)											C	C		C							F		
Haliclona rosea (Bowerbank)						O								O									
Hymeniacidon perleve (Montagu)						O					O	R		O							O		O
Leucoselenia botryoides (Ellis & Soll.)							O									O							
Scypha compressa (Fabr.)						F												O	F	F	F	R	
Stylostichon plumosum (Mont.)														R									
Cnidaria																							
Actinia equina (L.)	C							C		F	F	C	C	C	O			F	C		C	C	C
Actinothoe sphyrodeta (Gosse)	F					O						F		C					F	C	O		
Amphisbetia operculata (L.)																					F		
Anemonia viridis (Forskål)	O											F	R	F		R					F	O	
Aglaeophenia pluma (L.)					R						R										O		
Bunodactis verrucosa (Pennant)						O					O			C									
Candelabrum cocksi (Cocks)														F							R		
Cereus pedunculatus (Pennant)																					C		
Coryne pusilla Pallas					R	R					O			O		R	R				R		
Diphasia rosacea (L.)																					O		
Dynamene pumila (L.)					C	O	F			O	C	F		C	A	O	O	O	C		C		
Haliclystus auricula (Rathke)					O	O				F					O	O		F	C	F	O		
Kirchenpaueria pinnata (L.)											O								O		C		
Laomedea flexuosa Alder																					C		
Obelia geniculata (L.)																					O		
Plumularia setacea (L.)						O	O				O			O		O							
Sagartia elegans (Dalyell)												F									O	O	F
Sertularella polyzonias (L.)						R						O									O		
Tubularia larynx Ellis & Soll.						O						O		O		O							
Urticina felina (L.)											F	R		O							F	R	
Platyhelminthes																							
Procerodes littoralis (Strøm)														C									
Nemertea																							
Emplectonema gracile (Johnston)									R														
Lineus longissimus (Gunnerus)								R															
Lineus ruber (Müller)									R														
Prosorochmus claparedii (Keferst.)									R														
Tetrastemma melanocephalum (Johnst.)																							R
Polychaeta																							
Alentia gelatinosa (Sars)																					O		
Amblysyllis formosa (Claparède)									R		R							R					
Amphictene auricoma O.F.Müller																		R					

Table 1 ***continued***

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Amphiglena mediterranea (Leydig)						O					O							A					
Amphtritides gracilis (Grube)														R									
Anaitides maculata (L.)														F				O					
Arenicola marina agg.																		R					
Arenicolides ecaudata Johnston																		R			R		
Autolytus prolifera (O.F. Müller)														R									
Brania clavata (Claparède)														F	O			F					
Brania pusilla Dujardin						C				F						F		F					
Caulleriella bioculata (Keferstein)																		R					
Cirratulus cirratus (O.F. Müller)								C	F		O										C		
Eulalia viridis (L.)							R	F	O		F	O		F				O		F			O
Eusyllis blomstrandi Malmgren									F		F	O		F					O		F		
Exogone gemmifera (Pagenstecher)						F				F						F		F					
Fabricia sabella (Ehrenberg)	C					C																	
Flabelligera affinis Sars																					R		
Gattyana cirrosa (Pallas)																					R		
Glycera tridactyla Schmarda														R									
Harmothoe imbricata (L.)														O							O		
Harmothoe impar Johnston																		O			O		
Hediste diversicolor (O.F. Müller)											O							O			O		
Janua pagenstecheri (Quatrefages)														O							O		
Kefersteinia cirrata (Keferstein)						F				F	F	O						F			F		
Lagisca extenuata (Grube)																		O					
Lanice conchilega (Pallas)																					F		
Lepidonotus clava (Montagu)														O							O		
Lepidonotus squamatus (L.)														F				F					
Malacoceros fuliginosus (Claparède)																						O	
Mysta picta (Quatrefages)																		O					
Mystides limbata de St Joseph																		O					
Nereis pelagica (L.)						F		O		F		F						F	R			F	
Nicolea venustula (Montagu)															O				O	O			
Odontosyllis ctenostoma Claparède																		R					
Pholoe minuta Fabricius						F				F						F		F					
Phyllodoce laminosa Savigny														R									
Pionosyllis divaricata (Keferstein)																		R					
Platynereis dumerili Aud. & Milne Edw.						C				C				R									
Polydora ciliata (Johnston)												F						R					
Polydora giardi Mesnil						O	O																
Polyophthalmus pictus (Dujardin)												R											
Pomatoceros triqueter (L.)	O										O							F					
Potamilla torelli (Malmgren)														R									
Scolelepis foliosa (Aud. & Milne Edw.)																		R					
Sphaerodoropsis minutum (Webst. & Ben.)														R									
Sphaerodorum gracilis (Rathke)																		R					
Sphaerosyllis ovigera Langerhans																		O					
Spirorbis corallinae de Silva & Kni. Jones						F				F						O							
Spirorbis rupestris Gee & Knight Jones														O				O					
Spirorbis spirorbis (L.)												F			A						A		
Spirorbis tridentatus Levinsen														O				O					
Syllis amica Quatrefages										O				O									
Syllis gracilis Grube						F			F	F	F			F									
Trypanosyllis zebra (Grube)						O					O			O				O					
Typosyllis armillaris (Müller)																		O					

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Typosyllis krohni (Ehlers)						R								O				O			O		
Typosyllis prolifera (Krohn)						R												R					
Typosyllis vittata Grube																							
Websterinereis glauca (Claparède)																		R					
Clitellata																							
Clitellio arenarius (Müller)													O										
Enchytraeus albidus Henle												R		C									
Enchytraeidae indet.	C								O														
Grania mira Locke & Coates						F																	
Grania pusilla Erséus	O					C		O	O														
Inermidrilus georgei Erséus	F					R		F	F														
Inermidrilus sp.	O					R		O	O														
Lumbricillus bulowi Niels. & Christ.														R									
Lumbricillus lineatus (O.F. Müller)														R									
Lumbricillus pagenstecheri (Ratzel)														R									
Lumbricillus rivalis Levinsen														R									
Lumbricillus semifuscus Claparède	O			A		O		A	C	O													
Marionina appendiculata Niels. & Christ.						R																	
Marionina macgrathi Healy	C			C		F		F	F				O										
Marionina ulstrupae Healy						A		F	O	R		R											
Marionina southerni (Cernosvitov)	R																						
Tubificoides benedii (d'Udekem)									O			R											
Hirudinea																							
Oceanobdella blennii (Knight Jones)														R									
Sipunculida																							
Nephasoma minuta (Keferstein)						C			O	O	O	O				O		O					
Entoprocta																							
Pedicellina cernua (Pallas)						F										F					O		
Copepoda																							
Thersitina gasterostei (Pagenst.)																			O				
Tigriopus brevicornis (O.F. Müller)												A											
Ostracoda																							
Heterocytheris albomaculata (Baird)												R											
Cirripedia																							
Acasta spongites (Poli)														R									
Balanus crenatus Bruguière													O										
Chthamalus montagui Southward	A												C								C	F	A
Chthamalus stellatus (Poli)	A							F					C								A	C	A
Elminius modestus Darwin	R																						
Semibalanus balanoides (L.)	A							C			R	O	A	O						O	A	A	A
Verruca stroemia (O.F. Müller)								R			O			O							R		
Leptostraca																							
Nebalia sp.																					R		

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Cumacea																							
Bodotria scorpioides (Montagu)																		R					
Cumopsis fagei (Bacescu)														R									
Cumopsis goodsiri (Van Beneden)																				O			
Mysidacea																							
Neomysis integer (Leach)												R							F				
Praunus flexuosus (Müller)												R							O				
Praunus inermis (Rathke)												R								R			
Praunus neglectus (G.O. Sars)												R							O				
Siriella armata (Milne Edwards)												R								R			
Siriella jaltensis Czerniavsky												R							R	R			
Tanaidacea																							
Apseudes talpa (Montagu)																			R				
Parsinelobus chevreuxi (Dollfus)							C																
Tanais dulongii (Audouin)					R																		
Isopoda																							
Campecopea hirsuta (Montagu)	F			F																	F		O
Clypeoniscus hanseni Bonnier	O																						
Dynamena bidentata (Adam)														O				O	O		F		
Hemioniscus balani (Spence Bate)	O																						
Idotea baltica (Pallas)												O				O	O						
Idotea granulosa Rathke					C		F			O		C		O	C	O	A	O	F	F	F	F	
Idotea pelagica Leach						F	O	A	O		O										F		C
Jaera albifrons Leach														F									
Jaera nordmanni Rathke														R						R			
Jaera praehirsuta Forsman												O											
Janira maculosa Leach														F				F			O		
Janiropsis breviremis Sars											O			O									
Ligia oceanica (L.)			O	C					F				O										O
Munna kroyeri Goodsir												R		R									
Sphaeroma serratum (Fabricius)									R					F							F		
Amphipoda																							
Amphitholina cuniculus (Stebbing)											O	O											
Ampithoe helleri Karaman												O											
Ampithoe gammaroides (Bate)																							
Ampithoe rubricata (Montagu)						O	F				O	C		O		O			O				
Apherusa bispinosa (Bate)											R			R									
Apherusa cirrus (Bate)											O			O							F		
Apherusa henneguyi Chev. and Fage																							R
Apherusa jurinei (Milne Edwards)										O		O			F			F	C		O	O	
Bathyporeia pilosa Lindstrom																			R	R			
Calliopius laeviusculus (Krøyer)												R		C								R	
Caprella penanti Leach											F			O									
Colomastix pusilla Grube										R				R									
Dexamine thea Boeck														O									
Echinogammarus marinus (Leach)									O					O									
Elasmopus rapax da Costa														C							O		
Eulimnogammarus obtusatus (Dahl)														R									
Gammarus locusta (L.)																F							

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Gammarellus angulosus (Rathke)											C												
Hyale nilssoni (Rathke)			A	A		R			R	R				F	F			F			F		
Hyale perieri (Lucas)									C														
Hyale pontica (Rathke)					F	F				F	F			R		F		O					
Hyale stebbingi Chevreux															O								
Jassa falcata (Montagu)					R									O				O					
Jassa ocia (Bate)														R				R					
Lembos websteri Bate														C				O			O		
Leucothoe spinicarpa (Abilgaard)														O									
Lysianassa ceratina (Walker)														R									
Megaluropus agilis Hoek																		R				R	
Melita hergensis (Reid)														O							O		
Melita palmata (Montagu)					R							R		C	F	F		F					
Microdeutopus gryllotalpa da Costa												R											
Orchestia gammarellus (Pallas)									R														
Pariambus typicus (Krøyer)																		R					
Parajassa pelagica (Leach)					C		F				F	C										O	
Podocerus variegatus Leach											C			C				F					
Pontocrates altamarinus (Bate & Westw.)														R									
Scopleocheirus hopei (da Costa)																							R
Stenothoe monoculoides (Montagu)					R					R	R	C		F	R	R	R	F	O	O	C		
Euphausiacea																							
Nyctiphanes couchi (Bell)												R											
Decapoda																							
Athanas nitescens (Leach)											O			O							R		
Cancer pagurus L.									F					F				O			F		
Carcinus maenas (L.)						R			R		F	F	F	R					F		F		
Caridion steveni Lebour																			R				
Eualus occultus Lebour														R							R		
Galathea squamifera Leach														O									
Galathea strigosa (L.)											R												
Hippolyte longirostris Czerniavsky												R											
Hippolyte varians Leach														O					O				
Hyas coarctatus Leach											R			R									
Inachus phallangium (Fabricius)														R				R					
Necora puber (L.)											R			O							R		
Pagurus bernhardus (L.)														O					O		O		
Palaemon elegans Rathke												F							C				
Palaemon serratus (Pennant)												O							O				
Pilumnus hirtellus (L.)														O				F			R		
Pirimela denticulata (Montagu)												R				R							
Pisidia longicornis (L.)						R					R			O						O	F	R	R
Pontophilus fasciatus (Risso)																			R				
Porcellana platycheles (Pennant)														A							C		
Thoralus cranchi (Leach)											R			R					R		R		
Pycnogonida																							
Achelia echinata Hodge						R								R					R				
Achelia simplex (Giltay)														R		R							
Ammothella hispida (Hodge)																		R					
Ammothella longipes (Hodge)																R		R					

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Anoplodactylus virescens (Hodge)						R												R					
Anoplodactylus angulatus (Dohrn)														R									
Callipallene tiberi (Dohrn)											R												
Nymphon gracile Leach											R	R		O		O			R		R		
Phoxichilidium femoratum (Rathke)											R			R									
Pycnogonum littorale (Strøm)														R							R		
Chelonethi																							
Neobisium maritimum (Leach)									O														
Acari																							
Arctoseioides ibericus (Willm.)				R					R														
Cheiroseius necorniger (Oudmns.)	R																						
Halolaelaps balticus Willm.	R																						
Halolaelaps marinus (Brady)	R																						
Hydrogamasus littoralis G. and R. Can.								C															
Typhlodromus richteri Karg.		O																					
Chilopoda																							
Strigamia maritima (Leach)									R														
Tardigrada																							
Milnesium tardigradum Doyère		R																					
Echiniscoides sigismundi (Schulze)	R																						
Insecta																							
Aleochara algarum Fauvel												R											
Anurida maritima (Guerin)	A	O	F	F					A				C								F	F	C
Cafius xantholoma Grav.												R											
Clunio marinus Haliday	F						F																
Halocladius fucicola (Edwards)												C											
Myrmecomora brevipes Butter												R											
Ochthebius subinteger lejolsi M. & R.												O											
Petrobius brevistylis Carpenter	C																						O
Tipulidae (larvae)				F																			
Xenylla xavieri da Gama		F																					
Polyplacophora																							
Acanthochitona crinitus (Pennant)										R													
Lepidochiton cinereus (L.)														F									
Prosobranchia																							
Alvania semistriata (Montagu)														O						R	R		
Brachystomia scalaris MacGillivray						R																	
Buccinum undatum L.																						R	
Calliostoma zizyphinum (L.)														F				O		F	O		
Chrysallida spiralis (Montagu)															R				R				
Cingula cingullus (Montagu)								O	O												O		
Coriandria fulgida (J.Adams)						R								R			R						
Gibbula cineraria (L.)										F	F	F		C	C				C	C	C		
Gibbula umbilicalis (da Costa)	O												C	C	O			O		O	F	O	O
Graphis albida (Kanmacher)														R									
Helcion pellucidum (L.)					F	F	F			F								O		O	F	O	O

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Hinia incrassata (Strøm)																					O		
Lacuna pallidula (da Costa)					F		O					O		O	F	F	F			O	O		
Lacuna parva (da Costa)																R	R						
Lacuna vincta (Montagu)					C	F	F							O	O		C				F		
Lamellaria latens (Müller)														R						R	R		
Lamellaria perspicua (L.)																					R		
Littorina littorea (L.)	F		O						R		O	O	C	A	F				C	F	A	C	O
Littorina arcana Hannaford-Ellis	F																						
Littorina mariae Sacchi & Rostelli					C	C				O	O	O			A	C	A	O			C	C	
Littorina neglecta Bean	A			C		R		R				C		O								O	C
Littorina obtusata (L.)	F		O											F	A						A	A	
Littorina saxatilis Olivi	A	O	A	A					A				A	C							A	A	A
Manzonia crassa (Kanmacher)														R									
Melarhaphe neritoides (L.)	A	C	C	A	O	O		C	A		O	F	O								F	F	A
Monodonta lineata (da Costa)	F											O	A	F	O				O				
Nucella lapillus (L.)	A							C	O		F	O	A	C							A	A	A
Ocenebra erinacea (L.)																				R			
Odostomia unidentata (Montagu)									R					R							R		
Omalogyra atomus (Philippi)						O					O												
Onoba aculeus (Gould)						R																	
Onoba semicostata (Montagu)														C		F		O			O		
Patella ulyssiponensis Gmelin	A					O		F			O	C								F		O	A
Patella vulgata L.	A					O		F	F		O	C	A	F				R	C	F	A	A	A
Rissoa parva (da Costa)					F	A	A				O	F		F		A	A	O			F		
Rissoella diaphana (Alder)						R																	
Skeneopsis planorbis (Fabricius)				F	R	C		O	O		O	C											O
Tectura virginia (Müller)	F										F	F		O							O		
Tricolia pullus (L.)						O	O			O		O		R		R		R		R	R		
Trivia monacha (da Costa)												R		F				R		F	O		
Opisthobranchia																							
Aeolidia papillosa (L.)														O						O	R		
Aeolidiella alderi (Cocks)														O									
Ancula cristata (Alder)												O							O	O	R		
Aplysia undata (Cuvier)												O							O				
Berthella plumula (Montagu)														F						O	R		
Catriona aurantia (Ald. & Han.)														R									
Doto coronata (Gmelin)																					R		
Elysia viridis (Montagu)												F		R				R	O		O		
Eubranchus farrani (Ald. & Han.)												R									R		
Facelina auriculata Grenalin																				R			
Facelina coronata (Forbes & Goodsir)																							
Placida dendritica (Ald. & Han.)																					R		
Jorunna tomentosa (Cuvier)												R		R									
Limapontia capitata (Müller)												F							R		R		
Limapontia senestra (Quatrefages)												R											
Polycera quadrilineata (Müller)												R								R	R		
Runcina coronata (Quatrefages)												F		R									
Pulmonata																							
Leucophytia bidentata (Montagu)									F												O		R
Otina ovata (Brown)									O												R		

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Lamellibranchia																							
Anomia sp.														O							F		
Hiatella arctica (L.)									O					O				O			R		
Kellia orbicularis (Montagu)									R					R									
Lasaea rubra (Montagu)			O	A	F	F		A	A	O	F	F	O	O							A		A
Musculus discors (L.)					O	C				F								O					
Mysella bidentata (Montagu)																					R		
Mytilus edulis L.				O	R	C		A	C	O	F	F	O	O							A	A	A
Paphia rhomboides (Pennant)																R		R			R		
Thracia distorta Montagu						R																	
Turtonia minuta (Fabricius)				R	C	A	O			O	O	O		O				R					
Bryozoa																							
Alcyonidium hirsutum (Fleming)																		R					
Alcyonidium gelatinosum (L.)														F									
Bowerbankia sp.						R																	
Callopora lineata L.																		R					
Electra pilosa (L.)						F	F			F		F			F		O	O					
Flustrellidra hispida (Fabricius)															A		C						
Membranipora membranacea (L.)										O								O					
Schizoporella unicornis Johnst. Wood													O	O									
Walkeria uva (L.)														R									
Echinodermata																							
Amphipholis squamata (Delle Chiaje)									C	F	C	A		C				F	F		C		
Antedon bifida (Pennant)																				O			
Asterias rubens L.	O										O										O		
Asterina gibbosa Pennant										O	O	C		O				O	F				
Leptosynapta inhaerens (O.F. Müller)																					R		
Ophiothrix fragilis (Abilgaard)										F				F				F		F			
Pawsonia saxicola (Brady & Rob.)																					R		
Psammechinus miliaris (Gmelin)																					F		
Tunicata																							
Ascidiella sp.														O							O		
Botrylloides leachi (Savigny)																	O				O		
Botryllus schlosseri (Pallas)														C	C			O			F		
Clavelina lepadiformis (Müller)														F							O		
Dendrodoa grossularia (Van Bened.)											F			F				O			F		
Diplosoma listerianum (Milne Edw.)											O			C									
Morchellium argus (Milne Edwards)														R									
Polyclinum aurantium (Milne Edw.)														R									
Sidnyum turbinatum (Fleming)														F									
Osteichthyes																							
Anguilla anguilla (L.)																			R				
Apletodon dentatus (Facciola)										O									O				
Chelon labrosus (Risso)												F							F				
Coryphoblennius galerita (L.)												O											
Crenilabrus melops (L.)												O							F				
Ctenolabrus rupestris (L.)																			O				
Cyclopterus lumpus L.														R									
Gaidropsaurus mediterraneus (L.)												R							R		R		

Table 1 *continued*

	CARNSORE EXPOSED SHORE												CARNSORE SHELTERED SHORE										
	Rock surfaces	Supralittoral lichens	*Pelvetia*	*Lichina*	*Mastocarpus*	*Corallina*	*Himanthalia*	Mussels	Crevices	Laminarians	Under boulders	Pools	Rock surfaces	Under boulders	Fucoids	*Corallina*	*Mastocarpus*	Laminarians	Pools	At LW	FORLORN POINT	CAHORE	HOOK HEAD
Gasterosteus aculeatus L.																			F		R		
Gobius paganellus L.												O							R				
Gobiusculus flavescens (Fabr.)												F							F				
Labrus bergylta Ascanius												R											
Lepadogaster lepadogaster (Bonnat.)																			R		F		
Liparis montagui Donovan										R											R		
Lipophrys pholis (L.)												C		F					C		C		
Nerophis lumbriciformis (Jenyns)												O		F					O				
Pholis gunnellus (L.)												O		F							R		
Pollachius virens (L.)																			O				
Pomatoschistus microps (Krøyer)												O											
Pomatoschistus minutus (Pallas)												O											
Spinachia spinachia L.												F							F		O		
Sprattus sprattus (L.)																			O				
Taurulus bubalis (Euphrasen)												F		O					F		F		

Table 2. Characteristics of eight boulder shores in south-east Wexford

	Forlorn Pt. W	Forlorn Pt. E	Carnsore F	Carnsore Q	Carnsore X	Carnsore HH	Crossfintan Pt. S	Crossfintan Pt. N
Aspect	WNW	ESE	SW	ESE	ESE	E	ESE	NE
Width of shore (m)	90	75	73	80	85	115	85	115
Rock:boulder:sand (%)								
upper zone	20:60:20	95:0:5	90:10:10	50:45:5	90:0:10	0:75:25	10:50:40	5:0:95
middle zone	0:70:30	0:70:30	50:50:0	20:75:5	90:0:10	0:50:50	0:50:50	0:50:50
lower zone	0:70:30	0:70:30	20:80:0	5:90:5	0:95:5	0:50:50	0:50:50	0:50:50
Water (%)								
upper:middle:lower	25:5:5	<5:5:5	10:10:30	5:0:0	<5:10:10	<5:10:5	<5:<5:10	0:10:25
Algal (%)								
upper:middle:lower	50:40:90	60:50:95	5:2:15	50:20:90	70:5:80	65:80:95	50:2:80	60:5:85
Dominant algae:								
upper zone	*Pelvetia*	*Pelvetia* *F. spiralis*	*Pelvetia* *F. vesiculosus*	*F. spiralis*	*F. vesiculosus* *Ascophyllum*	*F. spiralis* *F. vesiculosus*	*F. spiralis*	*F. vesiculosus*
middle zone	*F. vesiculosus*	*F. vesiculosus*	*F. vesiculosus*	*Ascophyllum*	*Ascophyllum*	*Ascophyllum*	*Ascophyllum*	*F. vesiculosus*
lower zone	*F. serratus*	*F. serratus*	*F. serratus* *Mastocarpus* *Laurencia*	*F. serratus*	*F. serratus*	*F. serratus*	*F. serratus*	*F. serratus*
Lichens (%)								
upper:middle:lower	2:2:0	80:0:0	5:1:0	25:15:0	5:30:0	15:10:2	40:30:7	20:15:10
Barnacles (%)								
upper:middle:lower	60:80:70	5:70:70	20:40:60	<5:<5:<5	<5:20:40	10:5:10	<5:<5:15	5:35:40
Barnacle spp. (Cm:Cs:Sb) (%)								
upper zone	100:0:0	100:0:<1	90:0:10	95:0:10	70:0:30	5:0:95	100:0:0	40:0:60
middle zone								
lower zone								
	<1:0:100	20:0:80	30:10:60	10:0:90	5:0:95	0:0:100	50:+:50	40:1:60
	0:0:0	0:0:100	0:10:90	0:0:100	0:0:100	0:0:100	0:0:100	1:0:100

Table 3. Species recorded on sandy beaches in County Wexford. Abundance categories: A – Abundant, adults generally found in hundreds, present all the year round, likely to be typical of the community everywhere; C – Common, adults generally collected in tens, present all the year round; F – Frequent, common seasonally *or* small numbers throughout the year; O – Occasional, one specimen on several occasions *or* a few specimens on a few occasions *or* large numbers unpredictably; R – Rare, single specimens only *or* a few specimens on one occasion

	Sandy Beaches										Mud, etc.		
	Pollshone	Raven Point	Rosslare Point	Rosslare Harbour	Carne	Carnsore	Kilmore Quay	Ballyteige	Bannow Bay	Coombe	Cull Inlet	Bannow salt marsh	S. Wexford Harbour
Cnidaria													
Aurelia aurita (L.)						R				O			
Chrysaora hysoscella (L.)					R								
Rhizostoma octopus (L.)		R				R							
Velella velella (L.)						O				O			
Ctenophora													
Pleurobranchia pileus (O.F. Müller)					F	F							
Polychaeta													
Arenicola marina agg.				C	A	A	A				A		
Capitella capitata (Fabricius)						A	A						
Cirratulus cirratulus (O.F. Müller)							R						
E. longa (Fabricius)			R										
Euclymene lumbricoides (Quatrefages)							R						
Eusyllis blomstrandi Malmgren					R								
Harmothoe impar (Johnston)					O								
Hediste diversicolor (O.F. Müller)											A		C
Lanice conchilega (Pallas)							O						
Lepidonotus squamatus (L.)							O						
Magelona mirabilis (Johnston)							R						
Malacoceros fuliginosus (Claparède)					C	F	C	C					
Nephtys caeca Fabricius					R	R	R						
N. cirrosa Ehlers							F						
N. hombergi Savigny							O						
Orbinia latreillii (Aud. & Milne-Edw.)							R						
Paraonis lyra Southern						R							
Pholoe minuta Fabricius						R	R						
Pygospio elegans Claparède							R						
Scolelepis foliosa (Aud. & Milne-Edw.)							R						
Scolopos armiger (O.F. Müller)							C						
Sigalion mathildae Aud. & Edw.							R						
Spio martinensis Mesnil							F						
Sthenelais boa (Johnston)							R						
Syllis gracilis Grube						R							
Clitellata													
Cernosvitoviella immota (Knöllner)													R
Enchytraeus albidus Henle			C		C		C			A			
E. capitatus Niels. & Christ.										R			
Fridericia callosa (Eisen)										O			
Lumbricillus lineatus (O.F. Müller)										O			
L. kaloensis Niels. & Christ.													O
L. pagenstecheri (Ratzel)										O			
L. rivalis (Levinsen)										A			
L. viridis Stephenson				A	C	A	A						

Table 3 *continued*

	Sandy Beaches										Mud, etc.		
	Pollshone	Raven Point	Rosslare Point	Rosslare Harbour	Carne	Carnsore	Kilmore Quay	Ballyteige	Bannow Bay	Coombe	Cull Inlet	Bannow salt marsh	S. Wexford Harbour
Marionina appendiculata Niels. & Christ.						R							F
M. arenaria Healy					O					O			
M. preclitellochaeta Niels. & Christ.				A	A	A	O						
M. sjaelandica Niels. & Christ.										O			
M. southerni (Cernosvitov)										F			
M. spicula (Leuckart)										F			
M. subterranea (Knöllner)				F	F	F	A						
Tubifex costatus Claparède												F	
Tubificoides benedii (d'Udekem)												O	
Cladocera													
Evadne nordmanni Loven							R						
Podon intermedius Lilljeborg							R						
Copepoda													
Acartia clausi Giesbrecht							R						
Asellopsis intermedia (T. Scott)				R			R						
Canuella perplexa T. & A. Scott				F			F						
Harpacticus flexus (Brady & Roberts.)							F						
Stenhelia palustris (Brady)							R						
Tachidius discipes Giesbrecht							R						
Temora longicornis (O.F. Müller)							R						
Thompsonula hyenae (Thompson)				R									
Parapontella brevicornis (Lubbock)							R						
Cirripedia													
Elminius modestus Darwin												C	
Lepas anatifera L.						R				R			
L. pectinata Spengler										R			
Cumacea													
Bodotria scorpioides (Montagu)				F		F							
Cumopsis fagei Bacescu			F	F		F	R						
C. goodsiri (Van Beneden)			C	C	R	C	R						
Pseudocuma longicornis (Bate)				R									
Mysidacea													
Gastrosaccus spinifer (Goës)	R		R		R	R							
Leptomysis lingvura (G.O. Sars)					O	O							
L. mediterraneus G.O. Sars						R							R
Neomysis integer (Leach)				R	O	F					O		
Paramysis arenosa (G.O. Sars)				R	F	O							
Praunus flexuosus (Müller)						F							
P. inermis (Rathke)						F							
P. neglectus (G.O.Sars)				R	R	R							
Schistomysis parkeri (Norman)			R	R	C	C							
S. spiritus (Norman)	R		R	R	F	F							
Siriella armata (H. Milne Edw.)					F	F							
S. jaltensis Czerniavsky					F	F							
Isopoda													
Eurydice pulchra Leach		C	C	F	F	F		F					

Table 3 *continued*

	Sandy Beaches										Mud, etc.		
	Pollshone	Raven Point	Rosslare Point	Rosslare Harbour	Carne	Carnsore	Kilmore Quay	Ballyteige	Bannow Bay	Coombe	Cull Inlet	Bannow salt marsh	S. Wexford Harbour
Idotea baltica (Pallas)			R		F	O		O		F			
I. emarginata (Fabricius)					R	R							
I. granulosa Rathke					O	O							
I. linearis (L.)					R	R							
I. neglecta Sars										R			
Jaera praehirsuta Forsman													R
Lekanesphaera rugicauda (Leach)													F
Limnoria lignorum (Rathke)			R	C	R								
L. quadripunctata Holthuis										O			
Paragnathia formica (Hesse)												C	C
Amphipoda													
Ampelisca brevicornis (da Costa)							R						
Amphitholina cuniculus (Stebbing)						R							
Ampithoe gammaroides Bate							R						
A. rubricata (Montagu)					R								
Apherusa bispinosa (Bate)					R								
A. jurinei (Milne Edw.)						R							
Atylus guttatus (Costa)					R								
A. swammerdami (Milne Edw.)	O	O	O	O	O	F	O	O					
Bathyporeia elegans Watkin	R												
B. guilliamsoniana (Bate)					R	O	C						
B. pelagica (Bate)				A	A	A	O						
B. pilosa Lindstrom		F		A	A	A	A						
Calliopius laeviusculus (Krøyer)			O	O	O								
Corophium volutator (Pallas)									C		A		A
Gammarellus angulosus (Rathke)	R												
Gammarus locusta (L.)				R	R	R	R	C	R				
G. zaddachi Sexton													C
Haustorius arenarius (Slabber)			F		C	C							
Jassa falcata (Montagu)					R	O							
Leptocheirus pilosus Zaddach													O
Megaluropus agilis Hoek	O		O										
Microprotopus maculatus Norman		R	O	R									
Orchestia gammarellus (Pallas)						C							
Perioculodes longimanus (Bate & Westw.)				R									
Podocerus variegatus Leach						R							
Pontocrates altamarinus (Bate & Westw.)			C	C	C	C							
Pontocrates arenarius (Bate)			O	F		O							
Stenothoe monoculoides (Montagu)						R							
Talitrus saltator (Montagu)					C		C			C			
Talorchestia deshayesii (Audouin)					C					C			
Urothoe brevicornis Bate					R								
Decapoda													
Carcinus maenas (L.)					O	O							O
Crangon crangon (L.)		F	C	C	A	A	C		R		C	F	C
Hippolyte varians Leach						R							
Liocarcinus depurator (L.)					R	R							
L. holsatus Fabricius		R											
Pagurus bernhardus (L.)							R						
Portumnus latipes (Pennant)		R	R		R	R							

Table 3 *continued*

	Sandy Beaches										Mud, etc.		
	Pollshone	Raven Point	Rosslare Point	Rosslare Harbour	Carne	Carnsore	Kilmore Quay	Ballyteige	Bannow Bay	Coombe	Cull Inlet	Bannow salt marsh	S. Wexford Harbour
Philocheras trispinosus Hailstone		R	R		O	R	R						
Palaemon serratus (Pennant)						R							
Palaemonetes varians (Leach)													C
Acari													
Arctoseioides ibericus (Willm.)													R
Cheiroseius necorniger (Oudms.)													O
Halolaelaps celticus Halbert						R							
Dissoloncha superbus (Hull)						O							
Pseudoparasitus sellnicki Breg.& Kerol.													R
Parasitus kempersi Oudm.						R							
Phaulodinychus repletus Berlese													R
Pseudoparasitus centralis (Berl.)						R							
Rhombognathus setosus (Lohman)													R
Thinoseius fucicolus Halbert						O							
T. spinosus Willm.						O							
Pycnogonida													
Achelia echinata Hodge						R							
A. longipes Hodge						R							
Ammothella hispida (Hodge)						R							
Nymphon gracile (Leach)					R								
Chilopoda													
Necrophloeophagus longicornis (Leach)						R							
Tardigrada													
Echiniscoides sigismundi (Schulze)			R	R									
Mollusca													
Abra tenuis (Montagu)									R				
Alderia modesta (Loven)												C	O
Angulus tenuis da Costa			R		R		C						
Cerastoderma edule (L.)		O					C		C				
Eledone cirrhosa (Lamarck)		R											
Fabulina fabula (Gmelin)							C						
Gibbula cineraria (L.)						R							
Hydrobia ulvae (Pennant)									A		A		A
Lacuna pallidula (da Costa)						R							
L. vincta (Montagu)						R							
Limapontia depressa (Ald. & Hank.)												C	
Littorina littorea (L.)													O
L. saxatilis Olivi												F	F
Macoma balthica (L.)							O						O
Mysella bidentata (Montagu)							R						
Mytilus edulis agg.												A	A
Nucella lapillus (L.)			R										
Phytia myosotis (Draparnaud)													C
Retusa obtusa (Montagu)									R				
Rissoa parva da Costa		R											
Sepiola atlantica d'Orbigny					F	F							
Spisula solida (L.)								R					

Table 3 *continued*

	Sandy Beaches										Mud, etc.		
	Pollshone	Raven Point	Rosslare Point	Rosslare Harbour	Carne	Carnsore	Kilmore Quay	Ballyteige	Bannow Bay	Coombe	Cull Inlet	Bannow salt marsh	S. Wexford Harbour
Osteichthyes													
Ammodytes tobianus L.					F	F							
Atherina presbyter Valenciennes		R				R							
Buglossidium luteum (Risso)					R								
Callionymus lyra L.					R	R							
Chelon labrosus (Risso)						O							
Echiichthyes vipera Cuvier		R			R	R							
Gaidropsaurus mediterraneus (L.)					R								
Gasterosteus aculeatus L.					R								
Gobiusculus flavescens (Fabricius)					R								
Limanda limanda (L.)					R	R							
Liparis montagui Donovan						R							
Lipophrys pholis (L.)						R							
Nerophis lumbriciformis (Jenyns)						O	R						
Pegusa lascaris (Risso)					R	R							
Pholis gunnellus (L.)							R						
Pleuronectes flesus (L.)						O							
P. platessa (L.)					A	A	A						
Pomatoschistus microps (Krøyer)		R					F						R
P. minutus (Pallas)						R	O						
Psetta maxima (L.)					F	F							
Scophthalmus rhombus (L.)					R	R							
Spinachia spinachia (L.)							R						
Sprattus sprattus (L.)													
Syngnathus acus L.					R								
S. rostellatus Nilsson					R	R							
Taurulus bubalis (Euphrasen)						O	R						

Table 4. Mean median grain size (Md) and sorting index (σϕ) for five beaches in south-east Wexford

	Date	Stations	Md (ϕ)	Md (μm)	Range (μm)	σϕ	Range (σϕ)	Class
Kilmore Quay	25-10-1976	1–10	2.9	136	136–180	0.66	0.49–0.83	moderately well sorted
Carnsore	22-11-1976	1–10	2.8	147	124–158	0.45	0.41–0.49	well sorted
Carne	26-10-1976	1–9	2.4	200	160–245	0.45	0.44–0.45	well sorted
Rosslare Harbour	?-7-1976	1–6	1.8	315	150–800	1.35	0.39–2.31	poorly sorted
Rosslare Point	?-7-1977	1–7	1.6	320	270–400	0.57	0.30–0.83	moderately well sorted