Subtidal sediment biotopes in Red Wharf and Conwy Bays, North Wales: A review of their composition, distribution and ecology

Rees, E.I.

Published: 01/01/2004

Publisher's PDF, also known as Version of record

Subtidal sediment biotopes in
Red Wharf and Conwy Bays, North Wales:
A review of their composition, distribution and ecology
.

E. Ivor. S. Rees

CCW Contract Science Report No 655

Llywodraeth Cynulliad Cymru
Welsh Assembly Government
CORFF NODDEDIG | SPONSORED BODY

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

Report Number: 655

Publication Date: June 2004

Contract Number: FC 79-01-04

Nominated Officers: Kirsten Ramsay

Title: Subtidal sediment biotopes in Red Wharf and Conwy Bays, North Wales: A review of their composition, distribution and ecology

Authors: E. Ivor. S. Rees

Restrictions: None

Distribution List:
Core:
CCW HQ Library
CCW North Region Library, Mold
CCW North Region Library, Bangor
CCW South East Region Library, Cardiff
CCW West Region Library, Aberystwyth
National Library of Wales
Welsh Assembly Government Library
British Library
English Nature Library
SNH Library

Others
Kirsten Ramsay (5 copies)
Lucy Kay, North Region
Kate Smith, North Region (5 copies)
Bill Sanderson
Rohan Holt
Rod Jones
MFSG Library (Mandy McMath)
Ivor Rees

Subtidal sediment biotopes in Red Wharf and Conwy Bays, North Wales: A review of their composition, distribution and ecology

by

E. Ivor. S. Rees

School of Ocean Sciences

University of Wales Bangor

Menai Bridge, Anglesey. LL59 5EY

January 2003 – Revised May 2004

A Report prepared for the Countryside Council for Wales

Contract No. FC 79-01-04

Subtidal sediment biotopes in Red Wharf and Conwy Bays, North Wales: A review of their composition, distribution and ecology

CONTENTS

1. Introduction

2. Ecological setting and history of studies

3. Geomorphological context

4. Archived data sources of assistance in local biotope definition and mapping

5. Notes and comments on biotopes
    5.1 sediment classifications
    5.2 muddy sand biotopes
    5.3 temporal variation and interpretation of inshore muddy sand biotopes
    5.4. Revised classification of North Wales muddy sands

6. Sedimentary biotopes and their distributions in Red Wharf and Conwy bays

7. Notes on some prominent species

8. Notes on sensitivities and conservation priorities

9. Suggested priorities for further investigations and monitoring

10. Conclusions

Acknowledgments

References

Figure 1 Sedimentary biotopes and their distributions in Red Wharf and Conwy Bays

SUMMARY

Subtidal sediment biotopes in Red Wharf and Conwy Bays, North Wales: A review of their composition, distribution and ecology.

Prepared by E. Ivor S. Rees, School of Ocean Sciences, University of Wales Bangor.
January 2003, revised May 2004
Report for Countryside Council for Wales. No 655

1. Conwy Bay and parts of Red Wharf Bay have been included within the candidate Special Area of Conservation for the Menai Strait and Conwy Bay, partly for the Annex I feature "Sandbanks covered by seawater all the time". Criteria for "Shallow inlets and bays" are also met, though designation was not primarily for this feature.
2. About 98% of the seabed in the bay complex is covered by sediments. These range from lag gravels with sand veneers, through areas of sand ribbons and sand waves overlying shell hash, to fully developed sand banks and with enriched muddy sand patches inshore of the banks.
3. There is a long history of scientific sampling of the sedimentary biotopes in these bays and much additional data that was not incorporated into the Marine Nature Conservation Review summaries for this Sector of the North Wales coast. Older data of various types has been reviewed for this report and some more recent data incorporated including time series indicating substantial variability.
4. Ecologically the most interesting and also most sensitive sediment parts of the cSAC are not the sandbanks (*sensu stricta*), but the areas of partly sheltered muddy sand, which form part of the large shallow bay feature. Depositional gradients between tide swept areas and less exposed parts of the bays cause the advection and selective settlement of organic matter in the muddy sand patches. This causes localised enrichment of the benthos, but excessive accumulation of decaying material may at times cause near bed hypoxia and mass mortality of the benthos after intense phytoplankton blooms.
5. Suggestions are made for ways to classify the local sedimentary habitats which reflect the factors most strongly influencing the benthos. The categories are not entirely coincident with the MNCR biotope classification.
6. Recommendations are made for additional work and for longer term monitoring of the more sensitive features and those most likely to vary.

CRYNODEB

Biotopau gwaddodion islanwol Y Traeth Coch a Bae Conwy, Gogledd Cymru: adolygiad ar eu cyfansoddiad, eu dosbarthiad a'u hecoleg.

Lluniwyd gan E. Ivor S. Rees, Ysgol Gwyddorau Eigion, Prifysgol Cymru, Bangor.
Ionawr 2003, diwygiwyd Mai 2004
Adroddiad ar gyfer Cyngor Cefn Gwlad Cymru. Rhif 655

1. Mae Bae Conwy a rhannau o'r Traeth Coch wedi eu cynnwys o fewn yr ymgeisydd am Ardal Cadwraeth Arbennig (yACA) ar gyfer Y Fenai a Bae Conwy, yn rhannol oherwydd y nodwedd Atodiad 1 "Banciau tywod a orchuddir bob amser gan ddŵr môr". Hefyd, bodlonir y meini prawf yn ymwneud â "Chilfachau a baeau bas", er nad y nodwedd hon oedd yn bennaf gyfrifol am y dynodiad.
2. Mae oddeutu 98% o wely'r môr yn y bae wedi ei orchuddio â gwaddodion. Mae'r rhain yn amrywio o raean sydd â chaenen o dywod o'u hamgylch, trwy lecynnau lle ceir rhubanau tywod a thonnau tywod yn gorchuddio cregyn, i fanciau tywod wedi gorffen datblygu gyda llecynnau o dywod lleidiog cyfoethocach ymhellach i'r tir o'r banciau.
3. Ceir hanes maith o samplo'r biotopau gwaddodol yn wyddonol yn y baeau hyn, a hefyd ceir llawer o wybodaeth ychwanegol na chynhwyswyd yng nghrynodebau'r Adolygiad Gwarchod Natur Forol ar gyfer y rhan yma o arfordir Gogledd Cymru. Mae data hŷn o fath gwahanol wedi cael ei adolygu ar gyfer yr adroddiad hwn, ac mae rhywfaint o ddata mwy diweddar wedi ei ymgorffori, gan gynnwys data a gasglwyd yn rheolaidd sy'n dangos cryn amrywioldeb.
4. Yn ecolegol, nid banciau tywod yr yACA yw'r rhannau mwyaf diddorol na'r rhannau gwaddodol mwyaf sensitif (*sensu stricta*), ond yn hytrach y llecynnau wedi eu cysgodi'n rhannol lle ceir tywod lleidiog. Mae graddiant dyddodiadol rhwng llecynnau llanwol a rhannau mwy cysgodol y baeau yn peri i ddeunydd organig lorfudo a gwaddodi peth yn y llecynnau o dywod lleidiog. Arweinia hyn at gyfoethogi'r benthos, ond fe all gormod o ddeunydd pydredig o dro i dro arwain at ddiffyg ocsigen ar/ger gwely'r môr ac at farwolaethau lu ymhlith y benthos ar ôl i'r ffytoplancton flodeuo'n brysur.
5. Awgrymir ffyrdd o ddosbarthu'r cynefinoedd gwaddodol lleol sy'n adlewyrchu'r ffactorau sy'n dylanwadu fwyaf ar y benthos. Nid yw'r categorïau'n cyd-fynd â dosbarthiad biotopau yr MNCR.
6. Argymhellir y dylid cynnal gwaith ychwanegol, yn ogystal â chaw golwg yn yr hirdymor ar y nodweddion mwy sensitif a'r rhai sy'n fwyaf tebygol o amrywio.

1. INTRODUCTION

The north facing coast of Wales has a broad inset made up of Red Wharf and Conwy Bays. The whole inset is about 15 nautical miles across, with a maximum of about 7 nautical miles from the 30 metre depth contour across the mouth to the coast. On maps and in biogeographic quality, this area forms the most south-westerly part of Greater Liverpool Bay in the Eastern Irish Sea. About 98% of this shallow sub-tidal bay complex is floored by sediments (Admiralty Chart No.1977 - Holyhead to Great Ormes Head; Admiralty Chart No. 1463 – Conwy Bay and approaches to the River Conwy; British Geological Survey seabed sediment map - Anglesey (James and Wingfield 1990)). The combined bays lie between two prominent headlands, Point Lynas, on the north eastern corner of Anglesey, and the Great Orme, near Llandudno, (Figure 1). The above named bays make up the inner parts of an area which lacks a generic name. Conwy Bay also forms the north eastern approach to the Menai Strait and for this reason it was in the past also referred to as Beaumaris Bay (see the pre-metric Admiralty charts).

This report is concerned with the biotopes of sub-tidal sediments. There are only very limited amounts of sub-tidal rock habitat and even at the headlands sediment cover extends close to the base of the cliffs. The review was prompted by the inclusion of the two bays within a proposed (now candidate) marine Special Area of Conservation (SAC) for the Menai Strait and Conwy Bay, under the EU Habitats Directive (upgraded to candidate SAC January 2003). It also provides an opportunity to bring together a diverse range of mainly unpublished data on the sub-tidal benthos of the bays. To encompass the full extent of the area bounded by natural features and to put the biotopes within the cSAC into context, the review actually extends slightly more widely than the northern boundary of the cSAC.

Designation of the Menai Strait and Conwy Bay as a cSAC came about through the moderation process which was required to rectify deficiencies in the range of sites put forward by the UK government in the first round of candidate SACs. Parts of Red Wharf and Conwy Bays are deemed to qualify under the Habitats Directive Annex I category of "Large shallow inlets and bays", though this was not a primary reason for site selection. The category "Sandbanks which are slightly covered by sea water all the time" was given as one of the primary selection reasons. In practice, both 'bays' and 'sandbanks' are very wide categories of habitat and are thus open to a variety of interpretations. Indeed, the agreed Habitats Directive definition of sand banks (BOX 2) extends much more widely than most geomorphologists would include within a classification scheme for sub-tidal sand banks (Dyer & Huntley, 1999).

To the east, the cSAC area extends beyond Conwy Bay as far as the Little Orme, thus bringing within the boundary another smaller shallow bay, also floored by sub-tidal sands and muddy sands, namely Llandudno Bay. To the west the cSAC extends just beyond Moelfre, where the east-west northern boundary line happens to meet the coast. Most of Dulas Bay is thus outside the SAC, although the benthic habitat there is effectively part of the same complex of muddy sand patches as in the rest of the Red Wharf / Conwy embayment.

BOX 1.

Description and ecological characteristics

Sandbanks which are slightly covered by sea water all the time consist of sandy sediments that are permanently covered by shallow sea water, typically at depths of less than 20 m below chart datum (but sometimes including channels or other areas greater than 20 m deep). The habitat comprises distinct banks (i.e. elongated, rounded or irregular 'mound' shapes) which may arise from horizontal or sloping plains of sandy sediment. Where the areas of horizontal or sloping sandy habitat are closely associated with the banks, they are included within the Annex I type.

The diversity and types of community associated with this habitat are determined particularly by sediment type together with a variety of other physical, chemical and hydrographic factors. These include geographical location (influencing water temperature), the relative exposure of the coast (from wave-exposed open coasts to tide-swept coasts or sheltered inlets and estuaries), the topographical structure of the habitat, and differences in the depth, turbidity and salinity of the surrounding water. Within the UK's inshore waters **Sandbanks which are slightly covered by sea water all the time** can be categorised into four main sub-types:

i. gravelly and clean sands;
ii. muddy sands;
iii. eelgrass *Zostera marina* beds;
iv. maerl beds (composed of free-living Corallinaceae).

Sandbanks which are slightly covered by sea water all the time are frequently associated with other marine Annex I habitats, for example grading into **1140 Mudflats and sandflats not covered by sea water at low tide** in the intertidal zone. They are often component habitats of **1130 Estuaries** and **1160 Large shallow inlets and bays**.

From JNCC SACs Site Selection Web Site

Previously a smaller part of Red Wharf and Conwy Bays had been included within the proposed boundaries of a Menai Strait Marine Nature Reserve. This proposal was under provisions in the Wildlife & Countryside Act 1981. Thus a limited part of the current SAC had previously had some notional protection before 2000 as part of a pMNR. This marine reserve had been awaiting ministerial decisions for several years after being formally submitted to the Welsh Office long before the relevant powers were devolved to the National Assembly for Wales. Indeed, a Marine Nature Reserve for the Menai Strait had been under serious discussion from soon after the 1981 Act was passed. The broad intertidal sand flat of Traeth Lafan, adjoining Conwy Bay, had had SSSI status even longer. Originally this shore was amongst those SSSIs made under the National Parks and Access to the Countryside Act 1949. The site was renotified in 1984 under the Wildlife and Countryside Act 1981. Primarily this was for wetland birds rather than for the marine ecological features, although the 1981 citation makes reference to the mudflat and sand flat communities present within the site. There were no provisions in the 1949 or 1981 Acts for the sub-tidal areas adjoining it to be included.

2. ECOLOGICAL SETTING AND HISTORY OF STUDIES

The northern part of Anglesey protrudes into the Irish Sea and thus shelters Red Wharf Bay and Conwy Bay from the prevailing westerly to south westerly winds and the longer open sea swells which can impinge on the western side of Anglesey. More importantly, the two rocky headlands deflect the tidal currents running to and from the inner parts of Liverpool Bay. The mean spring tide range at Liverpool is 8.7m, giving rise to currents that are particularly strong across the north coast of Anglesey. Because of the protection afforded to the bays there are marked depositional gradients where the tidal currents slacken in parts of Dulas, Red Wharf and Conwy and Llandudno Bays. Coupled with the relatively high amounts of suspended organic matter in these coastal waters, the gradients foster the deposition of localised patches of somewhat enriched muddy sand. These patches typically carry higher biomass benthic macrofaunas than the adjacent more tide swept sands and gravelly sands typically found offshore in the southern and eastern Irish Sea (Rees, et al. 1976). The benthos of such muddy sand patches often contains, and may be dominated by opportunistic species with short life spans and high production rates, such as the polychaete worm *Lagis koreni* and the bivalve *Abra alba*. Because of this the species composition of the fauna of the inshore muddy sands is liable to be quite variable from year to year.

Offshore at about the 4^{o} W longitude there is often a discontinuity in water quality between Liverpool Bay water and that more similar to water from St George’s Channel and the South Irish Sea (Foster, et al. 1982). At the coast Crisp & Knight-Jones (1955) also detected a biogeographic discontinuity on the rocky shores of the north coast of Anglesey in the vicinity of Carmel Head. The faunistic character of Red Wharf and Conwy Bays would put the inshore benthos into the same groupings as much of the rest of Greater Liverpool Bay. Further offshore to the northeast of Point Lynas the coarser ground has populations that include some macrofaunal species more characteristic of areas to the west of Anglesey.

An asymmetry in the time of high water and tide heights on the two sides of Anglesey causes a residual flow south-westwards through the Menai Strait (Campbell, et al. 1998). Water may be drawn in differing proportions from one or other side of the offshore water quality discontinuity, but inshore in the bays it usually has more affinity with Liverpool Bay. The water quality variation shows up in the variable presence of the indicator species of planktonic chaetognaths (*Sagitta elegans* and *S. setosa*). These characterise different amounts of the Liverpool Bay water masses from time to time (Khan & Williamson 1970). As with the rest of Liverpool Bay inshore waters, Red Wharf and Conwy Bays are prone to develop intense blooms of the bladder forming dinoflagellate *Phaeocystis pouchetii*.

There has been an unusually long history of marine biological investigations off this particular part of the North Wales coast. Early significant work was by the Liverpool Marine Biological Committee, who maintained a field laboratory in the old signal station on Puffin Island for several years at the end of the 19th century (Herdman 1920; Baker 1994). The multi-part *Fauna of Liverpool Bay*, produced in the 1890s, contains many interesting papers on particular taxonomic groups. Apart from work at Puffin Island, the LMBC group undertook some offshore dredging with paddle tugs and a salvage vessel hired from Liverpool (Herdman 1889; Herdman 1893). Activity in the area then declined for several decades after the LMBC moved their activities to the Isle of Man. Nevertheless there are some useful species records in existence from the 1930's and 1940s arising mainly from trawl sampling by the Lancashire & Western Sea Fisheries Committee patrol vessels (see notes in unpublished card index fauna list UW Bangor). In the 1950s the Menai Bridge laboratory of the University College of North Wales was set up and student parties were often taken out sampling to Red Wharf Bay on field courses using the small fishing vessel / research vessel *Nautilus,* then owned by the Marine Station (Crisp 1953).

Since the late 1960s when Bangor University acquired the first RV *Prince Madog*, the bays off the north end of the Menai Strait have provided convenient locations for student teaching trips and for much research student work. A recent example of this was an autecological study on the sandstar *Astropecten irregularis* (Freeman, et al. 2001). The bays are only about an hour's steaming time from Menai Bridge and being partly sheltered can be worked with few weather interruptions. There is thus a considerable amount of past experience and unpublished data on the sedimentary biotopes covering the period from the late 1960's to the present day. Even before this, when the Menai Bridge laboratory worked the bays with smaller vessels or chartered local trawlers, material was also provided for workers based elsewhere or specialists in particular groups who joined the field courses. For example, *Pharus legumen* and *Thracia villosuiscula* were supplied from Red Wharf Bay for the seminal studies on the biology of these two bivalves (Yonge 1959; Allen 1961).

In 1965 an extensive campaign of exploratory dredging was carried out all round northwest Wales by the author using the chartered M.V. *Insula*. A small part of the sampling was within Red Wharf and Conwy Bays, though rather more attention was paid to the coarse grounds further out. Decca Navigator was fitted to this vessel and for the first time locations were based on more than bearings from features on the land. During 1964-1967 field course parties were also taken out on M.V. *Shamrock*, a trawler which then also served as the Caernarfon Pilot vessel. A few trials were done at this time in Conwy Bay comparing a Smith-McIntyre grab with a Van Veen grab and surviving notes on the benthos from this exercise indicated there had been a particularly strong recruitment of the sea potato *Echinocardium cordatum.*

In the early to mid 1960s MAFF scientists from the Lowestoft laboratory were studying the recruitment of plaice (*Pleuronectes platessa*) in the Irish Sea. Red Wharf Bay was one of the prime study areas for the work on newly settled 0-group fish. They used both RV *Platessa* and RV *Tellina*. A catalogue of research vessel log books indicates that some basic information on these cruises is held in the Lowestoft laboratory archives (Goodwin, et al. 2001), However little of the basic data from benthos sampling in the surf zone, known to have been done to study the food of the newly settled plaice, can be traced, although some information from epibenthic sledge samples was given by Macer (1967). MAFF / CEFAS have also included a beam trawl station within Red

Wharf Bay in standardised Irish Sea demersal fish monitoring surveys in recent years. The benthos by-catch is also recorded in these surveys. More widely, such benthos data has been used to compare biotopes in the Irish and Celtic Seas (Ellis, et al. 2000).

Seabed photographs in the bays and off Point Lynas have several times been taken using sledge mounted cameras by different groups (UW Bangor, CEFAS, MBA). Sometimes this has been done while testing equipment prior to studies in Liverpool Bay and elsewhere in the Irish Sea. An archive database prepared by (Allen & Rees 1999) contains a number of images that help put the sedimentary seabed environment of Red Wharf and Conwy Bays into context.

Marine Nature Conservation Review (MNCR), Area Summaries were produced for Red Wharf and Conwy Bays (Sector 10, areas 21&22) (Brazier, et al. 1999). For the MNCR report biotope recognition and the accompanying biotope maps of the sub-tidal sediments of these bays was based mainly on 6 spots where the MNCR team dived, plus records from a single grab station taken from the National Museum of Wales southern Irish Sea survey (Mackie, et al. 1995). Inevitably the spatial interpretations were more speculative than would have been the case had a wider range of earlier data been drawn upon.

During a survey of a range of sandbanks around the Welsh coast in 2001, grab sample transects were run across the banks in Conwy and Red Wharf Bay (Darbyshire, et al. 2002). At the same time the epifauna was also sampled with a 2m beam trawl and demersal fish stomach contents were examined (Kaiser, 2004). A notable feature of the 2001 sampling of the Four Fathom Bank in Red Wharf Bay was the particularly high biomass of large bivalves *Pharus legumen* in some samples. Samples, not yet fully worked up, were taken at one muddy sand station in Red Wharf Bay in 2003 by the National Museum of Wales team while on passage to another survey. Notes at sea indicated large numbers of the polychaete worm *Lagis koreni*. A few samples, from which only the bivalves were extracted, were also taken in Red Wharf and Conwy Bays in August 2003 and April 2004 as part of Crown Estates sponsored investigations into the relative abundance of suitable food for scoters (*Melanitta nigra*) displaced from offshore wind farm locations.

The present report brings together much of the pre-existing and spatially more comprehensive data not used for the MNCR area summary. This comes from a variety of published and unpublished sources, coupled with some more recent data. The compendium should aid understanding of the ecology of the sediments in this area. Temporal changes in the benthos of the inshore muddy sands are also reviewed and suggestions are made about the definitions of sedimentary biotopes appropriate for the Eastern Irish Sea. These vary somewhat from those used by Brazier et al (1999) which followed the version of the MNCR classification then in use (Connor, et al. 1997). Using the fuller range of data sources and 35 years of local experience it is possible to refine the distributions of the biotopes in relation to the local physiographic and hydrographic features of these inshore waters.

3. **GEOMORPHOLOGICAL CONTEXT**

Like most parts of the Irish Sea the sediment and the medium scale seabed relief of the Red Wharf - Conwy Bay area derives in large measure from the events of the last glaciations and the associated sequences of sea level change. Underlying the immediate seabed of much of the Eastern Irish Sea there are extensive deposits of glacial till of varying thickness (see Sections shown on British Geological Survey, seabed sediment and Quaternary maps). Most of this glacial till came from the Irish Sea ice sheet which pushed southwards from southern Scotland and the Cumbrian mountains. Smaller amounts of distinctively coloured deposits derived from the Snowdonia glaciers can be found interleaved with the Irish Sea till on parts of the North Wales coast. Such deposits were found under the sands of Traeth Lafan during the construction of the Shell oil pipeline (pers. obs.).

With sea levels 100m or more lower than at present after the ice retreated, most of the shallow eastern Irish Sea was land for several millenia. There are still extensive peri-glacial outwash deposits of sands and gravels, as well as the underlying glacial till. River channels were cut into both the till and the outwash deposits. These can be traced offshore by shallow seismic methods. In a few places sub-tidally there are beds of peat which date from the period between the retreat of the ice and the subsequent marine transgressions.

The rate at which sea level changed, in the Irish Sea is of considerable interest as it bears on the post-glacial spread of terrestrial plants and animals to Ireland. Taking into account both absolute sea level change, the fore bulge resulting from crustal depression under the Scottish ice sheet and the isostatic rebound of parts of the earth's crust, models have recently clarified the probable sequence of events (Wingfield 1995; Yalden 1999; Scourse & Furze 2001). It is important to note that erosive processes acting to modify seabed morphology, at locations that are now well offshore, would have been very much greater in the advancing surf zones than under present conditions when the areas are fully submerged. Understanding of the seabed ecology of the Irish Sea, in particular the occurrence of very extensive areas of lag gravel, has to take into account the reworking of the glacial and peri-glacial deposits during the advance of the surf zone. Computer models of post-glacial sea levels suggest that there was a period when the sea rose particularly fast, so given the wide extent of a former Greater Liverpool Bay lowland plain, the shoreline may have advanced abnormally fast across it. The balance between isostatic rebound and sea level rise may have been complex with incursion of the sea into the northeastern Menai Strait taking place more than once (J. Scourse, pers. comm.).

Geomorphological features of any sedimentary coast take time to develop to maturity. However there are indications of former tidal flat deposits in places that are now well offshore from the North Wales coast. Archaic shells of cockles (*Cerastoderma edule*) frequently occur in positions well away from the usual intertidal habitat of this species, indicating the possible locations of pre-historic tidal flats. Locally the offshore cockle shells from sands several miles north of Puffin Island have not been dated, but the mineral coatings on them suggest they may be of archaic origin.

Evidence for a dramatic change brought about by rising sea levels on the morphology of the North Wales coast, can be found in Conwy Bay. In the present mouth of the Conwy Estuary and just offshore there is a series of boulder and cobble skears. These are the remains of moraines that once blocked the mouth of the Conwy Valley causing the Conwy River to flow to the sea eastwards to Penrhyn Bay through the narrow valley at Mochdre, rather than on the more or less direct north-south alignment where the estuary now opens. When boreholes were put down prior to the A55 Conwy Tunnel trench being excavated a thin horizon of gravel was found between the modern estuary sediments and underlying clays, thought to have been laid down in a moraine dammed lower Conwy Valley lake. This gravel horizon is assumed to represent the break through event. The date at which the Menai Strait opened for through flows remains of considerable interest and the influence this may have had on the shoreline alignments and sediments in Conwy Bay awaits clarification.

Although seabed features of Red Wharf and Conwy Bays are for the most part gently shelving and depths are less than 30 metres, some physiographic features do have relevance to the present day distributions of the benthic biotopes. The more obvious features are listed below (N.B. there are two different banks both with the name "Four Fathom Bank"): -

A. HIGHS

A1. *Lynas Bank*. This name, on Admiralty Charts, is given to a small sandbank lying to the northwest of Point Lynas. The British Geological Survey interpretation of the bed morphology here, on the Anglesey 1;25,000 Sheet by James and Wingfield (1990), is of a pair of small ‘banner’ banks on either side of Point Lynas. (Carter 1988) refers to features of this sort, associated with headlands or other marked corners in coastal alignment, as rectilinear banks. Bank types have also been classified by Dyer and Huntley (1999)

For convenience the pair of banks are referred to here as Lynas Bank West and Lynas Bank East. The west bank is the larger but both have similar well sorted loose medium sand holding only a very sparse macrofauna (pers. obs.). Echo-sounders show mega-ripples super-imposed on the banks. Both banks have tidal overfalls associated with them. Judging from the frequent concentrations of birds (auks & gannets) feeding here the banks are probably attractive to sand eels and hence predatory fish.

A2 *Dulas Bank East*. There is a small feature to the southeast of Ynys Dulas, not named on the chart and with only very slight indication of in the seabed contours. No equivalent is found to the north east of Ynys Dulas. There is however a ‘tombolo’ like feature between Ynys Dulas and the shore. It does not break surface and may possibly be a lower sea level relic feature.

A3. *Red Wharf Bay - Four Fathom Bank*. This seems to be a hybrid between a bay type mud shoal and a rectilinear tidal bank, both types being described by Carter (1988) as being consequent upon headlands deflecting tidal streams and causing gyres to form in adjoining bays at some tidal states. At both ends of the Red Wharf Bay – Four Fathom Bank and along the outer side of it, the sediments are clearly sandy as would befit a rectilinear sand bank, but in the middle of the inner side the muddy sand sediment would be more akin to that found in the mud shoal category.

A4. *Ten Feet Bank*. The situation and sediment would put this small feature in the 'banner' bank category. It lies to the northwest of Puffin Island with an extension that runs towards the Red Wharf - Four Fathom bay bank along the Dinmor shoal. It is positioned where the westwards ebb from Conwy Bay is deflected by Puffin Island. The feature is clearly a small sand bank, with megaripples on the seaward side.

A5. *Irishman Spit*. This is to some extent the pair to Ten Feet Bank as a quasi-banner bank but on the southeast side of Puffin Island. However because it is also subject to the flow to and from the Menai Strait it is not the conventional rectilinear shape and moreover it partly dries at extreme spring tides.

A6. *Conwy Bay - Four Fathom Bank.* This bank lying to the west of the Great Orme has many of the features of the type of rectilinear bank often associated with a prominent headland. The features include a channel between the bank and the headland. The slopes are quite gentle and it has features in common with the Red Wharf Bay bank of the same name, though without the mud shoal of the bay merging with it. The sand here is also finer and less well sorted than the classic medium sand banner banks that are associated with Point Lynas.

On at least two separate occasions in the last decade the relatively shallow but flat area of outer Conwy Bay has been used by specialist vessels while loading or unloading jack-up rigs. For this the vessels are ballasted so as to temporarily ground while the rigs are manoeuvred on or off them.

A7. *Constable Bank*. The western end of this major linear bank on the southern margin of Liverpool Bay lies to the north of the Great Orme and it can be considered as forming the outer eastern corner of the combined Red Wharf / Conwy Bay area. In northwesterly gales seas can be seen from the land to be breaking on Constable Bank. Extension of the bank shows in the charted bed contours where traces of it run further westwards beyond the actual limit of the bank proper (usually taken as being at the West Constable Buoy). A substantial field of sand waves extends on the same alignment as bank. These sand waves are clearly part of the same physiographic feature and they appear to terminate roughly north of the middle of Red Wharf Bay.

A8. *Conwy Skears*. In addition to those patches of stones that uncover at low water, there are a series of boulder / cobble skears off the mouth of the Conwy estuary. Those that break surface at low water have names such as Bwrligau Rocks and Llys Elysiap, but there are also others subtidally that lack individual names. These are all believed to represent the residue of a line of eroded moraines that now barely protrude from the cover of the modern sand / muddy sand deposits. The skears sometimes carry sub-littoral beds of small mussels *Mytilus edulis* though these are subject to heavy predation by starfish *Asterias rubens*. Some clumps of old horse mussels *Modiolus modiolus* have also been found there too. The skears were mapped using RoxAnn by North Western & North Wales Sea Fisheries Committee (W, Cook) as part of investigations of seed mussel resources suitable for transplanting. Selected side-scan sonar images of these skears were given by Coppock (1998). Apart from lag cobble grounds where tidal currents pick up NW of Point Lynas, in Puffin Island Sound and the limited hard ground extending out a short way from rocky shores or as talus below cliffs, there is very little other subtidal ground capable of carrying fully developed communities of sessile epifauna. Trawls do however often pick up clumps of loose hydroid and bryozoan fragments probably brought in by the currents (most commonly the hydroid *Hydrallmania falcata* and hornwrack *Flustra foliacea*). Some of this may originate from further offshore and might have been brought in by scallop dredgers clearing their decks while coming into the bay to shelter.

B. LOWS

B1 *Ynys Moelfre hollow*. Dulas Bay is divided from the main part of Red Wharf Bay by a limestone headland which terminates in a tidal island at Ynys Moelfre. There appears to be just enough acceleration of the tidal streams off here to produce a slight seabed depression which is mainly floored by a very shelly muddy sand, though cobbles are also exposed close in to the island.

B2. *Table Road channel*. This is the channel which runs inside the banks off the NE Anglesey coast from the eastern end of Red Wharf Bay towards Puffin Island Sound. It is mainly floored by slightly muddy fine sand. On the landward side it gives way to the boulder talus that has fallen from the steep limestone cliffs. Possibly the natural talus has been supplemented by material from the several now defunct coastal quarries. On the seaward side the channel rises to a linear sand bank.

B3. *Menai Strait NW Entrance low*. In addition to the deep tidal rapid between Trwyn Ddu (Penmon Point) and Puffin Island, there is a low outside the Sound but inside of Ten Feet Bank. This seems to have a heterogeneous bed comprised of boulders and cobbles with some sand or even muddy sand in pockets.

B4. *Turbot Hole - Puffin Island scour pit*. The name Turbot Hole does not appear on the modern charts but the name was applied to the scour hole off the northern tip of Puffin Island by the LMBC group who worked there in the late 19th century. It has long been known to local boatmen by the same name. A chart of the immediate area around Puffin Island appears in the LMBC reports. The hole is floored by slightly muddy sand but with much coarse shell. This includes quantities of old oyster shells and other shells big enough to be to support epifauna such as colonies of dead men's fingers *Alcyonium digitatum* and serpulid worm crusts. There is sufficient shell to armour the bed here with lag. Currents flowing round Conwy Bay meet those to and from the Menai Strait and so off the tip of the island there are slight tidal overfalls. The hole, which has depths to 24 metres, has a steep slope on the south side adjacent to the island but it shelves gently on the other sides. On the steep slope leading to the shallow channel on the southeast side of Puffin Island there is, or at least was in the 1950s and mid 1960s, a small bed of horse mussels *Modiolus modiolus*, from which Crisp (1954) sourced material when studying the reproduction of the barnacle *Balanus porcatus*.

Turbot Hole has in the past been used as a disposal ground for dredge spoil and the dumping other debris. It is on the list of recognised disposal grounds which DEFRA now maintains in respect of responsibilities under Part 2 of the Food & Environment Protection Act 1985. However, since the Menai Strait was put forward as a proposed Marine Nature Reserve DEFRA officials (previously MAFF) have taken account of this. They have been reluctant to issue FEPA licences for dumping here whenever there was any practicable alternative. More recently, following the designation of the Menai Strait and Conwy Bay cSAC, Regulations 48 and 49 of the Conservation (Natural Habitats, &c.) Regulations 1994 require that any proposal to use Turbot Hole as a disposal ground should be considered by DEFRA, in consultation with CCW, to establish whether it is likely to have a significant effect on the cSAC. Caution is advised in bottom sampling here in view of the debris deposited in the past with or without official approval.

B5 *Penmaen Swatch*. A remarkably steep sided channel divides the Dutchman Bank from the main part of Traeth Lafan in the northeastern part of the Menai Strait. The precise mechanisms for keeping this channel open are not known but it appears in part to be related to the way the tide floods and ebbs from the extensive Traeth Lafan tidal flats. Little is known of the composition of the seabed here.

B6 *Great Orme Swatch*. Off the western side of the Great Orme, a slight channel exists between the headland and the Four Fathom Bank. Close to the shore it is floored by embedded cobbles but only a little way out the cover of shelly sand is nearly complete.

4. ARCHIVED DATA SOURCES OF ASSITANCE IN LOCAL BIOTOPE DEFINITION AND MAPPING

Red Wharf and Conwy Bays have been the subject of many separate sampling exercises, but without there having been a synoptic comprehensive survey of the whole area. The nearest to approach to extensive synoptic benthic surveys were those by UW Bangor, such as that done in Red Wharf Bay by Moore (1983) and the run of monitoring surveys on a grid in Conwy Bay by Allen (1993). The later derived from the A55 Conwy tunnel construction project. Neither of these covered a spread of stations extending to the seaward limits of the areas or the intervening section between the two bays. As often happens there is also a shortage of data for the shallowest zone between depths where research vessels can reach (about 3 m CD) and the ELWS level on the beach which can be accessed on foot.

Most of the UW Bangor sampling used 1mm mesh sieves, but National Museum of Wales sampling (BIOMOR & SWISS projects) as part of wider surveys of the whole of the Southern Irish Sea in 1989, 1991 and 1997, and of a series of sand banks all round Wales in 2001 used 0.5 mm sieves (Darbyshire et al, 2002) The finer sieves, as is usual, resulted in longer species lists, but the data sources are complementary in respect of defining the biotope extent. For the coarser sediment grounds at the northern margin of the area, studies on the impacts of beam trawling by Kaiser and Spencer (1996) from the former CEFAS Conwy laboratory gave an extensive list of species for the offshore gravelly sand biotopes.

A particularly useful indication of the long-term changes to the more reliably recognised benthos of the slightly enriched muddy sands of Red Wharf Bay comes from records of annual student class grab sampling exercises which were run in the same part of Red Wharf Bay, regularly from 1977-1997. While quality control in student sampling would not meet National Marine Monitoring Programme Analytical Quality Control (NMMP AQC) standards, results from such exercises are adequate to show the categories of biotopes present. More importantly, when repeated over a period of years and with multiple replicate samples being taken each year, they can show the temporal changes in the abundance of several common species. This particularly applies to the more reliably sorted and recognised molluscs and echinoderms.

5. NOTES AND COMMENTS ON BIOTOPES

5.1 SEDIMENT CLASSIFICATIONS

Descriptions of the sediments accompanying the accounts of each MNCR biotope were often rather imprecise in the Biotopes Manual (Connor, et al, 1997). This may have been because some biotopes cover a fairly broad range of sediment types or in some of the surveys there may have been a tendency to call sands "muddy sands" if a fines plume came up when divers disturbed the deposit. The British Geological Survey (BGS) used somewhat more precise categories for their seabed sediment map series. BGS used a modified version of the Folk classification where sands were in the "muddy sand = mS" category when the mud content exceeded 10% and was less than 50%. For the minor gravel content values between 1 and 5% put the sediment into a "slightly gravelly" category, the "g" symbol being put in parenthesis, e.g. "(g)mS " for "slightly gravelly muddy Sand". A weakness in the BGS categorisation for ecological purposes was in treating large and stable cobbles / boulders no differently from fine unstable gravel. However for mainstream superficial sediments, the BGS trigon approach has much to commend it.

Experience in Liverpool Bay and other relatively turbid parts of the Irish Sea suggests that the presence of quite small amounts of mud in the interstices of a sand can alter the habitat enough to markedly influence the abundance and composition of the fauna. Mud content is often indicative of different biotopes. For examples see the expanded corner of a Folk trigon, covering sandy stations, included by Mackie, et al. (1995). For ecological purposes and supplementing the BGS categories it may be worth introducing an additional "slightly muddy Sand - (m)S" category for sands with between 1 and 10% mud . For amounts of mud above this the muddy Sand –mS category applies.

There is a very important, but often overlooked, distinction between sands and muddy sands. This comes about because the filling of the interstices between the sand grains with silt/clay causes the sediment to become **cohesive**. The interstitial space (porosity) in typical sands or gravelly sands accounts for about 30% by volume of it. Because of the way water is bound to particles of clay, the volume of the mud component is somewhat greater than conventional dry sieve particle size analyses would suggest (Houwing, 1999). Thus the 9:1 ratio used by BGS in the modified Folk diagram used for the Seabed Sediment maps is not unrealistic as representing the point where free running sediments begin to change to more cohesive ones. The change to cohesive muddy Sands is ecologically very important in terms of habitat suitability for many of those burrowing organisms needing to maintain access to the sediment surface. It also strongly influences the tendency for a redox discontinuity to form within the sediment. The mud component, with a large surface area for microbial colonisation also accounts for most of the organic matter and adsorbed trace pollutants in most sediments.

It is important also to consider how fines become incorporated into the interstices of sandy or gravelly sediments. Immediately after disturbance by waves or currents in shallow inshore waters the sand will usually be left with a rippled surface. Fines from the turbid overlying water will initially be incorporated into the interstices through a process akin to filtration through the open pores of the superficial sediment. Later as the water movements slacken off, particularly on neap tides, a coating of fines may cover the surface of the sand ripples and / or settle preferentially into the troughs. Muds easily become slightly cohesive after settling, so when the currents pick up again after a calm neap tide period, lasting just a few days, the sand from the ripple crests may move over the more cohesive mud lying in the troughs. This creates a heterogeneous sediment with lenses of mud within the sand. Such deposits, with mud clasts in looser sand, are commonly found near to dredge spoil disposal grounds but can occur anywhere where muddy sand sediments are intermittently disturbed. Flume experiments by Hydraulic Research Station, on the deposition of sewage sludge on a rippled sand bed clearly demonstrated the above sequence (Burt, 1983). Bioturbation and the biodeposition of faecal pellets on and in the sediment provide further mechanisms by which organic fines are incorporated into muddy sand deposits. Because of variability in the depth into the sediment of erosive / disturbance processes, muddy sand deposits often show a strong degree of micro scale stratification. For example in the muddy Sand of Red Wharf Bay the sediment surface may show on photographs as a rippled sand, with obvious "lebenspuren" trails of the brittlestar *Ophiura ophiura* and the whelk *Buccinum undatum,* but underneath the bulk of the superficial sediment may be cohesive. Furthermore at only 300 - 500 mm below the surface, a rather stiff consolidated deposit hard enough to resist the penetration of gravity corers has sometimes been found. Partly dug into this stiff clay in places there was a significant population of large bivalves *Mya truncata*. Also there was often a shelly layer at the discontinuity between the intermittently disturbed and bioturbated superficial sediment and the consolidated deposit underneath.

Plate 1.
Sharply rippled sand bed in Red Wharf Bay with a few protruding tubes probably of the sand mason worm *Lanice conchilega*, brittlestars *Ophiura ophiura* and a hermit crab *Pagurus bernhardus*.

Plate 2.
Sediment Profile Image from Red Wharf Bay showing rippled sand surface with more cohesive anaerobic sediment beneath. Arm of a brittlestar *Ophiura* sp. top right.
Photo Brendan O'Connor, Aquafact.

5.2 MUDDY SAND BIOTOPES[1]

Sediments are not normally found in Red Wharf and Conwy Bay that exceed the 1:1 ratio of Mud to Sand, which would bring them to the BGS defined "sandy Mud" category rather than "muddy Sand". Experience of biotopes in the vicinity of the Morecambe Gas Platforms, at depths of 25 - 35 m about 12 miles off the Fylde coast, suggests that the 1:1 ratio dividing line has little ecological meaning. Stations on either side of the "mS - sM" boundary were found with very similar faunas comprising

[1] It should be noted that this report refers to the 1997 version of the MNCR biotope classification (Connor et al 1997). At the time of writing a revised version of this classification was about to be released, containing revisions to the sediment classification. This version is not discussed in this report.

brittlestars *Amphiura filiformis,* at abundances of c1000/m^2, and with sea potatoes *Echinocardium cordatum*, sea pens *Virgularia mirabilis*, mud runner crabs *Goneplax rhomboides* and burrowing shrimps *Callianassa subterranea* all being in the Abundant or Common categories of the MNCR SACFOR scale. This biotope, which is widespread in that part of the NE Irish Sea, most nearly fits the MNCR (1997 version) (Connor et al, 1997) biotope CMS.AfilEcor - *Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand. However it also contains significant elements of MNCR biotope CMU.SpMeg - Seapens and burrowing megafauna in circalittoral soft mud. It should be noted however that the NE Irish Sea form of the biotope frequently occurs in sediments around the “muddy Sand / sandy Mud” boundary. It is not entirely consistent with the MNCR descriptions of the sediment in either the AfilEcor or SpMeg biotopes. In the Irish Sea, biotopes resembling CMS.AfilEcor, where *Amphiura filiformis* most often occurs in SACFOR “common” or “abundant” quantities is always in sediments with enough mud to be cohesive. *Echinocardium cordatum*, which is included in the biotope name, was recognised by Thorson (1957) as having little value for characterising communities because it occurs in such a wide range of sedimentary habitats.

The CMS.AfilEcor MNCR biotope was listed by Brazier et al (1999) as having been found in both Red Wharf and Conwy Bays, though neither the text nor the maps show where the biotope was found. The characterising species, the brittlestar *A. filiformis,* has been found in the inshore muddy Sand of the Red Wharf / Conwy Bay area but only in small numbers. It usually occurs at a ratio of about 1 *A. filiformis* to 500 - 1000 *Amphiura (Acrocnida) brachiata.* These two brittle stars are fairly easy to distinguish. Since the MNCR (1997 version) classification lacked an inshore muddy sand biotope where *Amphiura brachiata* was the abundant characterising species, perhaps Brazier et al (1999) put some stations into a nearest fit.

The brittlestar *Amphiura brachiata* is quite common in the muddy or slightly muddy sand of several shallow bays in both southern Britain and northern France (Bourgoin & Guillou, 1991). Experience in the Irish Sea indicates that an inshore / shallow bay biotope characterised *A. brachiata* is distinct from the much more widespread offshore biotopes where *Amphiura filiformis* dominates. Using "infralittoral" in the terminology of (Glemarec 1973) for sediment facies, rather than the light penetration linked use of the term adopted by the MNCR, would help to clarify the situation. *A. brachiata* predominates in the "infralittoral etage" of Glemarec, whereas *A. filiformis* lives mainly in the "coastal etage" and spreads into the “open sea etage”. Glemarec's classification into three etages, based on the amount of seasonal thermal variation, fits the Irish Sea sedimentary communities rather better than linking "infralittoral" and "circalittoral" to photic depths. Glemarec's “open sea etage” also fits the parts of the western basin of the Irish Sea where there is very strong thermal stratification in summer and where *A. chiajei* becomes the predominant brittle star in muddy sediments (=CMU.BriAchi of the MNCR 1997 classification). The irregular urchin *Brissopsis lyrifera* is no longer a good characterising species for this biotope due to it’s vulnerability to the fishing gear used in trawling for Norwegian lobsters *Nephrops* *norvegicus* on the same habitat, though the easily recognised mouth shields often still persist in the sediment (Ball, et al. 2000).

The brittlestar *Amphiura brachiata* was listed in IMS.EcorEns (*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand). Strangely, *A. brachiata* was the only one in the list of "characterising" species for this biotope which was listed as being "common". All the others, including the two species which give their names to the biotope are listed as only "frequent" or "occasional". In Red Wharf Bay there is a zone, shallower than the muddy Sand where *Amphiura brachiata* is most abundant, where sea potatoes *Echinocardium cordatum* and razor shells *Ensis siliqua* are notable but widely dispersed large sized components of the fauna (O'Sullivan 1977). The sediment however would fall into a slightly muddy Sand, (m)S, category, as the fines component is less than 10%. *Amphiura brachiata* occurs only sparsely here, in contrast to the situation slightly further out, where abundances of c300/m^2 have often been found. *A. brachiata* also occurs very sparsely on the lowest parts of some shores which are only exposed on spring tides. The lowest parts of sandy shores emerging on extreme spring tides frequently show continuity with the faunal composition of truly sub-tidal shallow water biotopes, Water retained in the interstices and on the rippled surface permits this.

Given that light penetration for algal photosynthesis is largely irrelevant in turbid water sediment areas, the "I" in "IMS" biotopes might be better thought of as meaning "**Inshore**" rather than "Infralittoral", in the sense the term was originally used for the MNCR classification. Red Wharf and Conwy Bays, with extensive areas lying at depths <15m CD, are shallow enough to warm to the bottom in the summer months and have water column productivity characteristics typical of slightly enriched near shore waters. The whole area is also subject to annual dinoflagellate *Phaeocystis* blooms which can impose very heavy organic loadings on the seabed. At least, on and inside the sandbanks (sensu stricta) the whole of these two North Wales bays should be considered as holding biotopes with codes prefixed by "I" (IMS, IGS & IMX). Brazier et al (1999) put the muddy sand patches into a CMS category (CMS.AbrNucCor [*Abra alba*, *Nucula nitidosa* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment]). This category was however the only one available. The areas are very close inshore, shallow and infralittoral in most senses of the term.

A comparison between the MNCR biotope listing and the long term averages for Red Wharf Bay inshore muddy sand is shown in Table 2. The long term (1969 – present) top rank species in the muddy Sands of both Red Wharf and Conwy Bays has been the polychaete worm *Lagis koreni*. This is a species often reaching abundances that would put it into a super-abundant SACFOR scale category. Super-abundance occurs in a number of places around the Irish Sea, yet strangely, it is listed as only "occasional" in the MNCR CMS.AbrNucCor biotope description. Conversely the bivalve *Corbula gibba,* which is included in the title of this biotope, and is unmistakable, was only found at abundances that would put it into the "Rare" or an even lower category.

In Table 1 comparisons are made between the MNCR defined CMS.AbrNucCor biotope and the situation pertaining in Red Wharf Bay. The deviation between the two lists is considerable leading to the inescapable conclusion that same biotope was not being referred to.

TABLE 1

Comparison between MNCR Biotope Characterising species (from Connor et al 1997) and muddy sand in Red Wharf Bay (off Llandonna), averages of long term records.

MNCR Characterising Species & Description
"CMS.AbrNucCor *Abra alba*, *Nucula nitodosa* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediments".

	Red Wharf Bay	**`MNCR Listing**
Lagis koreni	Abundant - avg. 1563/m	Occasional = 1 - 9 / m
Amphiura brachiata	Abundant - avg. 224 /m	Not listed
Echinocardium cordatum	Abundant - avg. 34 /m	Present
Abra alba	Common - avg. 712 /m	Abundant = 1000 - 9999 /m
Nucula nitidosa	Common - avg. 519 /m	Abundant = 1000 - 9999 /m
Mysella bidentata	Common - avg. 178/m	Occasional = 1 – 9 /m
Ophiura ophiura	Common - avg. 14 / m	Present
Corbula gibba	Rare - <1/m	Common = 100 – 999 /m
Nephtys hombergii	(*N. caeca* avg. 14/m)	Present
Scoloplos armiger	Present	Present
Ophiura albida	Present	Present
Echiurus echiurus	Not recorded	Present

Plate 3
Inshore muddy sand biotope in Red Wharf Bay. Epifauna visible includes the whelk *Buccinum undatum*, the starfish *Asterias rubens* and brittlestars *Ophiura ophiura*.

5.3 TEMPORAL VARIATION AND INTERPRETATION OF INSHORE MUDDY SAND BIOTOPES

Classifications need to take account of the degree of temporal variation that may often occur in the abundance of several of their characterising species, as well as the variations over the geographic ranges of the biotopes. Of all the shelf sea sedimentary biotopes, those on inshore muddy sand have been subject to more long-term monitoring than any other, so there is a large literature of case histories, particularly from the German Bight and the bays on the north coast of France. Inshore muddy sands seem to particularly prone to large temporal variations in the predominance of various species. Red Wharf Bay fits the pattern reported so often elsewhere. The *Abra* community of inshore muddy sand was one of those targeted by the EU COST 647 collaborative programme on temporal variations.

A location in a rich part of the inshore muddy sand of Red Wharf Bay had been chosen in 1977 by the author as being a suitable place from which to take multiple grab samples for a student class teaching exercise on a day when winds were too strong to work further offshore. The chosen spot had a particularly rich benthos. Subsequently the ship was anchored in virtually the same position and at the same time of year (late October - early November) for similar class exercises. This was done each autumn from 1977 until 1997. Although variable numbers of replicate grabs were taken each year, they were always in sufficient numbers for confidence that most variations were not erratic artefacts of small samples. Often more than 15 replicate grabs being taken on each visit. Although the standards of sample processing by undergraduate or MSc students would not meet modern NMMP AQC standards, the data for the more easily recognised and abundant species can indicate the type of temporal changes taking place in such an inshore muddy sand biotope. It is of added interest because the site was not obviously subject to major man made impact events. Most long term benthic monitoring has targeted locations where anthropogenic effects were the reason for the work. Some records for the same general Red Wharf Bay location also existed, though with fewer replicate samples from various earlier dates back to the mid 1960s. Thus a 35+ year history can be drawn on for this inshore muddy sand habitat.

It is notable that the 20+ years of replicated data from this part of Red Wharf Bay could have possibly caused the same location to be allocated to several quite different MNCR (1997) biotopes, if the separate annual surveys had been viewed in isolation.

Given the degree of temporal variability it is clear that the "Inshore Muddy Sand" should really be regarded as a biotope complex, within which substantial variations take place on both the spatial and temporal axes. It is important that a distinction is made between those species that are short-lived opportunists and those with longer life spans. The later usually have more stable populations. Distinctions are also needed between species that are relatively unselective in their choice of habitat and those occupying a much more specific realised niche.

Both the polychaete worm *Lagis koreni,* which long term was the numerical top rank dominant species in Red Wharf Bay, and the bivalve *Abra alba*, from which MNCR biotope CMS.AbrNucCor takes the start of it's short-hand name, are short lived species prone to great temporal abundance variations (Rees, et al, 1976; Rees & Walker, 1983). Of the two, *Abra alba* is less specific in the choice of habitat, sometimes occurring in abundance in offshore muddy gravelly sands. It also occurs where organic faecal pellet mud accumulate in horse mussel *Modiolus modiolus* beds. On the other hand, bivalves of *Nucula* spp. are longer lived and less prone to wild swings in their abundance, though the precise species of *Nucula* needs to be shown, as the several superficially similar species occupy rather different habitats. The *Nucula* species also vary in their ability to withstand hypoxic events (Holmes et al. 2002). In the case of the inshore muddy sands the species primarily concerned is *Nucula nitidosa* (= *N. turgida*).

Figure 2A.

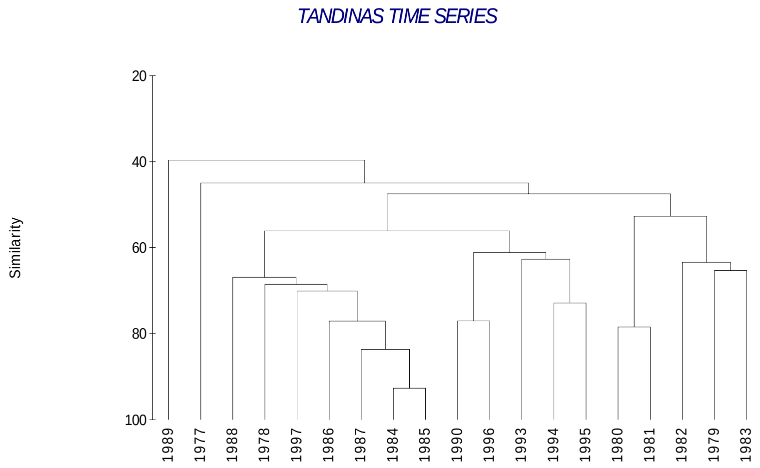

Figure 2B

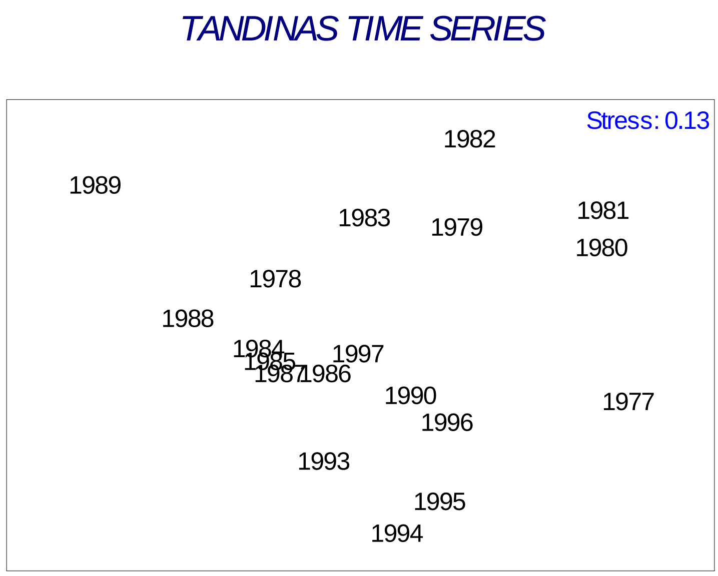

Figure 2A & 2B. Hierarchical cluster and MDS plots (square root transformation) of samples taken annually at a station off Tandinas, Red Wharf Bay.

Two sorts of trend were apparent over the 20 and 35 years of records from Red Wharf Bay. Firstly, there have been long term changes which were reflected most clearly in about an order of magnitude general increase in the abundances of both the bivalve *Nucula nitidosa* and the brittlestar *Amphiura brachiata.* Both are species that are less prone to wild fluctuations in abundance than the polychaete worm *Lagis koreni* and the bivalve *Abra alba*. These changes show up in the MDS plot (Fig 2B) with the samples from the 1970s and early 1980s clustering in a different part of the diagram from those taken in the 1990s Though less abundant overall, the razor shell *Pharus legumen* and the sea potato *Echinocardium cordatum* also became somewhat more prominent over the mid 1960s to mid 1990s period.

It appeared that over time there was a tendency towards increasing stability in the composition of the fauna in this part of Red Wharf Bay, with lessening domination by the opportunists. Although little more than speculation, it is worth noting that when quantitative samples were first taken here in 1969 it was only 6 years after the very severe winter of 1962/63. That winter was reported to have caused mass mortalities of razor shells *Pharus legumen* and other southern bivalves, as well as sea potatoes *Echinocardium cordatum*. This was observed both locally in Red Wharf Bay and in similar bays on the south coast of England (Crisp, 1964). As another inshore species with a general southerly distribution in separated bays, brittlestars *Amphiura brachiata* may also have suffered a major decline at this time. As the *A. brachiata* would have fragmented they would have been a less obvious component of the stranded debris on which the reports of soft bottom benthos mass mortalities were largely based. Further east in the inner parts of Liverpool Bay, both *Echinocardium* and *Amphiura brachiata* were virtually absent in the early 1970s from otherwise apparently suitable locations. At some inshore sites which were sampled regularly during sewage sludge disposal effects monitoring (1970-1995) these two echinoderms had become quite common at the same stations by the mid 1990s. Sludge disposal to sea had continued at high rates at the mid Liverpool Bay disposal ground until December 1998. It is possible that what was observed may have been a gradual return to greater stability in benthic populations after the exceptional and very widespread disturbance event of the 1962/63 winter. The polychaete worm *Lagis koreni* is an important agent of bioturbation and is capable of so destabilising the superficial sediment that it inhibits the recruitment of other species. This fits the "Trophic Group Amensalism" hypothesis of Rhoads & Young (1970). Superabundance of *L. koreni* could have been one agent which prolonged the period when the opportunists controlled the composition of the inshore muddy sand benthos. It should also be noted that the trend towards stability would have slightly moved the position that the Red Wharf Bay stations would have occupied along the organic loading succession axis of Pearson & Rosenberg, (1978).

In addition to sporadic outbursts of polychaete worms *Lagis koreni* and bivalves *Abra alba*, there were other but less expected short lived events in the relative abundance of particular macrobenthic species at the Red Wharf Bay inshore location. This included two separate occasions when there were abnormally large numbers of sand mason worms *Lanice conchilega* present. The sediment at the station off Tandinas remained as the familiar muddy sand, but with very large numbers of the sandy tubes of *Lanice* protruding from it. Eagle (1973; 1975) found similar periodic increases of *Lanice conchilega* in a somewhat similar inshore muddy sand location off the North Wirral coast. This was sub-tidally between the Dee and Mersey Estuaries. The MNCR classification has an IGS.Lcon biotope in the current swept shallow sublittoral, but a version was not listed with them in abundance in muddy sand. Occasional mass colonisation by *L. conchilega* originating mainly from nearby extensive littoral sands seems the likely explanation for such intermittent occurrences. Nicholaidou (2003) showed the way that displaced *L. conchilega* can re-establish.

The other, less explicable, short-lived outburst event was of the tube dwelling amphipods *Ampelisca brevicornis* and *A. tenuicornis*. For just two years in the early 1980s these two species, accompanied by abnormally high numbers of another amphipod, *Photis longicaudata*, were present in such quantities as would have put them jointly into the “Abundant” SACFOR category. The *Photis longicaudata* were assumed to have been clinging onto the numerous *Ampelisca* tubes. The reason for the short-lived high abundance of tube building amphipods was never explained, but there were enough of them at the time for parallels to be drawn with the MNCR biotope category IMU.TubeAP. This latter biotope had been included in the classification on the basis of Danish rather than UK examples of amphipod dominated biotopes.

Plate 4.
Grab sample from the middle of Red Wharf Bay at a time in 1973 when the bivalve *Spisula subtruncata* was particularly abundant. The area of the tray is about the same as that covered by the $0.1m^2$ grab. Also present (top centre) are a smaller numbers of other bivalves *Abra alba*, *Phaxas pellucidus* and one *Mactra stultorum*.

The bivalve *Spisula subtruncata* has nearly always been present in samples from the Red Wharf Bay and Conwy Bay muddy sands. However in most years those sorted from the grab samples were very small spat sized individuals, no bigger than the other very common small bivalve, *Mysella bidentata*. This would suggest that predation intensity on the small *S. subtruncata* was usually such that very few survived to their second or third years. Small mesh beam trawl samples and photographs frequently show substantial numbers of brittlestars *Ophiura ophiura* as well as various other potential predators of bivalve spat. In Red Wharf Bay in 1973 a substantial number of *Spisula subtruncata* from a single age cohort survived into the second and third winters, reaching shell lengths of about 10-15mm. At this time *Spisula subtruncata* became the biomass dominant in the muddy sand in the middle of Red Wharf Bay. Indeed when samples were spread out in trays of about the same dimensions as the $0.1m^2$ area sampled by the grab (Plate 4), they sometimes covered about 80% of the bottom of the trays. At this particular time there were abnormally large numbers (>2000) of Common Scoters *Melanitta nigra* in Red Wharf Bay. The birds were seen to concentrate their diving in the part of the bay where the 1+ and 2 year old *Spisula subtruncata* had been found in great abundance in the grabs. A similar short-lived event, with a single cohort of *S. subtruncata* surviving for 2 years and becoming a significant part of the total biomass, was also observed in Conwy Bay in 1994. *Spisula subtruncata* is well known for its intermittent occurrence in single age cohort patches.

The inshore part of Red Wharf Bay is known to have been subject to two other types of drastic factors influencing the macrobenthos. The shallow water in both Red Wharf and Conwy Bay is intermittently exposed to disturbance by severe northwesterly gales. (Rees, et al. 1977) document one such event that caused mass stranding of the benthic fauna in Red Wharf Bay. Several other storm-induced events are known to have occurred in recent decades. Because the bays are normally quite sheltered the bed is particularly vulnerable to disturbance to the fauna by erratic events with heavy seas from an atypical direction. Usually these events occur in the winter. Similar mass strandings of infaunal benthos have occurred from time to time at Llanfairfechan on the shore of Conwy Bay.

Plate 5
Mass mortality stranding of benthos following a winter storm event in Red Wharf Bay, showing mainly bivalves *Abra alba*, with *Spisula subtruncata* and *Phaxas pellucida*.

The second erratic type of event comes about in summer following intense blooms of the dinoflagellate *Phaeocystis pouchetii*. Recent studies elsewhere have shown that the collapse of intense *Phaeocystis* blooms may be brought about by viruses (Bratbak, et al. 1998). When these blooms collapse the decaying bladders of the colonial dinoflagellate sink to the bottom carrying with them other organic particles from the water column. Near-bed sorting and advective processes, through cyclic deposition and re-suspension, sometimes causes patchy concentration of this decaying organic matter to such an extent that near bed hypoxia occurs. In response to oxygen shortage several of the macrofaunal species commonly emerge onto the sediment surface (Diaz & Rosenberg, 1995). There are several anecdotal reports from Red Wharf Bay of masses of moribund sea potatoes *Echinocardium cordatum* being caught in trawls, coinciding with the times when significant blooms have collapsed. In a few years there have even been mass strandings on to the beach of a black oil-like sludge of decaying organic matter. This occurred when the decaying *Phaeocystis* became particularly concentrated in near bed patches. Masses of decaying benthic organisms were also seen to be entrained with the *Phaeocystis* sludge. At such times members of the general public often attribute what they see to sewage or oil pollution, although eutrophication of coastal waters and the particular sequences of weather events are really the cause.

Plate 6.
Concentrated residue of a *Phaeocystis* bloom forming a black oily sludge, with decaying benthic organisms killed by the associated hypoxia, stranding in Red Wharf Bay June 1989

Concentrations of decaying organic matter following *Phaeocystis* blooms were also reported to have settled in a trench dug to install the Llandudno West Shore outfall pipe to the extent that work was held up. Similar problems were experienced around the Conwy submerged tube tunnel during the installation of it in a dredged trench across the estuary. Intense *Phaeocystis* blooms are known to have occurred as far back as the time when the LMBC group were active on Puffin Island in the 1880s. It is likely that intermittent local mass mortality of the benthos due to patchy hypoxia has happened from time to time here several times in the past. Such events would parallel the similar reports from the North Sea (Dyer, et al. 1983). Although the mechanisms bringing about aggregation of detritus from plankton blooms has not been studied here, (Jago & Jones 1998; Jones, et al. 1998) investigated the mechanism whereby the settling of sticky organic particles brings down other materials as marine snow and cyclic re-suspension then enhances the patchy aggregations of it.

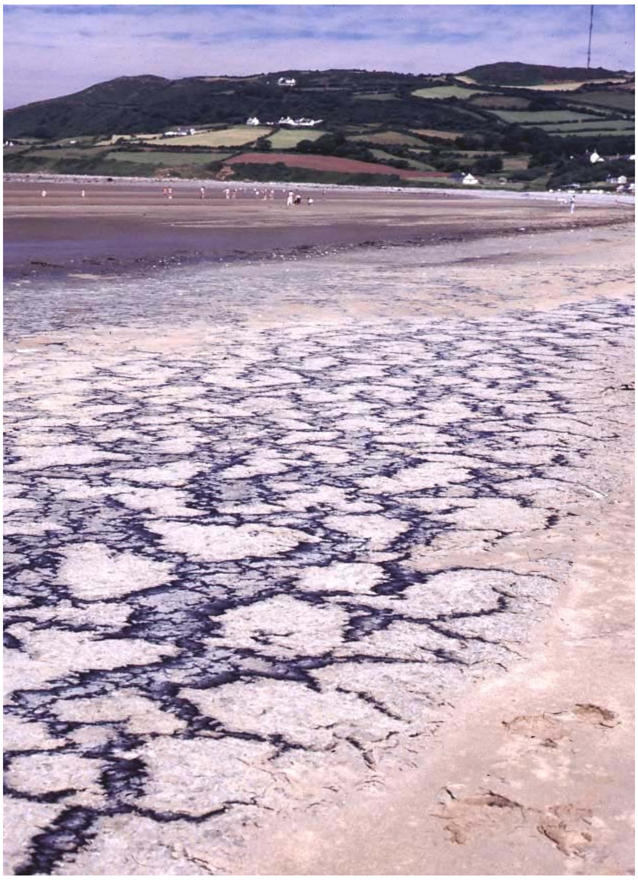

Plate 7
Residue of *Phaeocystis* bloom after the sludge had stranded, partially dewatered by draining into the sand and had begun to dry forming a surface crust. Red Wharf Bay June 1989.

5.4. REVISED CLASSIFICATION OF NORTH WALES MUDDY SANDS

The quite extensive sampling in time and space of Red Wharf and Conwy Bays gives insights into the distinctions that may be made amongst these sorts of inshore sedimentary biotopes. The following conclusions may be drawn from the observations made here: -

A. The Inshore Muddy Sands, having sufficient mud to be cohesive, should be treated in a hierarchical way as belonging to a single broadly defined biotope complex (c.f. the EUNIS system of hierarchy). Below this level the inshore muddy sand biotopes are poorly defined and the dominant constituents can be variable in both time and space.

B. Species with which to give name tags to the lower categories of the biotopes should be chosen with particular care. Those, such as sea potatoes *Echinocardium cordatum,* which are notably non specific in their habitat preferences, need to be avoided unless they have a particular role in structuring the community. This comment applies even though they may be the biggest things present and are easy to recognise in the field.

C. It should be noted that there may be several axes of habitat variation. The three most important for the inshore muddy sand biotopes being; (1) the mud proportion in the muddy Sand, which influences cohesiveness and porosity; (2) the frequency of intermittent disturbance by waves and/or the time elapsed after any catastrophic event, such as an extreme cold winter or a major bottom water hypoxia event, which may have influenced the balance between r and k species and hence community stability; (3) the rates of organic matter input, which if extreme can cause overload and lead to dominance by polychaete worm *Capitella* spp. and the development of IMS.Cap biotopes, as envisaged by (Pearson & Rosenberg 1978) in their organic loading succession series.

D. Variations can occur in both space and time on all the axes. Moreover some of the most abundant species may be prone to great changes due to a combination of chance recruitment events and biotic interactions between the species. The "Trophic Group Amensalism" hypothesis (Rhoads & Young 1970) would apply when the polychaete worm *Lagis koreni* is particularly abundant.

E. In addition to occurring in the Inshore Muddy Sand habitat some of the same muddy sand species can occur at much greater depths such as in the thermal stratification frontal boundary zones. These may also be coincident with fairly sharp transition zones between tide swept sands and muddy basins. It is not the stratification and phytoplankton production in the front as such that influences this but the presence of the sharp depositional gradients resulting in enhanced deposition of organic matter in the sand / mud ecotone zone (Creutzberg, et al. 1984).

F. A scattering of individuals more characteristic of other biotopes may occur regularly in the inshore muddy sands possibly due to post-settlement transport of spat to depositional areas. In Red Wharf and Conwy Bays these include the bivalves *Chamelea gallina* and *Fabulina fabula,* which are both considered characterising species of the adjoining areas of fine sand or only very slightly muddy fine sand. Because the clean sands support only a sparse fauna, *Chamelea* *gallina* and *Fabulina fabula* may be almost as numerically abundant in the muddy sand as in the adjacent clean sand community / biotope, for which they are characteristic. Advection after initial spat settlement is a common feature influencing the distribution of bivalves on the shore and in shallow tidal current influenced habitats (Beukema, 1973).

6. SEDIMENTARY BIOTOPES AND THEIR DISTRIBUTIONS IN RED WHARF AND CONWY BAYS

Following the hierarchical approach adopted for EUNIS, although not precisely the same structure, the sedimentary biotopes of the Red Wharf and Conwy Bay area appear to fall into five major categories. Several of these major categories also have a number of spatial or temporal variants. The higher level categories are dealt with here in a sequence that partly reflects a stratigraphical succession or a depositional gradient. The distribution is illustrated in Figure 1.

A fresh approach has deliberately been taken to the topic of biotope classification locally. Rather than artificially force the biotopes into the nearest MNCR categories (Connor et al, 1977).

1. Embedded Lag Cobbles and Gravel with Sand Veneer

The combination of surf zone processes that acted on deposits of glacial till during the marine transgression about 9000 to 8000 years BP, followed by tidal scour, have left extensive areas in the southern Irish Sea with a seabed of embedded cobbles and shelly gravel in a low relief. Thin patches of sand lie over the lag so that the bed appears to be a spatial mosaic of intermittently exposed sand scoured cobbles. The cobbles are usually embedded, with the interstices between them filled with gravelly sand or shell fragments. Generally only the larger boulders that stand slightly proud of the scour from the sand, carry much erect epifauna.

Being relatively sheltered from tidal currents, not much of the bay area has lag showing at the bed surface. However, four lower level versions of this lag habitat can be recognised in the wider Red Wharf and Conwy Bay area. Mainly these are in the adjacent areas offshore rather than within the current proposed SAC boundaries: -

1A. Lag with little superficial sand, the cobbles being partly cemented together by polychaete worm *Sabellaria spinulosa* tubes.
This type carries a substantial infauna in the spaces between and under the cobbles but otherwise it could also be classed as a much impoverished hard substratum (rock) habitat. Close to the present area it is mainly found in the most tide scoured areas off Point Lynas, but is a very widespread habitat further to the west and in the wider southern Irish Sea.

1B Lag with Serpulid crusts.
Inshore between Point Lynas and Ynys Dulas areas have been seen on seabed photographs where the sand scour is sufficiently reduced for the lag cobbles to develop substantial crusts of serpulid polychaetes, sometimes these form miniature biogenic reefs. On seabed photographs the whole is often seen to be dusted with very fine sand.

1C Lag and other mixed sediment overlain by brittlestar *Ophiothrix fragilis* beds.
Although *Ophiothrix fragilis* beds tend to vary in their position and extent over time, to the east of Point Lynas an extensive *Ophiothrix* bed has been found regularly, whenever the location has been sampled by dredges, trawls or camera sledges, at least since the 1960s. An infauna is still present underneath the brittle stars and with dead men's fingers *Alcyonium digitatum* and dahlia anemones *Urticina* spp. showing prominently on seabed photographs. Unlike the *Ophiothrix fragilis* beds overlying the horse mussel *Modiolus modiolus* in the north part of the Pen Llyn cSAC, the brittlestar *Ophiocomina nigra* did not co-occur in dredge samples or photographs from here.

1D Lag overlain by mussels (*Modiolus modiolus* or *Mytilus edulis*).
This is limited to the skear patches which are the remains of moraines at the mouth of the Conwy Valley and also occurred in the 1960s on the steeply sloping side of Turbot Hole adjacent to Puffin Island. The versions of these mussel biotopes in Conwy Bay are of the types where the faecal pellets are retained to form a muddy deposit amongst the mussels (Holt, et al. 1998). Individual horse mussels are widely but very sparsely present, often 'nested' in the mixed sediments offshore, but without there being enough present to form reefs.

Plate 8
Embedded lag cobbles and gravel partly overlain by a veneer of unstable sand at about 25 m East of Point Lynas. Sand scour preventing growth of much sessile epifauna on the exposed cobbles.

Plate 9
Massed brittlestars *Ophiothrix fragilis* overlying lag cobble / sand veneer habitat with a scattering of small dead men's fingers *Alcyonium digitatum* colonies, dahlia anemone *Urticina sp*. and other anemones.

2. Heterogeneous gravelly and slightly muddy Sand.

Extensive parts of the south-eastern Irish Sea / Liverpool Bay, beyond the coastal strip, have sediments composed of re-worked glacial outwash sands and gravels. Over the millennia since the marine transgression these have accumulated much shell debris so that the gravel component usually comprises a mixture of both mineral pea gravel and broken shell. When seen on photographs the surface appearance often suggests that the sediment is composed almost entirely of the gravel and shell (Rees 1976). However, this is an illusion, there being a scour resisting surface with a lot of dead shell effectively armouring it from erosion. This cover obscures the nature of the bulk of the sediment underneath, where medium sand size particles predominate. Owing to the sometimes turbid overlying water, the interstices between the coarser particles may also have become filled with very fine sand and silt/clay particles. The fine material gets into the interstices both through a filtration process and through the feeding / bioturbation activity of the fauna. On remotely deployed UWTV, whenever a supporting frame disturbed the superficial armour, plumes of fines were seen (Rees, 1976).

Plate 10.
Heterogeneous shelly sand, with mud in the interstices typical of offshore sediments beyond the zone of sand waves and ribbons across the mouths of the bays. The amount of shell visible on the surface is partly a superficial lag veneer. Bioturbation mounds and a few tubes can be seen indicating a fairly rich infauna.

This heterogeneous sediment at depths >25 metres in the Irish Sea often contains quite a rich and diverse fauna. The term 'heterogeneous sediment' is used here, in preference to the 'mixed sediment' term often used. This is to clarify the distinctions between sediment that contains material of a wide range of particle sizes and mosaic (mixed) habitats with a surface showing intermingled patches that might otherwise be considered as separate habitat types if they were separately more extensive.

Most of the observed variation in the fauna of heterogeneous sediment depends on whether there is more or less mud filling the interstices. As with muddy Sand, a critical point is reached when there is enough mud for the heterogeneous sediment to become somewhat cohesive. This allows permanent burrows to be maintained by such species as the burrowing shrimp *Upogebia deltaura*. The muddy gravelly sand version of this biotope off North Wales also has quite high populations of the burrowing anemone *Cerianthus lloydii*. Here and elsewhere in the Irish Sea on muddy heterogeneous sediment, the goose-foot starfish *Anseropoda placenta* is more frequently picked up in trawls and dredges than on any of the other sediment types.

In addition to a rich and diverse infauna the presence of large shells and a few cobbles allows the growth of epifauna including dead men's fingers *Alcyonium digitatum* colonies. These colonies are unable to reach a large size because the shells they are attached to are liable to be turned over by the added drag from the colonial epifauna. The commonest hydroid here is *Hydrallmania falcata* which seems to need only pea sized gravel to attach to.

Over the quasi-basement surface formed by the shelly heterogeneous sediment and away from the most tide swept locations there are often sequences of sand ribbons, patches and medium sized sand ripples. This erratic overlay of sand accounts for much of the variability that is seen when successive grab samples are taken on this type of ground. Much depends on whether the gear landed on the superficial mobile sand or on the shelly basement exposed between the ripples or ribbons. Such mosaic features can be seen on side-scan sonar images from this type of ground. The scale of variation is often such that the mosaic of basement gravel / sand patches cannot usefully be mapped. The mixtures in this biotope are thus on the intimate scale of a heterogeneous sediment as well as a small-scale spatial mosaic.

Also overlying the armoured quasi-basement are a few patches or waves of sand with particle size frequency distributions that are coarser than typical for the rest of the loose sand veneer. These local accumulations of coarse sand / very fine gravel often hold greater numbers than elsewhere of the larger veneriid bivalves such as *Circomphalus casina, Tapes rhomboides* and *Clausinella fasciata.* The purple heart urchin *Spatangus purpureus* is also quite common. There was also a substantial population of the bivalve *Laevicardium crassum* on the heterogeneous ground NE of Point Lynas when sampling was done here with dredges in the 1960s. This was before there had been intensive commercial scallop dredging or heavy beam trawl fishing for soles *Solea solea* in the same area. It also appeared that in places the surface of the coarser sand patches was in part being stabilised by large clumps of the hydroid *Nemertesia antennina*. This hydroid seasonally dies back but the ramifying holdfasts of the clumps remain and from these new fronds regenerate each year (Gili & Hughes, 1995). The grains of the medium sand veneer can readily be observed on UWTV to be moved by tidal currents. Different circumstances need to be envisaged to bring about the separate sorting of the coarse sand / fine gravel. Whether this takes place intermittently under extreme storm conditions or whether the fine gravel patches are partly relict features is unclear..

The most comprehensive recent data set on the benthos of the heterogeneous gravelly sands offshore from Red Wharf Bay derives from beam trawl impact experimental studies by Kaiser and colleagues (CEFAS – Conwy) (Kaiser & Spencer, 1996). The grab samples from this project were mainly worked up by Unicomarine. It happened that part of the chosen experimental area was on the basement gravelly sand with another part having overlying mega-rippled sand ribbons. With quite large numbers of samples having been processed from a limited area using 0.5mm mesh sieves, a long species list was generated. A somewhat impoverished version of the same fauna was found on the sand mega-ripple patch compared to the heterogeneous basement found in the other part of the experimental area.

Identifiable sub-divisions of the heterogeneous sediment biotope here and elsewhere in the Irish Sea seem to comprise the following, but the sub-divisions do sometimes grade one into another:-

2A Quasi-basement heterogeneous shelly gravelly slightly muddy Sand

2B As Type 2A, but overlain by a thin patchy veneer of rippled medium sand

2C As Type 2A, but with enough interstitial mud to become fully cohesive

2D As Type 2A, but with isolated patches or waves of coarse sand / fine gravel and having much more open interstices.

3. Major Sand Wave Fields and Banks of Unstable Sand

Two main fields of sand waves with generally sparse faunas lie across the combined Red Wharf / Conwy embayment. One of these fields lines up with Constable Bank and effectively forms a western extension of it. The other lines up with and forms the western extension of the Conwy Bay Four Fathom Bank. The sand waves are seen on echo-sounders to be asymmetrical in both these fields. Some of the banks further into the bays also have well sorted and obviously mega-rippled sand on their outer sides. More stable slightly muddy sand occurs on the inner side of the sand banks.

. In places the sequence of sand waves is continuous but in others the waves are separated and the more heterogeneous basement of shelly gravelly sand is exposed. Where this is the case, adjacent replicate grabs at the same station will often yield obviously different sediment.

The fauna of the sand waves is particularly sparse, though it becomes more diverse wherever the basement is uncovered. A crab that is a specialist in the sand wave habitat is the thumbnail crab *Thia scutellata* (Rees, 2001). Though a scarce species nationally, it has quite frequently been reported from the Red Wharf / Conwy Bay sand wave zone. Here it has been collected in grabs and recovered from the stomachs of thornback rays *Raja clavata*.

4. Plains of Medium – Fine Sand

Conwy Bay in particular has an extensive area of nearly flat sand. The dominant grain size is in the finer part of the medium sand range. Mostly there are only enough fines for it to be categorised as 'slightly muddy Sand'. This type of ground is characterised by the bivalve *Fabulina fabula* and such amphipods as *Bathyporeia guilliamsoniana*.

In addition to the sand plain extending well out in Conwy Bay, a somewhat similar biotope occurs in the immediate sub-littoral of the sandy bays. Only one quantitative study has been done here of the inshore transition between the muddy sands and the shallowest subtidal sand (O'Sullivan, 1977). There is often a gap between the depths where samples can easily be taken from research vessels and the lowest parts of the shores only exposed to sampling on foot on extreme spring tides. The fringes of the populations of generally sub-tidal species often extend onto the lowest part of the shore. The lower halves of the sand beaches in both Conwy Bay and Red Wharf Bay are predominantly of the ridge and runnel type. Below MLWS levels there are sparse populations of razor shells *Ensis siliqua,* brittlestars *Amphiura brachiata,* worms *Arenicola ecaudata* and sea potatoes *Echinocardium cordatum.* The depth at which the transition occurs to the muddy sand biotope was shown by O'Sullivan (1977) to be related to exposure to swell waves. The transition was much shallower in Red Wharf Bay than on the western and more exposed side of Anglesey at Aberffraw.

5. Inshore Muddy Sand Patches

Red Wharf Bay, Conwy Bay, Dulas Bay and Llandudno Bay each have inshore patches of muddy sand carrying dense macrofaunas, that in Red Wharf Bay is the most extensive, most sheltered and most consistent. That in Conwy Bay may have been slightly more extensive during the period when the Conwy Tunnel trench was being dredged in the estuary, but it does seem to have been a permanent feature. Only a few samples have been taken in Dulas Bay, so though the precise extent may not be clear, there is known to be a definite depositional muddy sand patch there also. By contrast Llandudno Bay is too shallow and the area protected from tidal streams too small to hold more than a very limited patch of ground only just has the qualifying as enriched muddy sand.

7. NOTES ON SOME PROMINENT SPECIES

Lagis (Pectinaria) koreni **(Polychaeta – polychaete worm)**

This tube building trumpet worm occurs for much of the time in quite large numbers in the muddy sand parts of the bays and long-term has been the numerical dominant. It is however an opportunistic species and numbers vary hugely from time to time. At times the population densities may exceed 10,000 / m^2 but 500 – 2000 / m^2 is more normal. From the size distributions observed it is likely that pulses of recruitment may occur over an extended period in summer. Very few survive more than a year. As they are deposit feeders, when they are very abundant, they are capable of turning over the top 30-40mm of the sediment every few weeks. At high densities they may inhibit the recruitment of other organisms. They are not very specific in their habitat requirements so some occur in a wider range of sediments than the inshore muddy sand. A few of the superficially similar *Amphictene auricoma* also come up in grabs but the species is usually larger and the more curved tube is notable.

Mya truncata **(Mollusca, Myacea – blunt gaper shell)**

This large bivalve occurs in the inshore muddy sand particularly in the SE part of Red Wharf Bay. Because it lives deeply in the sediment, grabs normally cut off the leathery siphons or break the tip of the shells. Using an Olafson box corer intact individuals were collected in the life position within the sediment. In the preferred habitat the full grown adults occurred at abundances of 5 – 20 / m^2. Only a few small spat sized individuals were found in the grab samples, suggesting that recruitment is intermittent and the large ones may be decades old. Erratic and intermittent recruitment is a common feature of the population dynamics of large benthic bivalves

Asterias rubens **(Echinodermata, Asteroidea – common starfish)**

Although often considered to be a hard ground species preying on such bivalves as *Mytilus edulis*, the common starfish is at times remarkably abundant on the muddy sand ground in Red Wharf and Conwy Bays. Allen (1981) studied the predation by *A. rubens* on infaunal bivalves in Red Wharf Bay. He used UWTV to estimate populations of the starfish and in large aquaria observed the selective predation rates on the various bivalves. In summary, they were very effective at digging out bivalves *Abra alba* and *Spisula subtruncata* from the sediment, but were less able to consume *Nucula nitidosa*. *Asterias rubens* is often abundant in the by-catch of benthos picked up in trawls in the two bays. There are anecdotal reports of there being so many starfish at times that it became impossible for small commercial trawlers to fish here for flatfish.

Astropecten irregularis **(Echinodermata, Asteroidea - sandstar)**

Freeman, et al (2001) studied the ecology of this species in a limited area off Table Road. They were fortunate to begin the study at a time when there had been a substantial recruitment of small *A. irregularis*, thus they were able to track the growth and survival of a particular cohort for two years. It is not as abundant as *Asterias rubens*, but it is a regularly picked up whenever small mesh trawls are deployed in Red Wharf and Conwy Bays. The commensal scale worm that lives in the ambulacral grooves of *A. irregularis, Acholoe astericola*, is frequently found in >25% of the starfish here.

Echinocardium cordatum **(Echinodermata, Spatangoida – sea potato**)

Though common in the muddy sands and sublittoral fine sands of both bays, recruitment variations result in abundances varying by one to two orders of magnitude. A particularly high recruitment was detected in 1995/96 as indicated by the size frequency below.

Conwy Bay E side – 14th Feb 1966

Length mm	10	11	12	13	14	15	16	17	18	19	20	21	----	31	32	33	34	35	36	37	38
Numbers	1		1	6	12	16	30	23	24	13	9	2		1		1	2	1	2	1	1

8. NOTES ON SENSITIVITIES AND CONSERVATION PRIORITIES

Both bays clearly meet the criteria for the Habitats Directive category of "Large shallow inlets and bays" in being both large and shallow. Red Wharf Bay has a particularly good example of inshore slightly enriched muddy sand ground. It is of the type that occurs in somewhat sheltered shallow bays that happen to be near to areas with much stronger tidal streams. These circumstances cause there to be sharp depositional gradients causing the net inward advection of organic particulate matter to locally enrich the benthos. Compared to other bays Red Wharf is bivalve rich, of particular note in recent years being the large populations of razor shells *Pharus legumen*. There is also an area with a substantial population of bivalves *Mya truncata*

The area contains sand banks of several types, although some of them fall outside the boundaries drawn for the SAC. The best examples, in geomorphological terms, of banner banks are those off Point Lynas and thus outside the proposed SAC boundaries. As for linear sand banks, only the tip of the Constable Bank is within the area, the other linear banks within the area are lesser examples of this type of feature.

No sedimentary benthic species of particular conservation concern, as listed on Wildlife & Countryside Act Schedules or in the Habitats Directive Annex II, are known to occur. Of species regarded as Rare or Scarce on the basis of numbers of 10 km squares where the MNCR had records of them (Sanderson 1996), only the thumb-nail crab *Thia scutellata* has been recorded at all frequently from the Red Wharf / Conwy Bay area. This crab has subsequently been shown to be rather more widespread, although it is rather specialised in the types of unconsolidated sand it occupies habitat (Rees 2001). Nevertheless, the sand wave areas off North Wales, including those to the east in Liverpool Bay, seem to be a notably good area for it.

Only a few of the species deemed to be of "Conservation of Concern in Wales" (Moore 2002) occur in the Red Wharf and Conwy Bay area. This is not surprising, as the major part of the list he was asked to review comprised rocky habitat species having southern distributions and which just reach SW Wales. The list did include oysters and there are a few, mainly old records of living *Ostrea edulis*. Also on the list was the horse mussel

Modiolus modiolus, but the clumps found in Conwy Bay pale into insignificance alongside the fully developed *Modiolus* beds in deep tide-swept areas NW of Anglesey.

A case can be made in support of conservation measures in these bays on account of their value as flatfish nursery grounds and because of the long history of scientific studies here.

There are several potential threats to the benthic ecology of the area. Some of these are more amenable than others to management actions through the statutory powers of the appropriate competent authorities. As usual some of the threats envisaged derive from unpredictable catastrophic events, though others do come within the ambit of provisions for “Plans & Projects”, whereby, under Regulations 48 and 49 of the Conservation (Natural Habitats, &c.) Regulations 1994 any “plan or project” which is not directly connected with, or necessary to the management of the site for nature conservation, be considered by competent authorities, in consultation with CCW, to establish whether the plan or project is likely to have a significant effect on the SAC.

The sea area lying to the east of Point Lynas and in Red Wharf Bay has long been one of the main anchorages for shipping in the Eastern Irish Sea. It is used both for shelter during SW gales and by ships awaiting berths in Liverpool. In the recent past the bay was used for transferring oil between vessels to lighten VLCC tankers. Some seabed disturbance arises from ships anchors, but this is mainly on gravelly sand grounds seaward of the present cSAC boundary.

A more serious, but unpredictable threat, would arise were a seriously damaged ship to be brought into the bay after an accident. Being a recognised and sheltered anchorage this is one of the obvious places to which a ship might be brought after a collision or other major incident. Various pollution or seabed disturbance scenarios during salvage operations may be envisaged given that the very shallow sandy grounds would favour the deliberate grounding of a sinking casualty while it is stabilised. An older vessel having little residual value to insurers or foreign owners might even be abandoned here. This was the case with the vegetable oil tanker *Kimya* in Caernarfon Bay. The best known example of salvage operations in Red Wharf Bay involving progressive dragging of a sunken casualty into water shallow enough for it to be worked on was when Traeth Bychan was used for this purpose after disaster overtook the submarine *Thetis* in 1939.

Twice in recent years the relatively flat sand grounds in Conwy Bay have been used for loading or unloading jack-up drilling rigs onto specialised ships. Such operations involve sinking a specialised carrier vessel onto the bottom in sufficiently shallow water and then using the tidal rise and fall to float the rig on or off its deck. Localised seabed disturbance pits from the legs of jack-up rigs are readily apparent on side-scan sonar records. With the upsurge in offshore wind farm construction in Greater Liverpool Bay, the “parking” of rigs or other construction barges in the Red Wharf / Conwy Bay area can be envisaged. It is therefore recommended that clarification be sought as to whether operations associated with such rather atypical ship loading activities would be classified as a "Plan or Project" in the context of SAC management

The second major cause for concern would be if there were proposals to exploit the populations of infaunal bivalves in the bays by hydraulic jet or suction dredging equipment. Markets exist for several of the bivalves that occur in the bay and some are at times present in quantities that might attract proposals for exploitation. Since such new fisheries would require permits under byelaws of the North Western and North Wales Sea Fisheries they would be subject to the "Plans & Projects" procedures for consultation and environmental assessment.

A third but unquantifiable threat comes from the potential within Greater Liverpool Bay for phytoplankton blooms, particularly enhanced by local eutrophication off the North Wales coast. Seasonally mediated regeneration of nutrients from the enriched inshore muddy sediments contributes to the localised potential for blooms to occur. Problems may arise from particularly intense *Phaeocystis* blooms causing nearbed hypoxia, or blooms of toxic dinoflagellates. The tendency for non-native phytoplankton species be found in sea areas adjacent to major ports adds to this cause for concern. It should be noted that the dominant planktonic diatom now found in the waters of the two bays during the autumn and winter months (*Cosscinodiscus wailsei*) is an introduced species (2001).

9. SUGGESTED PRIORITIES FOR FURTHER INVESTIGATIONS AND MONITORING

The least known parts of the sediment biotopes in the Red Wharf and Conwy Bay complex are in Penmaen Swatch as this channel amongst the drying banks is not considered a suitable place to take research vessels. Another poorly known zone is between the immediate sub-tidal and the depths that can easily be worked from ships. This zone will probably have to be worked by divers.

Although acoustic ground discrimination systems (AGDS), including both RoxAnn and QTC has frequently been employed as have side-scan sonar and boomers, there will eventually be a need for a concerted synoptic survey of the whole bay complex. The aim would be to derive more detailed maps of the bedforms and sediments. Probably multi-beam sonar would need to be employed.

There is need for better understanding of the mechanisms that result in the selective advection of settling organic detritus into the enriched muddy sand patches. Ecologically these muddy sands are both the most interesting parts of the bays and most productive. They are also the most vulnerable to hypoxic events causing mass mortality of the benthos and are sensitive to other forms of disturbance. Those responsible for the SAC should be prepared to contract out or themselves mount reactive surveys at short notice when such unpredictable events occur.

As there is already a time-series of macrobenthos sampling in part of the muddy sand biotope of Red Wharf Bay, it would be worth sampling the same location from time to time in the future. It is advocated that annual samples are collected from a series of carefully selected sites. No more than one day of ship time per year would be needed. Given the cost of processing benthos samples it would be worth collecting and archiving such samples even if they are not worked up immediately and every year. Notes made in the field while samples are sieved will often pick up sufficient evidence to show if major changes have taken place and whether the samples need to be fully sorted in the laboratory.

10. CONCLUSIONS

The Red Wharf and Conwy Bay complex encompasses a fairly wide range of shallow water sedimentary benthic biotopes. This is especially so if the natural area is defined as running out to the 30m contour off the headlands that define the area rather than being restricted to the smaller areas within the lines drawn for the SAC. The Menai Strait / Conwy Bay cSAC may be thought of as being in two major parts, namely the Strait and the bays outside the northern end of it. By area if not complexity the bays account for more than half the total extent. It is estimated that about 98% of the floor of the bays is covered by sedimentary biotopes. These are predominantly various types of sand biotope. The richest and most productive sediment biotope is the inshore cohesive muddy sand that occurs to some extent in each of the bays. In trying to fit this into various classification schemes there was no difficulty in finding a place for it in the schemes put forward by Petersen (1913), Jones (1950) and Glemarec (1973) but there were considerable discrepancies with any of the categories in the MNCR scheme (Connor et al, 1997).

Two major conclusions can be reached from considerations of the benthos and seabed data from this area. The first is a philosophical one which relates to the term "biotope". As presently understood this term is intended to cover both the physical habitat and the fauna found on or in it. There has been a tendency to classify sedimentary biotopes with the overwhelming weight being given to the fauna lists. This derives in part from the common habit of feeding biological data into statistical packages such as Primer to derive clusters. Insufficient weight is often given to the subtleties of the habitat half of the "biotope" term. Seabed photographs, particularly where more unstable sands overly other materials as veneers help understanding of habitat heterogeneity. The second conclusion is that more account needs to be taken of temporal variations in faunal composition. This is a particular feature of the inshore muddy sands. These can best be classified as a biotope complex that varies both in time and space. Furthermore the separate terms "Infralittoral" and "Circalittoral" have little meaning and may be misleading. In the context of the shallow North Wales bays the "I" is better understood as meaning "Inshore".

Some scope for confusion exists in terms of conservation priorities and terminology deriving from interpretations of the Habitats Directive. The bays at the northern end of the Menai Strait were included in the cSAC on the basis of "Sandbanks".

sensu lato the term has been stretched to include nearly level areas of muddy sand which *sensu stricta* would not fit geomorphological definitions of sub-tidal sandbanks. Although there are features within the cSAC validly classified as "Sandbanks", other examples of such geomorphological features are found outside the cSAC boundaries. The Habitats Directive Annex I feature "Shallow Inlets and Bays" is cited only as a feature type present in the cSAC rather than a primary reason for designation. The inshore muddy sand biotope is the type probably of most interest within the cSAC. This is really a natural component of "Shallow Inlets and Bays" rather than "Sandbanks".

ACKNOWLEDGMENTS

The background benthos data on which much of this review is based derive from sea trips with generations of undergraduate and MSc students some of whom now occupy prominent positions in the marine sciences. In view of the numbers and to spare blushes they are not all listed here, In addition I have drawn particularly upon MSc or PhD research projects by Jon Moore, Geoffrey O'Sullivan, Peter Allen, John Coppock and Artemis Nicholaidou, plus studies on the impacts of the dredging for the A55 Conwy Tunnel by Peter Allen. Michel Kaiser kindly gave access to raw results from his experimental work on impacts of beam trawling.

I am grateful to those staff of CCW who prompted me to dig back into old files, notes and memory and to this set out my views of the classification and distribution of biotopes in the inshore waters of the Eastern Irish Sea. In particular I thank Mandy McMath and Kirsten Ramsay for their support, forbearance and gentle goading.

REFERENCES

Allen, J. A. (1961). The British species of *Thracia* (Eulamellibranchia). J. mar. biol. Ass. U.K. **41**: 725-.

Allen, P.L. (1981). The role of Asterias rubens as a soft bottom predator. MSc thesis, School of Ocean Sciences, University of Wales Bangor.

Allen, P.L. (1983). Feeding behaviour of Asterias rubens L. on soft bottom bivalves: Astudy of selective predation. J.exp.mar.Biol.Ecol. 70: 79-90.

Allen, P. L. and Rees, E.I.S. (1999). Irish Sea Seabed Image Archive (ISSIA): a directory of seabed camera studies in the Irish Sea. Bangor, Report for the UK Department of Environment Transport and the Regions. School of Ocean Sciences, University of Wales.

Baker, R. A. (1994). The marine biological station on Puffin Island (Ynys Seiriol) and the work of the Liverpool marine biology committee (1887-1892). Archives of Natural History **21**: 217-224.

Ball, B. J., Fox, G. and Munday, B.W. (2000) Long- and short-term consequences of a *Nephrops* trawl fishery on the benthos and environment of the Irish Sea. ICES Journal of Marine Science **57**(5): 1315-1320.

Beukema, J. J. (1973). Migration and secondary spatfall of *Macoma balthica* (L.) in the western part of the Wadden Sea. Netherlands Journal of Sea Research **23**: 356-357.

Bratbak, G., Jacobsen, A. and Heidal, M.(1998) Viral lysis of *Phaeocystis pouchetii* and bacterial secondary production. Aquatic Microbial Ecology **16**: 11-16.

Brazier, D. P., Holt, R.H.F. Murray, E. and Nichols, D.M. (1999) Marine Nature Conservation Review Sector 10. Cardigan Bay and north Wales: area summaries,. Peterborough, Joint Nature Conservation Committee.

Campbell, A. R., Simpson, J.H. and Allen, G.L.(1998). The dynamical balance of flow in the Menai Strait. Estuarine, Coastal and Shelf Science **46**(3): 449-455.

Carter, R. W. C. (1988). Coastal Environments. An Introduction to the Physical, Ecological and Cultural Systems of Coastlines. London, Academic Press.

Connor, D. W., Dalkin, M.J., Hill, T.O., Holt, R.H.F. and Sanderson, W.G. (1997). Marine Conservation Review. Marine biotopes classification for Britain and Ireland. Volume 2. Sublittoral biotopes. Version 97.06. Peterborough, Joint Nature Conservation Committee.

Coppock, J. (1998). Benthic communities, sediment and acoustic studies in Conwy Bay. MSc thesis, School of Ocean Sciences, University of Wales Bangor**:** 88 + Appendices.

Creutzberg, F., Wapenaar, P., Duineveld, G. and Lopez Lopez M. (1984). Distribution and density of the benthic fauna in the southern North Sea in relation to bottom characteristics and hydrographic conditions. Rapp. et Proc. Verb. Cons.int perm Explor. Mer **183**: 101-110.

Crisp, D. J. (1953). Marine biology in North Wales. Proceedings of the Llandudno (Colwyn Bay) & District Field Club **1953**: 15-22.

Crisp, D. J. (1964). The effects of the severe winter 1962-1963 on marine life in Britain. J. Anim. Ecol. **33**: 165-210.

Crisp, D. J. and E. W. Knight-Jones (1955). Discontinuities in the distribution of shore animals in north Wales. Report of Bardsey Bird and Field Observatory **2**: 29-34.

Darbyshire, T., Mackie, A.S.Y., May, S.J. and Rostron, D. (2002). A Macrofaunal Survey of Welsh Sandbanks. National Museums and Galleries of Wales. CCW Contract Science Report No. 539.

Diaz, R. J. and R. Rosenberg (1995). Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanography and Marine Biology **33**: 245-303.

Dyer, M. F., Pope, J. G., Fry, P.D., Law, R.J. and Portmann, J.E. (1983). Changes in fish and benthos catches off the Danish coast in September 1981. J. mar. biol. Ass. U.K. **63**: 767-775.

Edwards, M., John, A.W.G., Johns, D.G. and Reid, P.C. (2001). Case history and persistence of the non-indigenous diatom *Coscinodiscus walesii* in the north-east Atlantic. J.mar.biol.Ass.U.K., **81**: 207-211.

Ellis, J. R., Rogers, S.I. and Freeman, S.M. (2000). Demersal assemblages in the Irish Sea, St. George's Channel and Bristol Channel. Estuarine, Coastal and Shelf Science **51**(3): 299-315.

Foster, P., Voltolina, D. and Beardall, J. (1982). A seasonal study of the distribution of surface state variables in Liverpool Bay III. An offshore front. Journal of Experimental Biology and Ecology **58**: 19-31.

Freeman, S. M., Richardson, C.A. and Seed, R. (2001). Seasonal abundance, spatial distribution, spawning and growth of *Astropecten irregularis* (Echinodermata: Asteroidea)." Estuarine, Coastal and Shelf Science **53**(1): 39-49.

Gili, J.-M. and Hughes, R.G. (1995). The ecology of marine benthic hydroids. Oceanography and Marine Biology **33**: 351-426.

Glemarec, M. (1973). The benthic communities of the European North Atlantic continental shelf. Oceanography and Marine Biology. An Annual Review. **11**: 263-289.

Goodwin, N. B., Dare, P.J., Belson, S.J., Gunstone, K.L., Ellis, J.R. and Rogers, S.I. (2001). A Catalogue of DEFRA Historical Research Vessel Data. Lowestoft, Centre for Environment, Fisheries & Aquaculture Science.

Herdman, W. A. (1889). The foundation and first season's work of the Liverpool marine biological station on Puffin Island. Fauna of Liverpool Bay and the neighbouring seas. Liverpool, Liverpool Marine Biological Committee. **3:** 38-53.

Herdman, W. A. (1893). Sixth annual report of the Liverpool marine biological committee, and their biological station at Port Erin. Report of the Liverpool Marine Biology Committee **6**: 3-31.

Herdman, W. A. (1920). Summary of the history and work of the Liverpool marine biology committee. Proceedings and Transactions of the Liverpool Biological Society **34**: 23-74.

Holt, T. J., Rees, E.I.S., Hawkins, S.J. and Seed, R. (1998). Biogenic Reefs (volume IX). An overview of dynamics and sensitivity characteristics for conservation and management of marine SACs, Scottish Association for Marine Science (UK Marine SACs Project)**:** 170pp.

Jago, C. F. and Jones, S.E. (1998). Observation and modelling of the dynamics of benthic fluff resuspended from a sandy bed in the southern North Sea. Continental Shelf Research **18**(11): 1255-1282.

James, J. W. C. and Wingfield, R.T.R. (1990). Anglesey. Sheet 53°N-06°W, including part of Dublin 53oN-08oW. Sea Bed Sediments. Southampton, British Geological Survey.

Jones, S. E., Jago, C.F., Bale, A.J., Chapman, D., Howland, R.J.M. and Jackson, J. (1998). Aggregation and resuspension of suspended particulate matter at a seasonally stratified site in the southern North Sea: physical and biological controls. Continental Shelf Research **18**(11): 1283-1309.

Kaiser, M. J. and Spencer, B.E. (1996). The effects of beam-trawl disturbance on infaunal communities in different habitats. Journal of Animal Ecology **65**(3): 348-358.

Kaiser, M.J. (2004). Sandbank survey – fish stomach content, fish epibenthic survey analysis. CCW Contract Science Report No. 610.

Khan, M. A. and Williamson, D.I. (1970). Seasonal changes in the distribution of Chaetognatha and other plankton in the eastern Irish Sea. Journal of Experimental Marine Biology and Ecology **5**: 285-303.

Macer, C. T. (1967). The food web in Red Wharf Bay (North Wales) with particular reference to young plaice, *Pleuronectes platessa*. Helgolander Wissenschaftiche Meeresuntersuchungen **15**: 560-573.

Mackie, A. S. Y., Oliver, P.G. and Rees, E.I.S. (1995). Benthic biodiversity of the Southern Irish Sea. Biomor 1, 263pp. Cardiff, National Museums & Galleries of Wales.

Moore, J.J. A benthic survey of Red Wharf Bay. MSc thesis, School of Ocean Sciences, University of Wales Bangor.

Moore, J. J. (2002). An atlas of marine Biodiversity Action Plan species and habitats and Species of Conservation Concern in Wales, Coastal Assessment Liaison & Monitoring**:** 202 pp.

Nicholaidou, A. (2003). Observations on the re-establishment and tube construction by adults of the polychaete *Lanice conchilega*. J.mar.biol.Ass.U.K., **83**:1223-1224.

O'Sullivan, G. (1977). The influence / effect of wave exposure on shallow water macrobenthos communities. MSc thesis, Bangor, University College of North Wales.

Pearson, T. H. and Rosenberg, R. (1978). Macrobenthic succession in relation to organic enrichment and pollution in the marine environment. Oceanography and Marine Biology. An Annual Review. **16**: 229-311.

Rees, E. I. S. (1976). Notes on benthos visible using underwater TV and in cores. Out of Sight Out of Mind, Report of a Working Party on sludge disposal in Liverpool Bay. **4**(Appendix M): 185-188.

Rees, E. I. S. (2001). Habitat specialisation by *Thia scutellata* (Decapoda: Brachyura) off Wales. J. mar. biol. Ass. U.K. **81**: 697-698.

Rees, E. I. S., Eagle, R.A. and Walker, A.J.M. (1976). Trophic and other influences on macrobenthos population fluctuations in Liverpool Bay. 10th European Marine Biology Symposium, Ostend, Universal Press, Wettern, Belgium.

Rees, E. I. S., Nicholaidou, A. and Laskaridou, P. (1977). The effects of storms on the dynamics of shallow water benthic associations. Biology of benthic organisms. P. J. S. Boaden. Oxford, Pergamon Press**:** 465-474.

Rhoads, D. C. and Young, D.K. (1970). The influence of deposit-feeding organisms on sediment stability and community trophic structure. Journal of Marine Research **28**: 150-178.

Sanderson, W. G. (1996). Rare marine benthic flora and fauna in Great Britain: the development of criteria for assessment.

Scourse, J. D. and Furze, M.F.A. (2001). A critical review of the glaciomarine model for Irish Sea deglaciation, evidence from southern Britain, the Celtic Shelf and adjacent continental slope. Journal of Quaternary Science **16**: 419-434.

Thorson, G. (1957). Bottom communities (sublittoral or shallow shelf). Memoirs of the Geological Society of America **67**: 461-534.

Wingfield, R. T. R. (1995). A model of sea-level changes in the Irish and Celtic seas during the end-Pleistocene to Holocene transition. Island Britain: a Quaternary perspective. R. C. Preece. London, Geological Society. **Special Publication 96:** 209-242.

Yalden, D. (1999). The History of British Mammals. London, T&A.D. Poyser.

Yonge, C. M. (1959). "On the structure, biology and systematic position of *Pharus legumen* (L.)." J. mar. biol. Ass. U.K. **38**: 277-290.

Figure 1. Sedimentary biotopes and their distributions in Red Wharf and Conwy Bays