Report to the
Department of Trade and Industry

Synthesis of Information on the Shallow Benthos of the SEA 4 Area

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CONTENTS

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1 INTRODUCTION

The following is a synthesis of information describing the seabed habitats, species and communities on the continental shelf of the west of Orkney and Shetland relevant to the SEA 4 area. The information was gained from a wide range of available sources (classical and recent scientific studies, regional surveys commissioned by government and government agencies, as well as industry).

This report will provide a background and context to the detailed SEA 4 assessment, in terms of processes (physiographic and biogeographic processes) and regional distributions of habitats, communities, assemblages and associations.

The more detailed information provided on the area in question is discussed in relation to the findings on previous studies in the region and elsewhere.

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2 OVERVIEW

The SEA 4 area includes the West of Shetland continental shelf (<200m). The area consists of a large variety of sedimentary structures which range from boulders to sand and fine mud, though rocky outcrops are common, making up to 10% of the sea bed, especially where bottom currents are strong or where there is a positive relief (Stoker *et al.* 1993). To a large extent the sea bed is covered by unconsolidated sediments consisting of terraginous deposits which were brought about by glacially related processes during the Pleistocene and subsequently reworked and redistributed by the strong currents which occurred following the Holocene rise in sea level.

The sedimentary bedforms show considerable variability in grain size, with sand and gravelly sediments scattered throughout the shelf. These bedforms occur as sand streaks, sand ribbons and longitudinal sand patches whose extent may range from only a few metres to several hundred metres in width and as much as several kilometres in length. The superficial sediments are often only a few centimetres deep, overlying coarser glacigenic material. The strong bottom currents on the shelf determine the orientation and distribution of the sedimentary bedforms which are aligned along-shelf or parallel to the coastline and parallel to the tidal currents (Hartley Anderson 2000). On the shelf the finer sediments are transported away from areas of high hydraulic energy, leaving coarser gravelly sediments, and are deposited in lower-lying sea bed areas, e.g. in depressions where the currents are weaker.

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3 SURVEYS AND STUDIES

3.1 Historical perspective - 19th century

The fauna of the area to the north of Scotland and in particular around the Shetland Isles has a long history of scientific study. The first British specimens of the cold water coral *Lophelia pertusa* were collected in 1832 by fishermen in this area (Wilson 1979a) and the Shetland Isles were the subject of a series of eight dredging and collecting cruises (see Jeffreys *et al*. 1869). These cruises were aimed at collecting and subsequent description of the wide variety of species present and it is clear from the list of taxa obtained that, in qualitative terms, this early work provided a comprehensive picture of the benthic fauna. The work of Jeffreys *et al*. also provided insights into the relative abundance of species and biogeography for the fauna since their collecting expeditions were not restricted to the Shetland Isles but ranged between the Mediterranean and the Arctic. The next major advance in understanding came from observations and seabed samples collected north-west of Britain by HMS *Lightning* in 1868, and more successfully from HMS *Porcupine* in her third cruise of 1869. These cruises used a variety of dredges to collect sediment, sometimes with “hempen tangles” attached to snag surface living animals particularly echinoderms and although focussed on the deeper waters, did collect some material on the continental shelf. The resulting volume (Wyville Thomson, 1874) is a classic marine biological text which remains useful today and established the vertical zonation of many species in relation to temperature. In 1880, the *Knight Errant* expedition carried out some dredging on the West Shetland shelf (Tizard and Murray 1882) with further observations were made from HMS *Triton* in 1882. The *Michael Sars* expedition of 1910 covered the North Atlantic but included parallel transects between Shetland and Faroe with some samples taken on the continental shelf (Murray & Hjort 1912).

It is evident that perspectives on the level of understanding of the seabed fauna can alter over time so that in 1912 Murray & Hjort stated that “British investigators have made the plateau round the Shetland islands to a depth of about 200 metres one of the most familiar” although by 1995 Kingston *et al*. concluded that “The offshore benthic fauna around the Shetland Islands is not particularly well known”. These divergent perspectives are believed to be a reflection of the shift over the last century from qualitative to quantitative sampling in soft bottom benthic ecology. In terms of species composition and broad scale community distribution, the early dredging work provides a picture that remains generally applicable today. However, some changes can be inferred to have occurred, for example Wyville Thomson (1874) noted that in the warm, Atlantic water area the coral *Lophelia* “forms stony copses covering the bottom for many miles” although extensive sampling and photography carried out during AFEN, DTI and other surveys have failed to find substantial colonies of the species on the shelf and shelf break to the west of Shetland.

3.2 20th century perspective

The first quantitative survey of the fauna of the area was carried out by Stephen (1923), who in fact sampled a station just southwest of the Clair field. Dyer *et al*. also carried out studies in this area (1982). More recently a number of surveys concerning the benthic infauna and or epifauna of the larger area of the North Sea have also extended marginally to some areas of the shelf around Shetland.

Relevant programmes and data sources containing primarily geophysical data relating to the seabed environment as well as a historical account of previous investigations on the Shetland shelf can be found in AFEN (1996). The nature and the distribution of the sediments in the Atlantic margin environment which include the Shetland shelf were described by Graham *et al*. (1996) for the AFEN 1996 survey while Masson *et al*. (2000) identified the different acoustic facies by means of 100Khz side scan sonar and high resolution profile data, also from the AFEN 1996 survey. These findings are consistent with previously published information on sediment transport, which indicated a NE and ENE direction (Kenyon 1986, Stride 1982). Hartley Anderson (2000) in their synthesis of the data from the Clair development area also summarise the existing information on the surficial geology of the area. General investigations conducted during the Magnus Enhanced Oil Recovery (Foinaven – Sullom Voe) and Clair pipeline route surveys (Anon. 2000) confirmed previous observations.

The coastal environment of the Shetland Islands has been extensively investigated and the results presented in a series of reports (e.g. Institute of Terrestrial Ecology 1975a,b, c, d, Moss and Ackers 1987, and MNCR, Hiscock 1986, 1988, Howson 1988), a compilation of which is presented by Howson (1999).

The biogeographical provinces were reviewed in a workshop on Habitat Classifications (OSPAR/ICES/EEA, Oban 6-10 September 1999.

The division of the North Sea into different zones based on different types of measurements, parameters and/or criteria has given rise to many studies, which are further developed below: Jones (1972); Adams (1987); Glémarec (1973); Dyer *et al*. (1983); Basford *et al*. (1989, 1990); Eleftheriou & Basford (1989); Künitzer *et al*. (1992).

Extensive surveys of the sublittoral of the Shetland Islands and the results are available in a large number of reports and publications e.g. Irvine (1974a, 1974b, 1980), Institute of Terrestrial Ecology (1975e), Earll (1975, 1982), Moss & Ackers (1987), Hiscock (1986a, 1988), Addy (1981), Howson (1988), Pearson & Eleftheriou (1981), May & Pearson (1995).

4 PHYSIOGRAPHIC CONTEXT AND SURFICIAL GEOLOGY

4.1 The shelf and offshore areas

Sand waves in association with sandbanks of high carbonate content are quite common on the shelf. Sandy sediments are particularly evident in the middle and inner shelf with sand waves being very well developed in the areas between Orkney and Shetland and off the coast of Caithness, consisting of carbonate-rich sediments of biogenic origin which make up to 100% of the weight in the seabed sediments. The carbonate material consists of bivalve and echinoid fragments, serpulid tubes, barnacle plates and bryozoan fragments. The composition of this fraction west of Shetland consists mainly of barnacles and serpulid tubes, where west of Orkney, bivalves predominate (Wilson 1979). Significant concentrations of gravelly sand and sandy gravel are found north of the coast of Caithness and in the area between Orkney and Shetland.

Glacial moraines in the form of rocky mounds and boulders are evident between the sedimentary deposits in the current-swept shelf and are responsible for a rugged topography. Pockets of mud are present in bathymetric depressions in the inner shelf west of Orkney and in St. Magnus Bay in Shetland (Stoker *et al*. 1993).

The outer shelf is formed by mounded and ridged glacigenic material occurring in a sequence of rises and depressions of dimensions normally 5–10m high, though occasionally up to 25m high, and found NW and NE of Shetland. Under the Habitats and Species Directive (92/43/EEC) some of these structures could be considered as rock reefs. Hartley Anderson (2000a,b) who conducted an extensive assessment of the sediments of the Clair development area in the outer shelf by benthic sampler and photography, described bottom deposits as ranging from clean sand to cobbles and boulders. The sediments are poorly sorted, covering a wide range of grain sizes, ranging from clean sands, which are extensive in the whole arc from W to NE of Shetland, to predominantly gravelly sands or sandy gravels at the N and NW of Scotland and W of Orkney. It seems that there was no clear relationship between water depth and sediment type or bedforms across the outer shelf. General investigations conducted during the MAGNUS EOR (Foinaven – Sullom Voe) and Clair pipeline route surveys (Anon. 2000) confirmed previous observations.

4.2 The littoral, shallow sublittoral and voes

The north coast of Scotland, the coasts of Orkney and Shetland differ in terms of their orientation in relation to the prevailing winds and their overall exposure. The shores of the north coast of Scotland (from Cape Wrath to Duncansby Head), less exposed than those of the islands, are predominantly rocky and backed by cliffs interrupted by a few pocket beaches, shallow and exposed (Eleftheriou & McIntyre 1976). Beaches are generally formed of offshore glacial deposits as accretion from cliff erosion is minimal (Barne *et al*. 1996). Boulder, pebble and shingle beaches are also present in the more exposed stretches of the coast while narrow inlets have mixed sediments including sand and mud patches in their inner and more sheltered areas.

In most rocky shores, the rock extends sublittorally at a variable depth from the shore, being replaced by sand and mixed sediments, which predominate further offshore but are present inshore in the vicinity of sandy beaches (Barne *et al.* 1996). Strong tidal streams and conditions of extreme wave action are typical of the northern coasts of Scotland and especially true of the west coasts of Orkney and Shetland. However, the indented coastline of these islands covers the whole range of the exposure spectrum from the extremely exposed to the extremely sheltered, especially within many firths, sounds and voes. The coast is predominantly rocky although there are also some extensive beaches both in Shetland and Orkney.

The sedimentary beaches of Orkney (some in Scapa Flow) consist of fine sediments and have been described by Mather *et al*. (1974) while the composition of different shore types has been described for the Orkney Islands by Baxter *et al*. (1985) who also carried out long-term monitoring studies of the rocky shores. The seabed between the islands consists of rock, gravel, sand and small quantities of mud, while the tide-scoured sounds are made up of rock, shell gravel or sand (Jones 1975). A Symposium held in 1984 on the marine biology of Orkney summarised all the environmental studies up to that time (Jones 1985). The sublittoral substrata of the exposed sites were predominantly rocky while in the more sheltered areas they consisted of boulders, mixed sediments with coarse sand and maerl in the outer sounds and mud in the inner and sheltered areas.

The Shetland Island archipelago consists of several islands, both large and small, with extensive and deeply dissected coastlines, with high cliffs, stacks, caves, arches and geos, with deep water occurring close inshore. As a result, the coastline of Shetland shows a transition from wave-exposed rocky habitats to several very well sheltered sedimentary shores. There are numerous channels between islands scoured by the tides with extensive rocky outcrops, while the few areas of littoral sediments occur as shingle at the head of very sheltered inlets or voes, or as pocket beaches with mixed sediments in sheltered areas and as sandy beaches on the more exposed coastline (Howson 1999). The sea floor of such voes grades from rock, boulders, cobbles and shelly sand to mud (Howson 1999, Pearson & Eleftheriou, 1981) with the presence of patches of submerged peat. Bedrock frequently continues into the sublittoral area with vertical rock reaching a floor of bedrock, boulders or cobbles followed by mixed sediments which eventually are followed by clean sand. The coastal environment of the Shetland Islands has been extensively investigated and the results presented in a series of reports (Institute of Terrestrial Ecology 1975a,b, c, d; Marine Conservation Society, Moss and Ackers 1987, and MNCR, Hiscock 1986, 1988; Howson 1988) compilation of which is presented by Howson (1999).

Eight types of rocky shore were identified by ITE (1975c) ranging from very exposed bedrock through intermediate exposure to very sheltered shores. Forty-three rocky shore sites were surveyed by Hiscock (1981) while Howson (1999) describes in detail the structure and sedimentary characteristics of 739 sites covering the whole range of exposure of littoral and sublittoral shores. Cliffs and extensive rocky outcrops form the main feature of the coastline, alternating with beaches of cobblestones, boulders and mixed sediments. There are clean sandy beaches, especially in the area of St. Magnus Bay, the sublittoral sediments of which consist exclusively of clean sand with some mud in the deeper parts (<200m). Most of the voes and the inlets have a similar pattern of coarse and finer sediments, in a landscape of rock and unconsolidated stones and boulders, extending into the sublittoral where in many areas shell gravel, gravelly sands and muddy sands predominate. The degree of exposure to wave action in these shallower areas and the strength of the tidal stream determine the sequence in the composition of sediments. The extensive studies carried out in the Oil Terminal of Sullom Voe, Yell Sound and the surrounding voes (ITE 1975a, b, Moore & Little 1995; Hiscock 1986, Pearson *et al*. 1994, Westwood 1985, Pearson & Eleftheriou 1981, Hiscock 1981, May & Pearson 1995) give a detailed account of the littoral and sublittoral sediments and also provide a typical example of these voes. The Magnus EOR project involving the construction of a subsea pipeline system to carry gas from the Foinaven, Schiehallion and Loyal fields to the Sullom Voe Terminal (Anon. 2000) produced a photographic record which confirmed the finding of Howson (1999) regarding the sea floor characteristics along the main axis of Yell Sound, a flooded glacial valley in the NE part of the Shetland mainland. Thus in the outer Sound there are hummocky moraines which with the mounds and rock outcrops fall within the current definition of the Habitat Directive (Annex 1) of a “reef habitat”. In the Inner Sound there is a sequence of gravelly sand, stony gravel, muddy stony gravel and leading to finer sediment accumulation in the inner smaller voes and with mud and silt along sand, pebbles and rock.

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5 BIOGEOGRAPHICAL CONTEXT DIVISIONS

The continental shelf and the upper continental shelf of the west and north of Scotland and the Orkneys have been firmly assigned to the boreal province, which extends to the north of the Wyville Thomson Ridge, in the North Sea and eastern English Channel and flanked by the Boreal-Lusitanian Province of the west coast of Scotland (extending to the western English Channel, the west of Ireland to the Wyville Thomson Ridge and the Rockall and Hatton Banks) and the Arctic and Atlantic Deep Sea Province along the lower continental slope fringing the Iceland /Faroe shelf at the 500m isobath. These biogeographical provinces were reviewed in a workshop on Habitat Classifications (OSPAR/ICES/EEA, Oban 6-10 September 1999) and put forward by the AFEN survey of 1996 (AFEN 1996) on the basis of hydrographic characteristics such as water temperature. Nevertheless temperature fluctuations along the boundaries of these provinces blur such divisions with the result that many species tolerant of environmental differences do not conform to their expected distribution (AFEN 1996; Hartley Anderson 2000).

The division of the North Sea into different zones using fisheries research data was proposed by Jones (1972) and although this system was inconclusive, ICES adopted it in 1978. Adams (1987) suggested that divisions of the North Sea could be drawn along depth contours with distinct physical characteristics and plankton communities, with his North British Coastal and Offshore Northern subdivisions impinging on the Orkney and Shetland areas.

The separation of the North Sea into different regions relating to physical conditions and the benthic communities associated with these conditions was put forward by several authors (Glemarec 1973, Dyer *et al*. 1983, Basford *et al*. 1989, 1990, Eleftheriou & Basford 1989, Künitzer *et al*. 1992). The thermal stability of the water column was used by Glémarec (1973) to subdivide the North Sea into étages of which his coastal étage circumscribes Shetland and Orkney within the 100m contour.

Other authors have used the type of substratum, in addition to other parameters to describe the faunistic regions of both the North Sea and the continental West Shetland shelf (Dyer *et al*. 1983, Basford *et al*. 1989, 1990, Eleftheriou & Basford 1990, Künitzer *et al*. 1992).

On the continental shelves and slopes, the type and distribution of the infaunal and epifaunal benthic communities assemblages and associations are strongly influenced by depth and associated sedimentary factors (Basford *et al.* 1989,1990) although regional distributions on the West Shetland shelf are very much affected by water temperature which is correlated with depth. In addition, there is extreme variability of habitats within short distances especially in inshore areas where the species and communities exhibit important regional differences in their composition and distribution. Such variations in the large epifaunal benthic organisms on the shelf alongslope and downslope have been documented by Bett (2000) on the basis of AFEN 1996 WASP data and attributed to different hydrographic and sedimentary parameters operating in these regions.

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6 BENTHIC COMMUNITIES, ASSEMBLAGES AND ASSOCIATIONS

6.1 Inshore areas - littoral and shallow sublittoral

6.1.1 Introduction

The communities of the different habitat types of the littoral hard substrata have been classified by MNCR using physical characteristics such as wave exposure, tidal stream strength, temperature and salinity. Exposure to wave energy is the overriding factor determining the composition of the animal and plant communities and the vertical and horizontal distribution of the different species (for zonation see Lewis 1964).

Climate is another important factor influencing the geographic distribution of species in this area of several water masses with different temperature regimes. The benthic communities, assemblages and associations in the north of Scotland, Shetland and the Orkney Islands have much in common with those in the North Sea, the west coast of Scotland and Ireland, and the NE Atlantic. Similar ecosystems with the same faunistic and floristic elements have the same structure under relatively similar conditions.

However, the prevailing conditions in the SEA 4 area are quite extreme and are responsible for a corresponding modification in the structure and distribution of these communities. In this way, severe exposure is responsible for modifying the distribution of the different species, while the temperature component is responsible for the incursion of southern and Arctic species in this area where they are found correspondingly at the northern or southern limits of their distribution. Hence Boreo-Lusitanian species from the west coast of Scotland are found in these waters, extending as far as Orkney and Shetland though not into the North Sea, while Boreo-Arctic species are found in Shetland and Orkney but not further south.

The proximity of deep water in the Faroe-Shetland Channel of temperature- fluctuating water masses also influences the continental shelf communities of the West Shetland shelf. We may therefore conclude that boundaries between biogeographic zones are not as sharply defined as is often suggested by some authors and textbooks; because individual species respond differently to ecological factors, they can as a result have different distributions. The dividing lines can be further blurred when there are changes in the environmental conditions over long time scales (AFEN 1996).

In the present report, the intention is not to provide complete faunistic and floristic lists from the different habitats, but rather to focus on those distinct elements of the different communities which make them different from those in the adjacent biogeographic zones and characteristic for the SEA 4 area.

6.1.2 The North Coast of Scotland -Caithness

6.2.1.1 Rocky littoral and shallow sublittoral

The exposed rocky shore communities of Caithness are distinguished by many brown algae and common encrusting forms of animals and plants (as described by Hiscock & Johnson 1989), with the addition of blue-green algae and many Lusitanian species such as the red alga *Porphyra*, the limpet *Patella ulyssiponensis siculosus*, with many species of brown algae such *as Fucus vesiculosus, F. linearis and Himanthalia elongata* (Lewis 1964) as well as the barnacle *Chthamalus montagui, Littorina neritoides* and the top shell *Gibbula umbilicalis*.

There are southern species at their limit of northerly distribution, which at present extend as far as Duncansby Head, though they do not enter the North Sea. The more sheltered inlet of the Kyle of Durness and the deep Loch Eriboll with their rocky outcrops, boulders and mixed sediments are dominated by typical encrusting forms of mussels and barnacles, the brown alga *Alaria esculenta* while in the more sheltered sites the brown alga *Saccorhiza polyschides* is present. In the outer parts below the *Laminaria hyperborea* fronds, rich communities of ascidians, sponges and hydrozoans are also present. In the inner parts, mixed sediments with mud patches are inhabited by communities of polychaetes and amphipods, while in the shallow soft sublittoral, common species such as dead man's fingers, *Alcyonium digitatum*, the anemone *Utricina felina*, the sea pen *Virgularia mirabilis* as well as scallops and Norway lobsters are present (Doody *et al*. 1993, Barne *et al.* 1996).

6.1.2.2 Sedimentary shores

The sedimentary beaches of Caithness have been studied by MNCR, and the different habitats and the corresponding communities were classified using the same characteristics as before, such as wave exposure, tidal extreme exposure, sediment grade and salinity. Those beaches exposed to strong tidal streams were classified as very to moderately exposed by OSPAR/ICES/EAA, and as exposed by Eleftheriou & McIntyre (1976). The grades were well-sorted medium to fine sand with a restricted infauna dominated by small crustaceans and characterised by a total absence of bivalves, a situation typical of exposed beaches. The sublittoral fauna present in similar sediments was more diverse but without any distinctive characteristics other than those of fauna usually found on sandy sediments.

6.1.3 The Orkney Islands

6.1.3.1 Introduction

The littoral habitats of Orkney range from those exposed to extreme wave action on the west coast to very sheltered conditions between the islands (Bennet & Covey 1998). A detailed study carried out by the MNCR programme in the marine environment of Orkney provides a detailed account of the marine habitats and communities (Murray *et al*. 1999) and a hierarchical classification of the biotopes (OSPAR/ICES/EAA Workshop, Oban 1999).

6.1.3.2 Rocky littoral and shallow sublittoral

Exposed littoral rock is inhabited by typical encrusting species found in exposed conditions, such as *Mytilus edulis* and barnacles with the limpet *Patella* spp., the barnacles *Chthamalus, Semibalanus balanoides*, and some lichens and brown algae such *as Fucus distichus* sub sp.*anceps* and *F. spiralis f. nana*, *Corallina officinalis, F. serratus* and a few red seaweeds (*Chondrus crispus, Mastocarpus stellatus, Rhodothamniella floridula*). In the sheltered parts of the rocky coast and on mixed sediments there were dense fucoids such *as Pelvetia canaliculata, Fucus spiralis, F.vesiculosus*, barnacles and in the very sheltered areas *Ascophyllum modosum* was present (Murray *et al*. 1999). It should be mentioned that the fucoids *Fucus distichus and F. spiralis f. nana* found on exposed shores on Orkney generally have a northern distribution, although the latter is absent from the whole North Sea. Elements of the southern fauna, species such as the barnacles *Chthamalus stellatus*, and *C. montagui*, as well as the gastropods *Littorina (Melaraphe) neritoides* and *Gibbula umbicalis* are also present on the Orkney shores. However the limpet *Patella ulyssiponensis* reported from the northern isles (Doody *et al*. 1993) does not appear in the faunal list of the detailed studies of Murray *et al.* (1999) of the Orkney area.

The shallow rocky sublittoral and other exposed hard substrata were dominated by the alga *Laminaria hyperborea* along with several brown algae such as *Alaria esculenta, Mytilus edulis* and several species of red algae, while in some wave-surged south coast sites dense growths of encrusting sponges (*Dendrodea/Clathrina*), ascidians, bryozoans and hydroids were present. In the less exposed areas, *Laminaria hyperborea* was replaced by *L. saccharina* with the presence of coralline crusts and other seaweed communities.

In the deeper and exposed sublittoral, faunal crusts with the polychaete *Pomatoceros triqueter*, the barnacle *Balanus crenatus* and bryozoans were present while dead man's fingers *Alcyonium digitatum*-dominated communities were found on moderately exposed rock. Bryozoans, mussel beds (both *Mytilus* and *Modiolus*) brittle stars and faunal and algal encrusting species with the presence of the sea urchin *Echinus esculentus* form the characteristic species of these communities.

In the shallow sublittoral mixed sediments, *Laminaria saccharina* and filamentous red seaweeds dominated while the bivalves *Venerupis senegalensis* and *Mya truncata* inhabited the muddy gravel in these areas. *Modiolus* beds are also present on these substrata. In the open coast and the outer areas of the sounds, maerl beds of *Phymatolithon calcareum* with red seaweeds, hydroids and echinoderms on coarse sediments are dominant while bivalves such as *Spisula elliptica* and venerid species are found on shell gravel. With a decrease in the median diameter of the benthic sediments there is a succession of benthic communities which are characteristic of the type of substratum conforming to Petersen's/Thorson's (1957) classic definition and description of shallow water communities. Thus we have shallow muddy sand communities of the sand urchin *Echinocardium cordatum* and spionid polychaetes and in the deeper areas bivalves (*Abra alba, Nucula nitida, Corbula gibba*), ophiuroids (*Amphiura filiformis, Ophiura* sp) but also the sea pen *Virgularia mirabilis* being dominant. In very sheltered areas, tube-building amphipods, polychaetes and synaptid holothurians were present.

6.1.3.3 Sedimentary shores

In the more sheltered conditions of Scapa Flow in the variable sediments, the species showed an uneven distribution (SOAFD- unpublished data). On the coarse sediments, diversity was greatest with populations of molluscs such as *Chaetoderma nitidulum* and several species previously unrecorded in Orkney, while in the finer sediments of the northeastern part diversity and abundance were low.

The coastline of Orkney with a complex configuration allows the presence of a range of sediments. Sandy shores occur on the exposed parts of the islands and can be completely devoid of any fauna or can be inhabited by a sparse fauna of cirolanid isopods (*Eurydice pulchra*) and amphipods such as *Pontocrates* sp. and *Bathyporeia* spp. with some polychaetes such as *Pygospio* sp., reminiscent of the exposed sedimentary beaches of Caithness. In the inlets the percentage of finer sediments including a mud fraction favour the presence of polychaetes such as *Arenicola marina* and a few species of bivalves such as *Macoma bathica* and *Cerastoderma edule* (Murray *et al*. 1999). However some beaches (for example, on Hoy) being more sheltered had a more prolific fauna of polychaetes and amphipods but yet again without some other groups (e.g. bivalves).

6.1.4 The Shetland Islands

6.1.4.1 Introduction

The Shetland Islands, the most northerly land of the British Isles, are also exposed to severe wave action. They are separated by very deep water from the Faroe Islands and by a less deep channel from Orkney. Most of the islands surround the Shetland “mainland”, creating a mass of inlets, voes or firths and geos which show a transition from the severely exposed areas from the south and west to the extremely sheltered areas in the inlets and voes. Furthermore, the proximity of deep water to the coastline, particularly along the coast where the 80m isobath is found close inshore, is particularly noteworthy. Wave action and strong tidal streams play an important part in structuring the habitats in these islands. The bottom water temperature is permanently rather low (7^0-11^0C seasonally) influenced by oceanic water masses.

The geographic position of Shetland implies that the islands’ fauna and flora should be enriched by the presence of northerly species. In an extensive review of the Scottish macroalgae, by Maggs (1986), it was shown that, although 71 southern species were found in Shetland, only two northern species reached their southern limit in Shetland (according to the principle of a reduction in species richness with increasing latitude) (Howson 1999).

There is a substantial volume of data concerning the fauna and flora of Shetland which has been compiled in several reports and publications. The MCNR review series of extensive surveys in Shetland, together with the data of the surveys commissioned by the oil industry in the Sullom Voe oil terminal in connection with the oil extraction platforms and pipeline, provide a substantial amount of information on the Shetland fauna and flora. Further surveys were carried out on the continental shelf E-NE of Shetland in relation to the prospected oil development on the West Shetland shelf. More recently, work was initiated in connection with the oil-related accidents at sea around Shetland. This has dictated a series of biotope mapping surveys with the data being processed and compiled by MCNR (Howson 1999). The coast was classified by the Institute of Terrestrial Ecology using its basic physical characteristics.

6.1.4.2 Rocky littoral and shallow sublittoral

On exposed littoral rock in the outermost locations are barnacles such as *Semibalanus balanoides,* the limpet *Patella spp., Fucus distichus subsp.anceps* and *F. spiralis f. nana*, *Blidingia* spp. *Mytilus edulis*, *Corallina officinalis, Himanthalia elongata* and accompanying species were characteristic. In moderately sheltered conditions, barnacles and fucoids such as *Fucus vesiculosus* and *F. serratus,* red seaweeds such as *Palmaria palmata, Gelidium pusillum*, *Chondrus crispus, Porphyra purpurea* and several others were typical of this biotope. The sheltered littoral rock was dominated by the alga *Ascophyllum nodosum* and had a low diversity of fucoids. On mixed sediments and boulders, *Littorina littorea*, barnacles and mussels were present (Howson 1999). It appears that in conditions of intermediate exposure the species diversity is greatest. The sides of geos on exposed rocky shores had a rich fauna of encrusting forms (sponges, ascidians and hydrozoans) in the inner part, and barnacles, the mussel *Mytilus edulis* and hydroids in the outer reaches. In the sheltered parts of the voes and in many inlets, the littoral is almost exclusively rocky with boulders, cobble, shingle and mixed sediments being present in the inner parts. *Ascophyllum nodosum* was characteristic of such biota accompanied by *Pelvetia canaliculata* and *Fucus vesiculosus,* while in gravelly and stony beaches there were amphipods, littorinids such as *Littorina saxatilis*, *L. littorea* and *Mytilus edulis*. At the outer and moderately exposed parts of the voes, rocky outcrops are animal-dominated, with the barnacles *Semibalanus balanoides*, limpets *Patella vulgata*, mussels *Mytilus edulis* and the dogwhelk *Nucella lapillus* with red algae such as *Laurencia pinnatifida, Porphyra umbilicalis, Mastocarpus stellatus, Corallina officinalis* and accompanying species. Fucoids were generally absent but brown algae such as *Laminaria digitata* was found lower down on the shore. The oil-related development in Sullom Voe sparked large and long-term studies of the benthic fauna and flora as a reference for possible future changes. The ecology of rocky shores was studied by Hiscock (1981) and subsequently by Moore & Little (1995), and the MNCR data conforms to these findings (Howson 1998, 1999). In the extensively surveyed Sullom Voe, the gastropod *Gibbula umbilicalis* was found, thus extending its northernmost distribution, a fact not recorded by Doody *et al*. (1993). On the other hand, many species of *Cystoseira* spp., and *Anemone sulcata*, *Chthamalus stellatus, Chthamalus montagui, Monodonta lineata, Littorina neritoides, Patella depressa* and *P. ulyssiponensis* are southern species which are nonetheless present in Shetland. Furthermore, the non-native Australasian barnacle *Elminius modestus* (Howson 1988, 1999) is present in small numbers in Sullom Voe (Hiscock 1981) as well as in other voes. Hiscock (1981) who compiled several years' data, produced lists about the common rocky shore littoral animals and plants in Shetland in connection with such organisms in the British Isles. He found that certain species such as *Lichina pygmaea, Margarites helicinus, Lacuna pallidula, Acmaea tessulata* are present in Shetland but were either absent or rarely recorded from areas further to the south in the British Isles. In the same way the fucoid *Fucus distichus*, represented by two subspecies *distichus* and *anceps* (*sensu* (Chapman 1985) is found in Shetland in the southern limits of its distribution.

Many researchers have carried out extensive surveys of the sublittoral of the Shetland Islands and the results are available in a large number of reports and publications including Irvine (1974a, 1974b, 1980) Institute of Terrestrial Ecology (1975e), Earll (1975, 1982), Moss & Ackers (1987), Hiscock (1986a, 1988), Addy (1981), Howson (1988), Pearson & Eleftheriou (1981) and May & Pearson (1995).

Data collected by the Institute of Terrestrial Ecology (1975c) distinguished six zones and communities. Subsequently four major site types, as opposed to zones of communities, were identified (Earll 1975) and classified as follows:

- Open coast sites with rock extending below the laminarian zone
- Bedrock in shallow water in extremely exposed sites
- Moderately exposed sites at the outer voes
- Sheltered muddy sand and gravel

A further analysis identified thirteen communities in the shallow sublittoral (Earll 1982) and highlighted the importance of the existence of dense beds of *Modiolus modiolus*. Moss & Ackers (1987) described nine major habitat and community types which to a great extent correspond with those described by Earll (1982).

For the purpose of this report and in order to curtail the large amount of information available in the literature, the description of the biotopes and the corresponding communities has followed the description and classification found in Howson (1999) which highlights the substratum type and the communities' dominant species.

Thus in the shallow sublittoral hard substrata are found *Alaria esculenta*, *Laminaria hyperborea, L.digitata* and *L.saccharina* with a variety of epiphytes including the northern species *Callophylis cristata* (Howson 1999). In areas of strong wave surges, sponges, such as *Dendrodea* and *Clathrina,* barnacles such as *Balanus crenatus*, spirorbid worms, bryozoans and coralline algae occur. With increase in shelter *Laminaria digitata, L.hyperborea* with coralline crusts, red seaweeds, *Halidrys siliquosa, Polyides rotundus*, *Chondrus crispus,* as well as *Echinus esculentus*, brittle stars and coralline crusts, and on vertical walls, *Metridium senile*, *Alcyonium digitatum*, and *Corynactis viridis* are present. With increase in depth and shelter, faunal crusts including coralline crusts, *Cariophyllia smithii, Haliclona* and *Corynactis viridis* on rock and the polychaete *Pomatoceros triqueter* and the barnacle *Balanus crenatus* on cobbles are present and *Alcyonium digitatum* on vertical rock. Under conditions of greater shelter, there are bryozoans (*Flustra foliacea*), hydroids (*Sertularia argentea*) with other hydroid species, the mussel *Modiolus modiolus* and brittle stars (*Ophiothrix fragilis, Ophiocomina nigra*) as well as *Echinus esculentus* and *Alcyonium digitatum* and algal crusts in the deeper rocky substratum. Very sheltered conditions promote brachiopod and solitary ascidian communities (*Ascidia mentula, Ciona intestinalis, Ascidiella aspersa*, as well as the anthozoan *Metridium senile, Antedon bifida* and beds of *Modiolus modiolus*.

6.1.4.3 The Voes and Sounds

The sublittoral sediments consist mainly of gravel and sands with rocky outcrops, boulders and cobbles. Maerl beds consisting of *Phymatolithon calcareum* and *Lithothamnion glaciale* are common in the outer parts of sounds and voes but where there is clean sand or shell-gravel bivalves such as *Spisula elliptica* and venerids with *Fabulina (Tellina) fabula* and the polychaete *Magelona mirabilis* dominate. In less exposed habitats where *Zostera* beds are apparent in the muddy sand of the inner voes, a diverse community consisting of the heart urchin *Echinocardium cordatum*, the bivalve *Ensis* sp., a variety of spionid polychaetes (*Spio filicornis, Spiophanes bombyx*), several bivalves such as *Abra alba, Nucula nitida* and echinoderms, *Echinocardium cordatum* and *Ophiothrix fragilis* were present. The deeper areas of the voes were frequently characterised by muddy sediments with amphipods and polychaetes (*Arenicola* sp.), synaptid holothurians, sea pens (*Virgularia* spp) and burrowing megafauna. In the deeper mixed sediments *Laminaria saccharina*, filamentous seaweeds (*Chorda filum*), bivalves (*Venerupis senegalensis* and *Mya truncata*) with *Modiolus* sp. beds and dense populations of the cerianthid *Cerianthus lloydii* were characteristic of these muddy communities (Howson 1999).

Sullom Voe, the longest and deepest of the Shetland voes, is a typical fjordic system, sheltered from wave action, and has been extensively and intensively surveyed for almost the last thirty years. It displays the whole range of habitats as described above, with all the corresponding animal and plant communities (Pearson & Eleftheriou 1981, Addy 1981, May & Pearson 1995). A very abundant fauna inhabits the varied substrata of the sublittoral with dense *Modiolus* beds, *Echinus*, the bivalve *Chlamys opercularis* and the red alga *Phyllophora,* several species of ophiuroids, asteroids and ascidians. The fine sediments were inhabited by a large variety of polychaetes with contributions from bivalve molluscs, echinoderms and crustaceans. There were changes in their distribution with depth and differences in their abundance. However there was evidence that the sediments of the inner parts of this voe and perhaps of other voes with the same configuration, become anoxic in the summer months as a result of an enhanced organic output from the surrounding areas. This results in a radical modification of the diversity and abundance of the macrobenthic infauna consisting mainly of small deposit feeding species. It is interesting to note that Addy (1981) in his study on the macrofauna of Sullom Voe concludes that the macrofauna of Sullom Voe (and perhaps other voes) in terms of species richness is similar and among the highest of undisturbed coastal areas on the British Isles mainland.

Yell Sound, a flooded glacial valley (<100m) dividing the Shetland mainland, is the largest sound in Shetland, with the sea floor consisting of a range of habitats which are modified by the very strong currents which structure the bottom and its sediments. The outer Yell Sound is characterised by hummocky moraines and the mounds fall within the current definition of the Habitat Directive "reefs" habitat. These structures formed by small rocks and pebble debris, host rich encrusting communities with brittle stars (*Ophiothrix fragilis* and *Ophiopholis aculeata*) and featherstars (*Antedon bifida*) while between the mounds there are coarse sediments and in parts exposed rock surfaces. The progressive increase in finer grades in the inner part of Yell Sound is accompanied by characteristic communities reflecting the sediment types and the hydrographic conditions. In gravelly sands, populations of *Echinus* starfish *Asterias*, and bivalves are present, while in the shallower and muddy parts sea pens (*Virgularia*) and sea urchins (*Echinus*) form the principal visible fauna. The horse mussels *Modiolus modiolus* and brittle stars appear in large but localised concentrations. In the shallows *Laminaria saccharina* and sea urchins are present on stony ground and gravel, while in the sheltered conditions a more prolific and diverse benthic fauna was found. The proposed construction of a subsea pipeline system to carry gas from the Foinaven, Schiehallion and Loyal fields to Sullom Voe and thence to the Magnus field included a large-scale study on the Atlantic margin west of Shetland and in Yell Sound. Sonar, photography and video-recording along the prospected route of the pipeline provided visual documentation as to the sequence of bottom structures and communities along the Yell Sound (Anon. 2000; Hartley Anderson 2000).

6.1.4.4 Sedimentary Shores

An extensive survey by ITE (1975d) produced detailed descriptions of these sedimentary beaches and their fauna. Two main associations were recognised: the first was found on muddy sand and was characterised by the bivalve *Macoma balthica* with the polychaete *Arenicola marina* and the bivalves *Mya arenaria*; the second was found on clean sand and was characterised by the bivalve *Tellina (Angulus) tenuis* with *Arenicola* and the bivalve *Ensis* spp. The fauna of these beaches was comparable to that found on similar locations on the mainland. The small sedimentary stretches found in the shelter of voes and inlets have coarse sediments but also fine sands where large populations of polychaetes dominated by spionids (*Scoloplos armiger, Pygospio elegans, Aonides oxycephala*) and accompanying species of bivalves such as *Tellina (Angulus), Venerupis rhomboides* and *Crenella decussata* along with the isopod *Eurydice pulchra* and the talitrid amphipod *Orchestia gamarella*. Pearson *et al*. (1994) described two variants of the *Macoma balthica* community, one in sediment with high shell contents accompanied by the polychaetes *Fabricia sabella* and *Tubificoides benedeni*. The other included the polychaete *Travisia forbesi*, the bivalve *Crenella decussata* and the isopod *Eurydice pulchra*. Shingle or gravel shores were close to a barren condition often inhabited by the isopod *Eurydice pulchra*, the bivalve *Venerupis senegalensis* and the polychaete *Arenicola marina* (Howson 1988). Several exposed sandy beaches had a restricted fauna consisting of highly mobile crustaceans (the isopod *Eurydic*e, the amphipods *Talitrus saltator* and *Echinogammarus pirloti*) but devoid of other groups (Howson 1998). Some sedimentary beaches at the head of voes are extremely sheltered and characterised by the polychaete *Nereis (Hediste) diversicolor* and the decapods *Pagurus bernhardus* and *Carcinus maenas* (Howson 1988).

Overall the sedimentary beaches of Shetland exhibited a benthic faunal complement which presented no surprises, akin to the fauna of the whole range of sedimentary beaches found in Orkney as well as further south in the mainland.

6.2 Offshore areas - the West Shetland Shelf and adjacent areas

6.2.1 Introduction

The West Shetland shelf (<200m), a predominantly current-scoured area, is characterised by extreme heterogeneity of sediments and bedform structures. The sediments are mixed comprising a wide range of grain sizes although sand streaks, sand ribbons and sand patches of different dimensions are widespread. Glacial moraines in the form of boulder and clay mounds are almost northeast and north- west of Shetland. Hartley Anderson (2000) in their survey of the Clair development and surrounding areas carried out by grab, photography and video-recordings, provided detailed information on the sediments and the associated communities. On the other hand, long-term studies by the British Geological Survey produced a detailed mapping of the structure and sediments of the sea floor of the continental shelf west of Shetland.

6.2.2 The epifauna

By comparison to the extensive and intensive studies carried out by many workers in the North Sea, the West Shetland continental shelf has received limited attention until the recent oil-related development which initiated environmental surveys in selected areas of specific interest to the oil industry. Some of the reports produced contained detailed information about the benthic environment and the animal communities, others provided little or only general information which was not always useful for comparison of data.

The epifaunal organisms considered in the present report were the larger benthic invertebrates, too large or sparse to be effectively collected by grab, but suitable for sampling by trawling or dredging. However, the encrusting forms of the hard substrata were mainly assessed by direct visual means. Thus Hartley Anderson (2000), using a combination of methods and apparatus including still photography and video recording from a remotely operated vehicle, provided extensive documentation as to the complex range and mixed nature of the sediments and bedforms as well as on the faunal assemblages associated with these substrata.

6.2.2.1 Hard substrata

The hard substrata of the West Shetland continental shelf have received very little attention up to the present. This is the result of the difficulties encountered in sampling relatively rough ground using grabs or corers, along with trawl surveys designed to sample only the soft substrata of the shelf in order to avoid gear damage. These difficulties were overcome to a certain extent by using visual survey techniques, both still photography and video-recordings (Hartley Anderson 2000). These authors found that the fauna of the offshore areas is typical of the west of Shetland continental shelf and varies according to the nature of the sea floor. Pebbles, cobbles and boulders are colonised by a wide range of encrusting or sessile animals, chiefly sponges, hydroids, bryozoans, anemones and motile species such as sea urchins, starfish and crustaceans. Closer to Shetland and in the vicinity of Yell Sound, the varied fauna reflects the varied seabed types. Epifaunal cover is typically extensive, with approaching 100% of exposed surfaces colonised by hydroid turf, sponge and bryozoan mats. The best-developed encrusting fauna is seen in areas with limited sand presence. Where cobbles and boulders are part buried in sand, hydroid turf is the predominant fauna. In addition to encrusting animals, a range of erect sessile species was observed, including the bryozoan *Cellaria* sp., other bryozoans, the anemones *Hormathia digitata, Parazoanthus anguicomus* and *Bolocera tuediae*, several sponges and what are believed to be small hard corals (up to 2cm high). The resolution of seabed photographs and video is such that the range of smaller encrusting species visible could not be identified further.

In addition to encrusting and erect sessile fauna, the hard seabed is typified by a range of motile animals, the most common of which are the sea urchins *Cidaris cidaris* (slate pencil urchin) and *Echinus esculentus*, the starfish, *Stichastrella rosea, Asterias rubens* and

Porania pulvillus (cushion star), brittle stars including *Ophiothrix fragilis*, and squat lobsters *Munida rugosa*.

Sonar and photographic data taken in connection with the Clair field development carried out by Hartley Anderson (2000a, 2000b) and the BP Clair Pipeline route (Hartley Anderson 2000) identified different major habitat types and the associated epifauna along the pipeline route from the continental shelf to Yell Sound.

Outer continental shelf consisting of mixed sediments but also of glacial boulders and cobbles where there is a sparse epifauna of bryozoans and serpulid polychaetes.

There are patches of sand and gravel which support a relatively uniform boreal shelf sand macrofaunal community dominated by tubicolous polychaetes such as *Galathowenia oculata,* a characteristic species of stable sediments, as well as polychaetes such as *Pisione remota* and *Hesionura elongata*, typical of more mobile, well sorted grades. On pebbles and gravel, starfish (*Porania*), brittlestars (*Ophiura*), anemones (*Bolocera tuediae*), encrusting and erect sponges and bryozoans were present, while on cobbles and pebbles there is a variable but well-developed epifauna consisting of erect and encrusting hydrozoans, sponges, anemones (*Parazoanthus anguicomus*), sea urchins (*Echinus*) and serpulid polychaetes.

Yell Sound approaches are characterised by very rugged topography comprising an extensive glacial moraine field up to 6m high, consisting of mixed sediments with gravels, pebbles, cobbles and boulders; there is a moderately to well-developed encrusting fauna on cobbles and pebbles, with abundant featherstars, serpulid polychaete worms, scallops, juvenile fish, prawns, squat lobsters and brittlestars. The moraines provide hard substrate colonised by numerous branching bryozoans (sea mats) and cup sponges with some small colonies possibly of the cold water coral *Lophelia pertusa* also present.

6.2.2.2 Seabed mounds

In the Clair Field development study, Hartley Anderson (2000) reported the presence of seabed mounds of low relief, composed of mixed sediments. A number of sponges and bryozoans and some hard corals were present and perhaps some small branches of *Lophelia.* The cold-water coral *Lophelia pertusa* was not found dead or alive in the wider continental shelf except in the proximity of Yell Sound. It is interesting to note that this reef-building coral has been found in the past on the shelf edge, the continental slope and recently (reported from the Foinaven area in the AFEN 1996 survey) in deeper water in the north and west of Shetland and Orkney. However, it is not reported consistently in the different surveys, indicating that the coral is extremely patchy (Wilson, 1979), and a comprehensive review of the species occurrence is given by Long *et al.* (1999). The larger reefs reported in the literature can be extensive and may be many thousands of years old, and because of their considerable scientific, conservation and ecological importance, constituted one of the reasons that the AFEN surveys were initiated – although all the mapping conducted to date of the SEA 4 area has not revealed any large coral reefs.

6.2.2.3 Mixed substrata

The epifauna of the unconsolidated sediments has received considerably more attention than the hard substrata, mainly because of their accessibility to different types of sampling equipment.

The first quantitative survey of the fauna of the area was carried out by Stephen (1923), who sampled a station (No.126 at 60° 40'W in 144m) just southwest of the Clair field. He reported a fauna numerically dominated by the free living tube worm *Ditrupa arietina* (360/m^2) with the only other species being recorded being the brittle star *Ophiura* sp. Stephen characterised the fauna as belonging to a "pure *Ditrupa*" community, which he had also found at a number of locations to the west and north of Shetland. Dyer *et al*. (1982) also recorded *Ditrupa* to the west of Shetland (south of Clair) and included a photo of the seabed showing numerous tubes present. *Ditrupa arietina* was identified in still photos from the Clair area although only as one or two individuals, a similar density to which the species is found over much of the northern North Sea.

In the mixed sediments of the shelf west and north of Shetland there exists a substratum which is considered as completely different from other substrata. Dyer *et al*. (1982) reported the patterns of faunal distribution from a series of trawls and underwater photographs throughout the North Sea and the west of Shetland continental shelf and subsequently (1983) published a description of the various regions present in the area based on seabed faunal distribution. The west of Shetland continental stations had a sparse epifauna dominated by northern species such as the asteroids *Hippasteria phrygiana, Stichastrella rosea*, *Solaster endeca* the anthozoan *Adamsia palliata*, the polychaete *Hyalinoecia tubicola*, and the sponges *Tetilla* and *Phakellia* with the echinoid *Echinus tenuispinus*, and additional species the asteroids *Pteraster militaris* and *Pontaster tenuispinus* and the anthozoan *Hormathia digitata* in the deeper northern stations. These stations, grouped together as region N4, differ from areas in the northern North Sea by the presence of the sea urchins *Cidaris cidaris* and *Echinus tenuispinus. Cidaris cidaris* is one of the most common animals seen in the photographs and videos of the Clair development area. However, no new attempts to classify the fauna of the area in terms of community types or assemblages have been published since the work of Dyer *et al*. (1983).

Dyer's stations were revisited in 1981-82 by Cranmer *et al*. (1984) and the epifaunal benthos was studied using underwater photography. They recognised a further 30 species in addition to those found by Dyer *et al*. (1982). The more important of these which were present in small densities, were the anthozoan *Actinauge richardi*, common around Shetland, the squat lobster *Munida rugosa* and the zoantharian *Epizoanthus incrustatus* (=*papillosus*) found in association with an anomuran crab. However it is interesting to note that an important number of encrusting and erect sessile forms of epifauna were not recorded from the Shetland shelf, perhaps because of the very small number of stations sampled.

Cranmer (1985) in his study of the North Sea echinoids between 1977-83 by trawl and underwater photography, also included the continental shelf west of Shetland in his sampling. Although this study did not add any new, previously unrecorded echinoid species, it did provide a better and more accurate picture of their distribution in the area. The species commonly found in the area were: *Echinus acutus* var. *flemingii, Echinus tenuispinus, Echinus elegans* and *Cidaris cidaris*. However the author reports that the two latter species were distributed on the continental slope although the depth ranges given for their distribution indicate that they were not found on the continental shelf. Furthermore, the sea urchin *Echinus esculentus*, abundant along the Scottish coast and around Shetland, was not found in this survey.

Basford *et al*. (1989) carried out an analysis of the epifaunal distributions, using a 2m beam trawl in a network of stations taken in the ICES rectangles covering most of the northern North Sea, of which two stations (182 and 190), located west of Fair Isle, are relevant to this report. The epifauna found in those stations was sparse and in low numbers and consisted of a few asteroids (*Asterias rubens, Porania pulvillus* and *Luidia ciliaris*) and echinoids such as *Spatangus purpureus* and, interestingly, both varieties of *Echinus acutus*, *E.a. flemingii* and *E.a. norvegicus*.

Multivariate analysis of the data showed that the major determinants of community composition were depth, particle size, sorting of the bottom grades and sediment organic carbon. By the application of two-way indicator species analysis, the epifaunal samples were separated into four major groups, each characterised by different environmental characteristics. One such group, which includes the stations found in the mixed sediments of the west continental shelf of Shetland, was characterised by common sessile species such as *Bolocera tuediae, Flustra foliacea* and *Alyconium digitatum*.

Jennings *et al*. (1999) carried out a study of the epifauna distinguished as sessile and free-living. By applying hierarchical classification analysis of presence and absence data for attached epibenthic species, one of the sampling sites located north of Shetland along with the stations in the northern North Sea, was allocated to a northern cluster, the central and southern areas being the other two clusters. However, calculation of the clusters for free-living epifaunal species, allocated the north of Shetland stations to a central North Sea cluster. Furthermore the calculation of the mean similarity within the group of the attached epifauna was only 15.8%, perhaps reflecting the heterogeneity of the benthic biota and environmental instability. The corresponding mean similarity figure for the free-living epifaunal species was in excess of 40%. These data seem to suggest the existence of a north-south split in the epifauna, indicated by the presence of sub-arctic species in the northern North Sea and in accordance with the data from other authors (Frauenheim *et al*. 1989, Dyer *et al.* 1983); however it is not easy to make comparisons with previous studies as the calculated clusters for this study were based on separate analyses for free-living and attached species. Investigations by the authors of the environmental factors which account for the differences in the faunal distributions suggest that temperature variation and depth are better descriptors of this separation than absolute temperatures. The authors also pointed out that the relationship with depth is clearly not expected to be causal; rather, depth will correlate with other environmental factors that have not been measured (such as nutrient supply, stability of the substrate, turbidity, etc).

Similarly, Zühlke *et al*. (2001), carried out a recent study of the epifaunal species in the North Sea, both sessile and free-living, using a 2m beam trawl to sample a large network of stations which covered the whole of the North Sea and impinged marginally on the continental shelf at the north of Shetland. The data from three stations of which only one is on the continental shelf were incorporated with those deriving from the stations of the northern North Sea. In this study, hierarchical cluster analysis was used to separate groups of stations with similar species assemblages. Such clusters were identified between the depth contours of 50–100m and 100–200m, with a greater number of species found between 50 and 100m depth, a feature of the northern reaches of the North Sea. The offshore areas were characterised by clusters of sessile species, including the actinians *Adamsia carcinopados* and *Hormathia digitata*, the hexacorallian *Caryophyllia smithii*, the hydrozoan *Epizoanthus papillosus* and the sponges *Suberites pagurorum* and *Phakellia ventilabrum*. At the edge of the shelf a cluster consisting of the polychaete *Hyalinoecia tubicola*, the sea urchin *Echinus* spp., the anomuran *Anapagurus laevis* and the asteroid *Astropecten irregularis*, were the main elements.

6.2.2.4 General remarks

On the strength of the data from all the above-mentioned studies, their authors drew boundaries for faunal communities and made comparisons with the results from previous studies (Dyer *et al*. 1983, Basford *et al*. 1989, Jennings 1999).

It was found that north of the 100m contour, epifaunal groupings as described by Zühlke *et al*. (2001) were different from those of the other authors, a fact that can be attributed to differences in sampling gear and data analysis. Even with this proviso, the restricted number of stations and the available data do not make it easy to draw comparisons and as a result, the conclusions might be rather subjective.

6.2.3 The infauna

6.2.3.1 Introduction

Some of the data presented and discussed so far have concerned macrobenthic invertebrates of the continental shelf placing emphasis on the epifauna sampled by trawl or surveyed by still photograph or video. There is inevitably a certain degree of overlapping between the epifaunal and infaunal groups, as there are certain infaunal species which were inadvertently taken by trawl but were also taken by grab, or infaunal species, recorded by visual techniques, which were lying or protruding from the surface of soft sediments. The heterogeneity of the bottom structures and the presence of mixed sediments provide an example of a situation where mixed communities do coexist over a short distance scale. Therefore in this grey zone, it will not always be easy to hold to hard and fast distinctions between epifaunal (other than species found exclusively on hard substrata) and infaunal species (especially those characteristic of communities) which may lead to certain repetitions in the text. However this should be considered as an interesting and relevant point in an attempt to show the inter-relationship and perhaps the interactions of the different communities.

The early surveys of the benthic macrofauna of the west of Shetland shelf consisted of qualitative assessments carried out by dredge and Hempen triangles which caught surface-living animals, particularly echinoderms.

Many years later, Stephen (1923) carried out the first quantitative surveys of the macrobenthic infauna in several sites in the northern North Sea and the continental shelf to the west of Shetland. Five stations (58, 52, 126, 150 and 144) on the continental shelf were sampled by Petersen grab while another two (138 and 156) are located on the continental slope north of Shetland. On the stations located west, north and northeast (stations 126, 150 and 144) he reported a fauna numerically dominated by the free-living tube worm *Ditrupa arietina* (360m^2) and characterised as belonging to a pure “Pure *Ditrupa*” community with the only other species recorded being the brittle star *Ophiura affinis*. This community was consistently found near the edge of the continental shelf while halfway along the continental shelf (station 52) a community dominated by *Ophiura affinis* with *Echinocyamus pusillus* was present.

6.2.3.2 Recent studies

More recently, benthic surveys which concentrated primarily on the infaunal communities of the North Sea only marginally included some stations on the west Shetland continental shelf (Eleftheriou & Basford 1989, Basford *et al*. 1990, Künitzer *et al.* 1992).

The studies of Eleftheriou & Basford (1989) and Basford *et al.* (1990) indicated a rich and varied fauna around the Shetland Islands, with high abundances (10-4000ind/m^2), due to the *Thyasira* bivalve complex, Foraminifera and the polychaetes *Owenia fusiformis* and *Heteromastus filiformis* found east of Shetland. There were high biomasses found around Shetland (>100g/m^2), considerably less around Orkney (<10g/m^2) but these were not coincident with the highest densities of the fauna. The predominant feeding types analysed for the five most abundant species were dominated by carnivores and filter feeders with sub-surface deposit feeders in the shelf with filter feeders and sub-surface deposit feeders west of Fair Isle. Basford *et al*. (1996) in their study of the benthic infauna in the Fair Isle inflow region over the period 1980-84 recorded a higher number of infaunal species than in the wider North Sea and abundances which could occasionally be very high due to an influx of juvenile *Ophiura* sp. and ascidians. In this time series, unique for the North Sea, no long-term or seasonal trends in the composition and abundance of the infaunal communities were noted, nor were any trends in the temporal variability in the parameters of the environment (chlorophyll, organic carbon) detected. Furthermore, species richness was not clearly related to sediment characteristics.

In their studies of the infaunal and epifaunal communities, Eleftheriou and Basford (1989) and Basford *et al*. (1990) by the application of a TWINSPAN analysis classified the infaunal stations which were divided according to their species composition into two groupings, one containing the coastal stations and the second the offshore stations. These groupings were also sub-divided into those shallower with coarse sediments stations which were inhabited by a diverse fauna dominated by polychaetes such as *Pisione remota, Exogone hebes, Glycera lapidum, Sphaerosyllis bulbosa*, and the echinoid *Echinocyamus pusillus* while the offshore stations deeper than 100m with finer sediments were characterised by the *Thyasira* bivalve complex and the polychaete *Prionospio* sp. The coarser and less silty sediments were characterised by the polychaete *Spiophanes bombyx*. The infaunal assemblages described in this study are closely related to the two regions of British coastal and offshore Northern as described by Adams (1987) and Glémarec (1973). However it should be pointed out that these infaunal assemblage distributions do not entirely coincide with either Adam's (1987) or Glémarec's (1973) Open-sea and Coastal étage schemes. This is because both of these schemes placed great emphasis on bathymetry and temperature whereas the infauna respond primarily to sediment parameters which do not always show a close association with depth.

Künitzer *et al*. (1992) carried out a synthesis of the data resulting from the ICES synoptic mapping of the infauna for the whole of the North Sea but not for the West Shetland continental shelf. These authors did however refer to the data from the survey by Eleftheriou & Basford (1989) on the Shetland shelf. The most extensive and reliable information concerning the West Shetland shelf, however, is available from the AFEN (1996, 1998) studies and those of Hartley Anderson (2000) and ERSTL (2001) carried out in connection with oil-related developments in the Clair development area and in the Foinaven, Schiehallion and Loyal fields and their potential pipeline routes along the continental shelf.

As commented on by many authors and classified by the OSPAR/ICES/EEA Working Group (1999), the continental shelf around Shetland, has been identified by the OSPAR/ICES/EEA Working Group (1999) as typical of the boreal province which extends south to the North Sea and to the eastern English Channel. The macrofaunal samples from the Clair field taken by grab were analysed by ERTSL (2001) who found that 79% of the species were annelids while the remainder was made up of arthropods (6.9%), molluscs (9.4%), echinoderms (0.9%) and miscellaneous phyla (3.4%). The analysis suggested a relatively uniform community dominated by tubicolous polychaetes characteristic of stable sediments. This interpretation may be influenced by the difficulties encountered in sampling the coarser sediments, or may reflect the tolerance of the dominant species to a range of sediment types. Faunal composition also suggests the presence of mixed or overlapping communities.

The seven most abundant taxa of the infauna ranked by maximal abundance at any of the sampled stations were all polychaetes. The most abundant taxon was the tube-constructing species *Galathowenia oculata*, which was among the most abundant ten taxa at 43 stations including locations categorised by particle size analysis (Wentworth scale) as fine, medium and coarse sands, and by visual interpretation of photographs as "rippled sand" through "gravel, pebbles and cobbles with sand and boulder". It is clear that this species has the capacity to be successful within the Clair area at any location where the sediment includes some sand, and the species is also dominant over large areas of fine sand and silt sediments in the northern and central North Sea. At the stations where *Galathowenia* was not dominant, the most abundant species comprised the polychaetes *Capitella capitata, Protodorvillea kefersteini, Aonides paucibranchiata, Pisione remota* and *Exogone hebes*.

An environmental survey of two prospective Foinaven-Sullom Voe pipeline routes was undertaken in August-September 1999, by Gardline with macrofauna analysis by the Natural History Museum, on behalf of BP Amoco. Seabed samples and photography/video were taken at 51 stations, with photography/video at an additional 31 stations. A total of 134 infaunal taxa was recorded from the direct Foinaven–Sullom Voe route samples, with 118 from the Foinaven-Sandwick route. This species richness is considerably lower than that recorded in the Clair area where over 500 taxa were found. The reasons for such a discrepancy remain unexplained (Hartley Anderson, 2000). In deeper water (>100m), a generally sparse and patchy macrofaunal community was dominated by the tubicolous polychaetes *Myriochele (=Galathowenia) oculata* agg. and *Aonides paucibranchiata* consistent with the communities described from the AFEN and Clair baseline studies. Shallower stations generally had coarser sand substrate, and supported a community dominated by *Prionospio (Minuspio) cirrifera*, together with a number of surface-inhabiting species exploiting the greater niche heterogeneity of these sites which had more gravel.

The numerically dominant macrofaunal species from previous surveys using directly comparable methods (i.e. AFEN 1996) in the area were similar to those recorded by the Clair baseline survey. In combined macrofaunal abundance data from 32 shelf samples at depths between 104 and 180m, the most abundant species was *Myriochele (Galathowenia) oculata* which comprised 861 individuals from a total sample set of 9581 individuals. The maximum abundance of this species was 621 individuals / 0.1m^2 at a single station 181km southwest of Clair.

However, in the AFEN samples taken closest to Clair, relatively low numbers of *Galathowenia* were present (<6 individuals 0.1m^2) and the macrofauna in three different stations was dominated by the following species:

A. Foraminifera, Nematoda, *Ditrupa arietina, Glycera lapidum* complex, *Harmothoe mcintoshi*
B. Nematoda, *Pisione remota, Protodorvillea kefersteini*, calanoid copepod spp., *Aonides paucibranchiata, Hesionura elongata, Glycera lapidum* complex
C. *Aonides paucibranchiata, Protodorvillea kefersteini, Ampelisca brevicornis, Echinocardium* sp., *Opisthodonta pterochaeta*

One of the AFEN stations was re-sampled as a Clair baseline station, which had a dominant macrofauna consisting of *Aonides paucibranchiata, Hesionura elongata, Exogone hebes* and *Protodorvillea kefersteini*, together making up 49.4% of numerical abundance. These data are a reflection of the consistency between the Clair and AFEN 1996 sampling and analytical methodologies, and broadscale persistency of community type over time.

Cluster analysis confirms the interpretation of a relatively uniform macrofaunal community characteristic of sand, little influenced by the presence of larger sediment particles (gravel, pebbles and cobbles) or by the acoustic patchiness evident on sidescan sonar – but this may in part be a result of “self selection” of samples in the sandier sediments since successful samples could not be collected in areas of cobble or boulders.

On disturbed sediments *Capitella capitata* was numerically dominant and comprised 34% of the total macrofaunal abundance. This opportunistic species (or species complex) is characteristic of disturbed sediments worldwide, particularly where organic enrichment is present (e.g. resulting from sewage, pulp mill or aquaculture waste discharges), and is frequently found in sediments contaminated by drill cuttings. The second most numerous species, the cirratulid polychaete *Chaetozone setosa*, is regarded as a secondary opportunist (e.g. Pearson & Rosenberg 1978) and is indicative of low to moderate sediment enrichment.

The overall interpretation of macrofaunal community distribution in the Clair and surrounding areas is of a relatively uniform boreal shelf sand community, dominated by tubicolous polychaetes characteristic of stable sediments. Taxa found at some stations, including the polychaetes *Pisione remota* and *Hesionura elongata*, are typical of more mobile, well sorted sands (Vanosmael *et al*. 1982).

6.2.1.2 General remarks

The fauna of the area is typical of a boreal mixed sediment community of the West of Shetland continental shelf and varies according to the nature of the seabed sediments. The mixed nature of the sediments and the shallow veneer of sand present in places have resulted in a widespread and apparently mixed distribution of animals. Thus the faunal assemblage present contains elements from different communities and does not correspond to any of the "classical" community descriptions. Eleftheriou & Basford (1989) and Basford *et al*. (1990), on the basis of the magnitude of the correlations found between infauna, epifauna and environmental parameters, concluded that the sediment is more important for the infaunal and depth for the epifaunal distribution, although sediment and depth interact in a complex way to determine distribution patterns. On the other hand Hartley Anderson (2000) elaborated that variations are not clearly related to spatial location, water depth or specific measure sediment parameter, but may be speculated to result from overlapping stable and mobile sediment facies and essentially random (stochastic) variability in larval settlement, or community development following occasional natural disturbance (e.g. current scour). Apparent variations in community structure may also be caused by sampling bias resulting from the reduced efficiency of sampling gears in coarser sediments, caused by a combination of reduced sampler penetration and wash-out of samples during recovery. Moreover, low intensity sampling in many areas, or the absence of any data from a very large percentage of the continental shelf makes it even harder to put forward interpretations of the shelf communities or to find inherent trends.

The analysis of the infaunal communities data from the Shetland sedimentary habitats by Pearson *et al*. (1994) suggested that they are comparable only with the infaunal communities, assemblages and associations described from other subtidal sedimentary habitats in boreal areas of western Europe in the most general terms, and they are only loosely comparable to those defined for the North Sea as a whole. Such similarities and comparisons of certain infaunal associations on different sedimentary types between the Shetland shelf and the North Sea were made by the latter authors within the general framework of the classical Petersen/Thorson community types, referring to data provided by Eleftheriou & Basford (1989) and Basford *et al*. (1990).

Pearson *et al*. (1994) analysing mainly the data from inshore areas in Shetland, commented that the difficulties in making comparisons from similar sedimentary habitats in boreal areas of Europe result from the poorly sorted nature of sediments at the examined sites, and the relatively high variability of habitats. Thus, community types are frequently mixtures of two or more of the classical Petersen/Thorson community types, based as they are on habitats of differing granulometries. Nevertheless Stephen (1923) in his studies of the fauna of the Shetland shelf identified, at stations 126 (144m) and 65 (75m), a "Pure *Ditrupa*" community dominated by the tubicolous polychaete *Ditrupa arietina*, with the only other recorded species being the brittle star *Ophiura* sp. However, Stephen's concept of a pure community should be treated with caution, as it was based on a very small number of samples, sieved through a much larger mesh size (1500mm) than the ones used in subsequent surveys. The latter point could explain the paucity of fauna reported and commented on by the author, but probably not the low numbers of *Ditrupa* found in subsequent surveys which suggest that high densities of the species only occur in a certain set of environmental conditions.

7 ANTHROPOGENIC ACTIVITIES AND IMPACTS

The human communities in the north of Scotland, Orkney and Shetland have been traditionally involved with crofting and the exploitation of marine resources. Some harvesting of algae on rocky shores for the alginate industry, as well as the harvesting of edible periwinkles *Littorina littorea* occurs on the rocky shores of Orkney. However, habitats on rocky substrata are generally robust and not as susceptible to damage as sedimentary systems.

The most obvious and direct impact on sedimentary beaches is caused by shore constructions which disturb the dynamic equilibrium of the coastline forces with substantial and at times irreversible erosional cycles. Sandy beaches, popular for recreation, suffer from trampling and the destruction of the backshore which leads to the progressive degradation of the beaches. However, the greatest impacts result from unplanned shore constructions such as jetties and wave-breakers which destabilise the sedimentary shore and cause long-term and potentially irreversible changes in the shore line. Furthermore, on the open coast, sea defences can also affect the stability of the soft sediment beaches and their animal communities.

Different discharges from different point sources or from accidental events have considerable impacts upon the structure and composition of the animal and plant communities.

Small-scale industrial effluents, but a considerable number of untreated domestic point source discharges, from the larger island communities in the bays, voes and sounds where water renewal is minimal, results in eutrophication and accumulation of organic matter which is responsible for the establishment of a gradient of effects on the biology of the shores with distance away from the effluent. In general there is a species diversity near to the source of effluents where the environment can be azoic to a zone of opportunistic polychaetes (such as *Capitella capitata* and some spionids) and nematode worms, which is replaced by a more diverse macrofauna away from the point source discharge following Pearson and Rosenberg's model (1978).

In connection with land-based oil-related installations in both Shetland (Sullom Voe) and in Orkney (Scapa Flow), the key sources or marine pollution recognised by Johnson (1981) from the operation of the oil terminal, i.e. tanker accidents and the resultant spillages in inshore areas, spillages at the terminal site and effluent discharges from terminal operations, all materialised within a few years with important environmental consequences. The shipwreck of the oil tanker "Braer" which caused a very large oil spill had an impact on local fisheries and highly productive fishfarms as well as on coastal flora and fauna. Repeated oil spillages have also taken place at the oil terminals on Orkney and Shetland, and it is possible that these areas now suffer from chronic low-level oil pollution which has a more insidious effect than that from a single, though much larger, accidental spillages. Oil spilt in sheltered areas and trapped in the sediments may itself form a source of chronic pollution.

Oil pollution may also cause long-term damage to rocky shore communities although these are likely to be least severe on wave-exposed coasts. Effects depend on a range of factors including the type and age of crude oil in question, and the use of dispersants. Oil spills can also have long-lasting chronic effects on areas such as the Shetland voes and other rocky inlets where subtle effects may be detectable many years after the original spillage occurred.

Radioactive substances in the form of artificial nucleides are discharged from the nuclear reprocessing plant on the coast of Caithnness (Dounreay) and these give rise to levels detectable well into the North Sea.

Dredges for sedimentary material in the inshore habitats is evident in some of the sounds of Orkney where maerl is extracted. Hydraulic dredging for bivalves such as *Ensis* and dredging for shellfish (scallops) also carried out in Orkney and Shetland cause a selective but serious damage to benthic communities (Eleftheriou & Robertson 1992).

Mariculture activities practised in Orkney and Shetland produce salmon and some shellfish, both species vulnerable to environmental contamination, especially by hydrocarbons as was shown in the case of the “Braer” oil spill in Shetland, which had an extremely deleterious effect on market for Shetland farmed salmon. In addition, high hydrocarbon levels, which lasted for some time, were also found in wild fish and inshore and offshore sediments.

Nevertheless, mariculture activities themselves are recorded as having environmental impacts both on the existing natural environment and on natural wild populations. Large inputs of organic matter, therapeutants and other effluents were responsible for changes in the benthic infauna and the environmental parameters particularly evident in areas with reduced water movement. Communities typical of eutrophic conditions, and dominated in certain extreme cases by *Capitella capitata* and nematodes were present.

Environmental impacts on offshore habitats have been recorded as deriving from several activities, such as oil and gas extraction, fisheries and waste disposal, with concomitant effects upon the biota and communities. Trawling for benthopelagic species of fish is an important economic activity, carried out intensively on the west Shetland continental shelf. Benthic sessile species are particularly vulnerable to fishing gear towed over the sea floor and effects deriving from such activities are now well documented in the literature. Disturbance of the bottom material on the shelf was attributed (Hartley Anderson 2000) to otter trawling or to anchoring in this area.

The offshore oil and gas industry, a major economic activity in the continental shelf and continental slope in the North Sea, and the west Shetland shelf and adjacent areas, have had a considerable impact on the biology and ecology of those areas. Although these effects have been shown to decrease rapidly in relation to distance from a point source of discharge, nevertheless a variety of contaminants is found in the sediments and in the organisms living there. Aliphatic hydrocarbons, Polycyclic Aromatic Hydrocarbons (PAH) and metals were found in the sediments in the vicinity of an exploration platform in the shelf break of the continental shelf. However, it should be pointed out that long-term routine pollution from drilling activities can have a significant impact on the composition and structure of the bottom communities. Thus in such disturbed sediments contaminated by drill cuttings, a restricted fauna of opportunistic species such as the polychaetes *Capitella capitata* and *Chaetozone setosa* and spionids, was numerically dominant. Large densities of *Thyasira sarsi* which are considered as an opportunistic species are usually found in oily drill cuttings piles present beneath many older North Sea oil production platforms. However, Hartley Anderson (2000) notes that the beneficial effects of the presence of this species can be shown through bioturbation which promotes the aerobic and anaerobic degradation of organic contaminants. Oil spills from offshore exploration platforms and accidental releases from tankers result in oil slicks with severe consequences for plankton, fish eggs and sea birds, as well as for the seafloor biota, as shown from data gathered from shipwrecks in the northern islands.

Oil and gas installations and their connecting pipelines on the seafloor provide a hard substratum for a variety of fauna and flora to colonise and provide shelter for numerous fish species. However, some disturbance of the seafloor and the biota are accompanied at the positioning of such structures and during operations.

In conclusion it is clear that the many and various anthropogenic activities do make impacts on the environment of the SEA 4 area. However, these effects are on the whole localised and in most cases reversible, even in the areas of intensive development. Nevertheless it should be stressed that though the sector in question, in comparison with the North Sea and adjacent areas, shows a lesser anthropogenic interference in the offshore areas, this has a greater impact in the vicinity of the oil terminals and along the coastlines. This means that a considerable extent of the SEA 4 sector area could be considered to be in a very good state of ecological balance but further work is needed in order to identify the very many and poorly known ecosystems, their structure and function. A significant effort should be directed towards the oil-related areas of disturbance both offshore and onshore in order to monitor any further deterioration and initiate a policy of remediation and further protection of the environment undertaken within the proper socio-economic context.

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8 INFORMATION GAPS

The coastal and inshore areas of Shetland, Orkney and the North Scottish coast, have been extensively and intensively surveyed over a period of several decades. The accumulated information on the biology and ecology of the faunal and plant communities has been compiled and is available in MCNR reports and publications. However, there are still some problems of species identification which remains an important stumbling block in the investigations, which could be alleviated by the correct systematics. Descriptions of the biota and information on the biodiversity of the benthic communities over a large expanse of the littoral and the shallow sublittoral provide an extremely well-documented database which could be invaluable in our assessment of any habitat loss and biodiversity changes in the area.

The offshore areas have been less well studied with the majority of sampling stations lying near the shelf break at the west of Shetland. The majority of these stations formed part of site-specific studies, in support of licence applications or in connection with exploration activities. However, a large expanse of the seafloor lying west of Orkney and to the north, northwest of the Caithness coast, has not been investigated in any systematic way and remains relatively unknown. While studies of the macrobenthic assemblages have concentrated on the infauna and epifauna, information concerning the smaller metazoan organisms, the meiobenthos of the soft sediments structured and grouped within roughly the same areas as the infaunal and epifaunal assemblages, is totally lacking. It is well established that meiobenthic organisms are good indicators of environmental conditions and therefore of the different biogeographic regions. Furthermore they are excellent sensors of climatic changes and respond fast to pollution conditions. This lack of information constitutes a definite and major gap in our knowledge, which should be taken into account when exploratory surveys of the geographical distribution of the communities in relation to the environmental parameters are designed and undertaken. Studies in the biodiversity of the benthos of the SEA 4 area should include not only the number of species but also the remaining and important biotic indices of abundance and biomass which need to be examined in relation to the environmental parameters and the productivity of the area. The links in the food web can provide invaluable information on the structure and functioning of the marine ecosystem.

On the other hand as the fauna is likely to vary both annually and seasonally, stations should be surveyed in the same season of the same year. Variations or differences observed between surveys are to a large extent due to the unsystematic and uncoordinated design of such investigations.

It is clear that the mixed sediments and the hard substrata observed in the shelf require a new methodological approach, as traditional equipment is no longer adequate to provide for representative examination of the fauna. Still photography and ROV video are now providing invaluable information concerning the composition, distribution and abundance of the larger fauna on the shelf. Suggestions to improve remote collection of specimens by ROV manipulator to ascertain identification of materials is an important addition to the combination of techniques and methods which should be employed in order to have a representative, detailed and useful account of the benthic assemblages and the environment of the shelf area.

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