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Marine habitat reviews

A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs

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2000

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Preface

Throughout the 1990s there has been a "call to action" for marine biodiversity conservation. The global Convention on Biodiversity, the European Union's Habitats Directive and recent developments to the Oslo and Paris Convention have each provided a significant step forward. In each case marine protected areas are identified as having a key role in sustaining marine biodiversity.

The Habitats Directive requires the maintenance or restoration of natural habitats and species of European interest at favourable conservation status, with the management of a network of Special Areas of Conservation (SACs) being one of the main vehicles to achieving this. Among the habitats and species specified in the Annexes I and II of the Directive, several are marine features and SACs have already been selected for many of these in the UK. But to manage specific habitats and species effectively there needs to be clear understanding of their distribution, their biology and ecology and their sensitivity to change. From such a foundation, realistic guidance on management and monitoring can be derived and applied.

One initiative now underway to help implement the Habitats Directive is the UK Marine SACs LIFE Project, involving a four year partnership (1996-2001) between English Nature, Scottish Natural Heritage, Countryside Council for Wales, Environment and Heritage Service, Department of the Environment for Northern Ireland, Joint Nature Conservation Committee, and Scottish Association of Marine Science.

The overall goal of the Project is to establish management schemes on 12 of the candidate marine SAC sites. A key component of the Project is to develop a fuller understanding of the ecology and sensitivity characteristics of the some of the features associated with the marine Annex I habitats and Annex II species. To this end, the Project has produced a series of nine reports reviewing in detail the current knowledge available on nine such features

The following report responds to the need of practitioners for a consistent summary of the key ecological requirements and sensitivity characteristics in order to inform the assessment of potential management requirements on sites. This report achieves this by providing an overview of the information contained in these reports and in other relevant documents. The value and transferability of the guidance to other marine protected area situations is enhanced by using a more consistent and detailed biotope complex structure to this information than was possible in the original nine reports.

This report is aimed primarily at staff in the statutory nature conservation bodies who are engaged in providing conservation objectives and monitoring advice to the marine SAC management schemes. However it will be a valuable resource to other relevant authorities and those involved in the broader network of coastal-marine protected areas. The information it contains represents the current position on an ever growing understanding of the ecology of marine features and of the best means of interpreting this understanding. There are on-going initiatives beyond this Project which will continue to take this work forward.

The report provides a sound basis on which to make management decisions on marine SACs and also on other related initiatives such as the Biodiversity Action Plans and Oslo and Paris Convention. As a result, they will make a substantial contribution to the conservation of our important marine wildlife. We commend them to all concerned with the sustainable use and conservation of our marine and coastal heritage.

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Chair, UK Marine SACs Project

Director, English Nature

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Projects Director

Joint Nature Conservation Committee

Introduction

Background

This report is a compilation of 22 habitat reviews, covering many of the significant marine habitats found around the UK's coastline and in particular within the network of marine Special Areas of Conservation[1] (SACs).

The purpose of these reviews is to provide a technical summary of the key characteristics of each habitat, to assist in their management and conservation. As such the reviews are primarily aimed at marine specialists involved in the conservation management of the habitats, both in the UK and in other European countries.

The information in this report is based upon nine more detailed studies undertaken through the UK Marine SACs Project[2] and upon the earlier work on habitat classification provided by JNCC's Marine Nature Conservation Review and BioMar[3]. The reviews were originally conceived to support the work of OSPAR[4] and in particular to contribute to our understanding of the ecological functioning of certain marine habitats in the north-east Atlantic[5]. Recognising their value in underpinning Special Areas of Conservation, the series of reviews has been extended as part of the UK Marine SACs Project.

The understanding contained in these reviews continues to evolve, both in terms of the knowledge of the ecology of the features themselves and in the most effective and practical means of categorising and interpreting this knowledge. The work will continue to be taken forward through the *MarLIN* programme[6] (see below).

The UK Marine SACs Project

The UK Marine SACs Project was set up in 1996 with the overall aim of promoting the implementation of the EC's Habitat Directive in marine areas, through trialing the establishment of management schemes on twelve sites in the UK and by providing proven good practice and guidance to practitioners in the UK and Europe. In support of this aim, it has undertaken a number of studies to collate and develop knowledge on marine features and in particular: their ecology and sensitivity of marine features, the impacts and management of human activities, and methods for monitoring them. The collation of knowledge on ecology and sensitivity focused on nine broad habitats that are key components within the marine SACs, resulting in the following reports:

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[1] Special Areas of Conservation are designated for particular habitats and species under the EC Habitats Directive.

[2] The UK Marine SACs Project is an EC *Life*-Nature funded project, running from 1996-2001, aimed at establishing management schemes and generic technical and conservation guidance for marine SACs.

[3] BioMar was an EC *Life*-Environment funded project which ran from 1992-97, in which JNCC developed a marine habitat classification for Britain and Ireland, as part of its Marine Nature Conservation Review programme.

[4] OSPAR is the Oslo and Paris Convention for the protection of the marine environment of the north-east Atlantic.

[5] Six reviews (moderately exposed circalittoral rock, *Sabellaria spinulosa* reefs, *Modiolus modiolus* beds, maerl beds, eelgrass *Zostera marina* beds and seapen faunal communities) were presented as IMPACT 98/6/6 (as reported in the meeting's Summary Record IMPACT 98/14/1-E).

[6] *MarLIN* is the Marine Life Information Network, a consortium-funded programme run by the Marine Biological Association of the United Kingdom, Plymouth.

I	*Zostera* species	Davison 1998
II	Intertidal sand and mudflats and subtidal mobile sandbanks	Elliott *et al.* 1998
III	Seapens and burrowing megafauna	Hughes 1998a
IV	Subtidal brittlestar beds	Hughes 1998b
V	Maerl	Birkett *et al.* 1998b
VI	Intertidal reef biotopes	Hill, Burrows & Hawkins 1998
VII	Infralittoral reef biotopes with kelp species	Birkett *et al.*1998a
VIII	Circalittoral faunal turf biotopes	Hartnoll 1998
IX	Biogenic reefs	Holt *et a*l.1998

Habitat reviews

The 22 habitat reviews in this report provide a summary of key information, contained in the nine studies noted above and other key references, in terms of more specific features. The selection of these features and the information presented in the reviews builds upon the habitat classification system developed for Britain and Ireland under the EC *Life*-funded BioMar Project. This system defines and describes seabed habitats (biotopes[7]) at a variety of hierarchical scales as an aid to the management and conservation of marine habitats.

The relationship between the 22 habitats and the marine habitats specified in Annex 1 of the EC Habitats Directive is provided in the Appendix at the end of this introduction.

Each habitat is described in a standard way, under the following headings:

- Biotope code and name
- Habitat classification
- Biotope description
- Similar biotopes
- Characterising species
- Distribution
- Frequency of occurrence

The reviews presented here provide the following key additional information on each habitat:

- A correlation with other national and international classifications

[7] A ***biotope*** is defined as the ***habitat*** (i.e. the environment's physical and chemical characteristics) together with its recurring associated ***community*** of species, operating together at a particular scale. The habitat is taken to encompass the substratum (rock, sediment or biotic reefs such as mussels) and the particular conditions of wave exposure, salinity, tidal streams and other factors, which contribute to the overall nature of the location. The term community is used here to signify a similar association of species, which regularly recurs in widely separated geographical locations; the degree of similarity will vary, depending on the scale considered (from Connor *et al*. 1997a, b).

- A description of the ecological role of the habitat or its key component species
- An assessment of the sensitivity of the habitat to various human activities
- An assessment of the present conservation status (degree of threat) of the habitat, its current level of protection, and an outline of the management measures that are required to improve its status.

The reviews provide a model for the development of a key information system on marine habitats, designed to provide essential information to underpin management and conservation of the marine ecosystem. They have a standard format to assist the user in quickly locating the relevant information and lead the user to more detailed information in supporting references if required. This standard approach lends itself to display on electronic media such as the Internet (some reviews are now available on JNCC's web site: www.jncc.gov.uk), where inclusion of photographic images or other graphics and hypertext links can greatly enhance the user's ability to access the information. The categories used in each review are defined below.

The habitats included here are mostly at the *habitat complex* level in the MNCR BioMar classification, that is they each comprise a number of more specifically defined *biotopes* which occur in broadly similar habitat conditions. In a few cases the habitat reviews are at a lower level in the classification, for example the habitats dominated by single species such as mussels, maerl, eelgrass and honeycomb worms.

Future developments within *MarLIN*

Further key information reviews for other marine habitats, and for marine species, are being prepared within the *MarLIN* programme, assisted by funding from the UK Department of the Environment, Transport and the Regions, English Nature and Scottish Natural Heritage. These are being developed on an interactive Internet platform (www.marlin.ac.uk), and follow a similar format to that presented here, but with further guidance on habitat sensitivity.

Layout of the habitat reviews

Each habitat review is laid out in a standard format. The main sources of information, criteria and terminology used are given below:

Classification

The habitat unit described is correlated to the following habitat classifications:

Area	*Classification*	*Source*
Europe	EUNIS (November 1999 version)	Davies & Moss (1999)
Wadden Sea	Wadden Sea biotope red list	Von Nordheim, Andersen & Thissen (1996)
Britain & Ireland	MNCR BioMar (version 97.06)	Connor *et al.* (1997a, b)
France	ZNIEFF-Mer	Dauvin *et al.* (1994)

Description

The habitat description is taken from the MNCR BioMar classification (Connor *et al.* 1997a, b).

GB distribution

The habitat distribution maps are generated from the JNCC's Marine Nature Conservation Review database, providing information on the known distribution of the habitat, including all relevant sub-types, at the date given.

Habitat requirements

Information relating to each habitat is derived from Connor *et al.* (1997a, b) and the relevant UK Marine SACs Project review.

The terms used for each of the habitat factors (e.g. moderately strong tidal streams) are given below, as defined in Connor *et al.* (1997a, b).

Factor	*Category*	*Definition*
Salinity	Fully marine	30-40 ‰
	Variable	18-40 ‰
	Reduced	18-30 ‰
	Low	<18 ‰
Wave exposure	Extremely exposed	This category is for the few open coastlines which face into prevailing wind and receive oceanic swell without any offshore breaks (such as islands or shallows) for several thousand km and where deep water is close to the shore (50 m depth contour within about 300 m, e.g. Rockall).
	Very exposed	These are open coasts which face into prevailing winds and receive oceanic swell without any offshore breaks (such as islands or shallows) for several hundred km but where deep water is not close (>300 m) to the shore. They can be adjacent to extremely exposed sites but face away from prevailing winds (here swell and wave action will refract towards these shores) or where, although facing away from prevailing winds, strong winds and swell often occur (for instance, the east coast of Fair Isle).
	Exposed	At these sites, prevailing wind is onshore although there is a degree of shelter because of extensive shallow areas offshore, offshore obstructions, a restricted (<90^{o}) window to open water. These sites will not generally be exposed to strong or regular swell. This can also include open coasts facing away from prevailing winds but where strong winds with a long fetch are frequent.
	Moderately exposed	These sites generally include open coasts facing away from prevailing winds and without a long fetch but where strong winds can be frequent.
	Sheltered	At these sites, there is a restricted fetch and/or open water window. Coasts can face prevailing winds but with a short fetch (say <20 km) or extensive shallow areas offshore or may face away from prevailing winds.
	Very sheltered	These sites are unlikely to have a fetch greater than 20 km (the exception being through a narrow (<30^{o}) open water window, they face away from prevailing winds or have obstructions, such as reefs, offshore.
	Extremely sheltered	These sites are fully enclosed with fetch no greater than about 3 km.
	Ultra sheltered	Sites with fetch of a few tens or at most 100s of metres.
		In the classification **exposed** (as in exposed littoral rock) encompasses the extremely exposed, very exposed and exposed categories, whilst **sheltered** (as in sheltered littoral rock) encompasses sheltered to ultra sheltered categories.
Tidal streams/currents (maximum at surface)	Very strong	>6 knots (>3 m/sec.)
	Strong	3-6 knots (1.5-3 m/sec.)
	Moderately strong	1-3 knots (0.5-1.5 m/sec.)
	Weak	<1 knot (<0.5 m/sec.)
	Very weak	Negligible
		In the classification tide-swept habitats typically have moderately strong or stronger tidal streams.

Zone	Supralittoral	Colonised by yellow and grey lichens, above the *Littorina* populations but generally below flowering plants.
	Upper littoral fringe	This is the splash zone above High Water of Spring Tides with a dense band of the black lichen by *Verrucaria maura* . *Littorina saxatilis* and *Littorina neritoides* often present. May include saltmarsh species on shale/pebbles in shelter.
	Lower littoral fringe	The *Pelvetia* (in shelter) or *Porphyra* (exposed) belt. With patchy *Verrucaria maura*, *Verrucaria mucosa* and *Lichina pygmaea* present above the main barnacle population. May also include saltmarsh species on shale/pebbles in shelter.
	Upper eulittoral	Barnacles and limpets present in quantity or with dense *Fucus spiralis* in sheltered locations.
	Mid eulittoral	Barnacle-limpet dominated, sometimes mussels or dominated by *Fucus vesiculosus* and *Ascophyllum nodosum* in sheltered locations. *Mastocarpus stellatus* and *Palmaria palmata* patchy in lower part. Usually quite a wide belt.
	Lower eulittoral	Fucus serratus, Mastocarpus stellatus, Himanthalia elongata or Palmaria palmata variously dominant; barnacles sparse.
	Sublittoral fringe	Dominated by *Alaria esculenta* (very exposed), *Laminaria digitata* (exposed to sheltered) or *Laminaria saccharina* (very sheltered) with encrusting coralline algae; barnacles sparse.
	Upper infralittoral	Dense forest of kelp.
	Lower infralittoral	Sparse kelp park dominated by foliose algae except where grazed. May lack kelp.
	Upper circalittoral	Dominated by animals, lacking kelp but with sparse foliose algae except where grazed.
	Lower circalittoral	Dominated by animals with no foliose algae but encrusting coralline algae.
		Zone definitions primarily relate to rocky habitats or those where algae grow (e.g. stable shallow sublittoral sediments). For use of the terms ***infralittoral*** and ***circalittoral***, especially for sediments, in the classification refer also to Table 2.2 in Connor *et al.* (1997a, b).
Substratum	Bedrock	Includes very soft rock-types such as chalk, peat and clay.
	Boulders	Very large (>1024 mm), large (512-1024 mm), small (256-512 mm)
	Cobbles	64-256 mm
	Pebbles	16-64 mm
	Gravel	4-16 mm
	Coarse sand	1-4 mm
	Medium sand	0.25-1 mm
	Fine sand	0.063 - 0.25 mm
	Mud	<0.063 mm (the silt/clay fraction)
		In the classification, bedrock, stable boulders, cobbles or pebbles and habitats of mixed boulder, cobble, pebble and sediment (***mixed substrata***) as well as artificial substrata (concrete, wood, metal) are collectively referred to as ***rock***. Highly mobile cobbles and pebbles (shingle), together with gravel, coarse, medium and fine sand are collectively referred to as ***gravels and sands***. ***Mixed sediment*** consists of various mixtures of gravel, sand and mud and may often have shells and stones also.

Species composition and biodiversity

The tables listing characterising species are taken from marine biotopes classification for Britain and Ireland (Connor *et al.* 1997a, b). Data on characterising species not contained within these reports were derived from the JNCC's Marine Nature Conservation Review database. The tables are explained below:

Factor	***Category***	***Definition***

Characterising species		A list of those species considered to best characterise the biotope together with associated information on their frequency of occurrence, degree of faithfulness and the typical abundance at which they occur.
% Frequency of occurrence		The species listed include those which are *constants* (i.e. they occur in >60% of the records for the type) plus those which occur in less than 60% of the records but which are *highly faithful* or *moderately faithful*. The symbols represent percentage occurrence in the samples as follows:
	●●●●●	Occurs in 81-100% of the records for the type
	●●●●	Occurs in 61-80% of the records for the type
	●●●	Occurs in 41-60% of the records for the type
	●●	Occurs in 21-40% of the records for the type
	●	Occurs in 1-20% of the records for the type
Degree of faithfulness		This is indicated by the following guidelines, based on the relevant *major habitat* and the appropriate level in the classification (i.e. *Ascophyllum nodosum* may be considered moderately faithful at the biotope level, but highly faithful at the biotope complex level):
	●●● *Highly faithful*	species restricted to this or very closely related types
	●● *Moderately faithful*	species found in this and other related types in the relevant *major habitat*
	● *Poorly faithful*	species found very widely in the relevant *major habitat*
Typical abundances		These are given according to the MNCR abundance scales (see Appendix) in Connor *et al.* (1997a, b) which are the scales used for all MNCR and BioMar field recording for *in situ* surveys. Sediment infaunal sampling usually yields counts of individuals per sample; these have been converted to the MNCR abundance scale for compatibility of data presentation here. The abundance given is a mean abundance derived from the records assigned to the biotope.

Ecological relationships

Information relating to each habitat is derived mainly from the relevant UK Marine SACs Project review.

Sensitivity to human activities

The measures of sensitivity are based on definitions developed for the *MarLIN* programme, and assessed using information derived mainly from the relevant UK Marine SACs Project review. The sensitivity ranks are the maximum likely for each activity assessed against the *benchmarks* given below (i.e. a given amount of activity over a particular period). Tyler-Walters & Jackson (2000) describe the *MarLIN* programme's methodology, definitions and procedures for assessing sensitivity of habitats and species.

Note: Whilst this methodology is now well advanced, it is likely that both the methodology and subsequent ratings will need to be modified in the light of their practical application and as new information becomes available. Also management of human activities needs to take account of site-specific conditions, such as the local extent and frequency of the activity, as these will have a strong bearing on whether the activity is having a significant damaging effect on the habitat.

Factor	*Category*	*Definition*
Biotope sensitivity		The intolerance of a habitat or community of species to damage, or death, from an external factor. Defined by the following categories:
	High	Keystone/dominant species in the biotope or habitat are likely to be killed/destroyed by the factor under consideration.
	Intermediate	Some of the keystone/dominant species in a community may be killed/destroyed by the factor under consideration, the habitat may be partially destroyed or the viability of a species population or diversity/functionality in a community will be reduced.

	Low	Keystone/dominant species in a community or the habitat being considered are unlikely to be killed/destroyed by the factor under consideration and the habitat is unlikely to be damaged. However, the viability of a species population or diversity / functionality in a community will be reduced.
	Not sensitive	The factor does not have a detectable effect on structure and functioning of a biotope or the survival or viability of keystone/important species
	Not sensitive*	The extent or species richness of a biotope may be increased or enhanced by the factor.
	Not relevant	Sensitivity may be assessed as not relevant where communities and species are protected or physically removed from the factor (for instance circalittoral communities are unlikely to be effected by increased emergence regime).
Benchmarks	Substratum removal	All of the substratum occupied by the species or biotope under consideration is removed. Once the activity or event has stopped (or between regular events) substratum within the habitat preferences of the original species or community remains or is deposited. A single event is assumed for assessment.
	Substratum change	All of the population of a species or an area of a biotope is smothered by sediment to a depth of 5 cm above the substratum for one month. Impermeable materials, such as concrete, oil or tar, are likely to have a greater effect [In the case developments, the substratum is replaced by new material, e.g. from construction]
	Siltation	A change in suspended sediment concentration of 100mg/1 outside the normal range experienced by the organism or community of interest for 1 year.
	Desiccation	A normally subtidal, demersal or pelagic species including intertidal migratory or under surface species is continuously exposed to air and sunshine for 1 hour.
	Changes in emergence regime	A 1 hour change in the time covered or not covered by the sea for a period of 1 year.
	Changes in water flow rate	A change of two [MNCR] categories in water flow rate for one year for 1 year. For example from moderately strong (1-3 knots) to very weak (negligible).
	Changes in temperature	A change of 5 °C outside normal temperature range for 3 consecutive days. This definition includes short term thermal discharges. A change in temperature of 2 °C outside normal temperature range for a year. This definition includes long term thermal discharges. For intertidal species, the normal range of temperatures includes the normal air temperature regime for that species.
	Changes in turbidity	Exposed to 50 mg/l suspended particulate matter or light absorption of 30% for five weeks.
	Changes in wave exposure	A change of two ranks on the [MNCR] wave exposure scale e.g. from Exposed to Extremely exposed for a period of 1 year.
	Noise	Underwater noise levels 130 dB re 1 µPa (for broad spectrum noise 45 – 7070 Hz) at 100 m from source intermittently over a 24 hour period for 1 month during important feeding or breeding periods. This approximates to the regular passing of a 30 m-trawler at 100 m or a working cutter-suction transfer dredge at 100 m. Atmospheric noise levels 98 dB re 1 µPa (for broad spectrum noise 45 – 7070 Hz) at 300 m below the source on and off over a twenty-four hour period for 1 month during important feeding or breeding periods. This approximates to the regular passing of a Boeing 737 passenger jet 300 m overhead.
	Visual presence	The continuous presence for one month of moving objects not naturally found in the marine environment (e.g. boats, machinery, and humans) within the visual envelope of the area in which the species under consideration occurs.

Synthetic compound contamination	Environmental Assessment Level/Environmental quality Standard (for seawater unless otherwise stated):	Exposed to the following contaminant concentration:
	Tributyl tin: 0.002 µg/l (Maximum Allowable Concentration)	Long term: 0.004 µg/l average in seawater for a 1 year period Short term: 1 µg/l seawater for 2 days (48hrs)
	DDT (all isomers): 0.025/l annual average	Long term: 0.05 µg/l average for 1 year Short term: 0.25 µg/l for 48hrs
	Lindane (γ-HCH): 0.02µg/l annual average.	Long term: 0.04 µg/l average in seawater for a 1 year period Short term: 0.2 µg/l for 48hrs
Heavy metal contamination	Environmental Assessment Level/Environmental quality Standard (for seawater unless otherwise stated):	Exposed to the following contaminant concentration:
	Copper: 5 µg/l annual average	Long term: 10 µg/l annual average for 1 year period. Short term: 50 µg/l for 48hrs
	Mercury: 0.3 µg/l annual average 0.13 mg/kg for sediments	Long term: 0.6µg/l annual average for 1 year, or 0.26 mg/kg in sediments for 1 year Short term: 3 µg/l for 48hrs
Hydrocarbon contamination	Environmental Assessment Level/Environmental quality Standard (for seawater unless otherwise stated):	Exposed to the following contaminant concentration:
	Benzo(a)pyrene: 88.8 µg/kg sediment	Exposed to 176 µg/kg in sediment for 1 year.
Radionuclide contamination	Exposure to concentration of radionuclide equivalent to 100 mBg/l. of caesium-137 (^{137}Cs) for 1 year.	
Changes in nutrient levels	A change of total nitrogen of 3 mg/l and/or phosphorus of 0.3 mg/l as an annual average. Alternatively, a 50% increase of nutrients as an annual average.	
Changes in salinity	A change of one category from the MNCR salinity scale, e.g. from reduced to low for 1 year. A change of two categories from the MNCR salinity scale, e.g. from full to reduced for 1 week.	
Changes in de-oxygenation	Exposure to dissolved oxygen concentration of 2 mg/l for 1 week.	
Abrasion	Force equivalent to a standard lobster pot or creel landing on the organism.	
Displacement	Removal of the organism from the substratum and displacement from its original position onto a suitable substratum. A single event is assumed for assessment.	
Introduction of microbial pathogens and parasites	Sensitivity can only be assessed relative to a known, named disease. Likely to cause partial loss of a population and will be assessed of intermediate sensitivity.	
Introduction of non-native species	Sensitivity assessed against the likely effect of the introduction of non-native species in Britain or Ireland.	
Removal of target species	Extraction removes 50% of the species from the area under consideration. The habitat remains intact or recovers rapidly.	

	Removal of non-target species	A species that is a required host or prey for the species under consideration (and assuming that no alternative host exists) or a keystone species in a biotope is removed.

Human activities

* Activities which have been assigned a sensitivity score in this report

Aquaculture

Aquaculture: algae

Aquaculture: fin -fish *

Aquaculture: shellfish

Climate change/global warming *

Coastal defence

Coastal defence: barrage

Coastal defence: beach nourishment *

Coastal defence: dredging *

Coastal defence: groynes

Coastal defence: sea walls/breakwaters *

Collecting (harvesting)

Collecting: algae (not kelp/wrack harvesting)

Collecting: bait digging *

Collecting: birds eggs

Collecting: curio

Collecting: higher plants

Collecting: kelp/wrack harvesting *

Collecting: peelers (boulder turning) *

Collecting: shellfish (winkles, mussels) *

Collecting: trade in wildlife

Development

Development (culverting lagoons)

Development: artificial reefs

Development: communication cables

Development: docks, ports & marinas *

Development: land claim *

Development: urban/industrial

Extraction (of resources)

Extraction: maerl *

Extraction: navigational/maintenance dredging *

Extraction: oil/gas

Extraction: rock/minerals (coastal quarrying)

Extraction: sand/gravel (aggregate dredging) *

Fishing

Fishing: angling *

Fishing: fixed netting (gill/tangle)

Fishing: mobile netting (seine)

Fishing: potting/creeling *

Fishing: suction/hydraulic dredging

Fishing: benthic trawling *

Fishing: pelagic trawling

Recreation

Recreation: diving/dive site

Recreation: marina

Recreation: popular beach/resort *

Recreation: water sports

Uses: archaeology

Uses: boats/shipping

Uses: boats/shipping (anchoring/mooring) *

Uses: boats/shipping (anti-fouling) *

Uses: boats/shipping (beaching/launching)

Uses: boats/shipping (oil spills) *

Uses: coastal forestry/farming *

Uses: education/interpretation

Uses: energy generation (wind/tide/wave)

Uses: freshwater extraction/storage on land

Uses: military

Uses: research

Waste

Waste: air (pollution)

Waste: cooling water (power stations) *

Waste: industrial effluent discharge *

Waste: land/riverine drainage (pollution)

Waste: litter and debris

Waste: nuclear effluent discharge

Waste: quarry waste dumping

Waste: sewage discharge *

Waste: spoil dumping *

Conservation and protection

The availability of *conservation status* information is very limited at present; assessment criteria are currently being developed by OSPAR, but are subject to change in the light of their practical application. The 'status of decline' criterion, as currently defined in the OSPAR 'Faial' criteria (most recent version: IMPACT 99/15/1, Annex 6), has been applied at a UK level. For the Wadden Sea, similar status criteria (Wadden Sea biotope red list categories: Completely destroyed, threatened by complete destruction, heavily endangered, endangered, potentially endangered, presumably not endangered at present) have been used, as defined by Von Nordheim, Andersen & Thissen (1996)).

Criterion	*Categories*	*Source/definition*
Status of decline		Decline means a significant decline in extent or quality. The decline may be historic, recent or current. The decline can occur in the whole OSPAR maritime area or regionally. 'Decline' will be assessed according to categories 1 to 4 described below for both decline in extent and quality, recognising the following descriptions: Extent – based on distributional coverage or areal extent. Quality – judgement of decline in quality should be based on change from natural condition caused by human activities. Such judgement is likely to include aspects of biodiversity, species composition, age composition, productivity, biomass per area, reproductive ability,

	non-native species and the abiotic character of the habitat.	
	Extent	Quality
Extirpated (extinct within the OSPAR Area)	A habitat which was previously present in the OSPAR Area, but no information is available that it still exists.	A habitat for which quality is affected so severely that it's typical or natural components are completely destroyed.
Severely declined	A habitat for which only 25% or less of its former natural distribution in the OSPAR Area still exists. If impacts start or continue and no protection or management measures are taken the habitat may be completely destroyed.	A habitat for which quality is negatively affected in the entire OSPAR Area so that typical or natural components can only be found in one or very few sub-regions.
Significantly declined	A habitat that has declined in extent to between 25% and 75% of its former natural distribution in the OSPAR Area, or that has become extinct in several sub-regions.	A habitat for which quality is negatively affected by: (1) a change of its typical or natural components over almost the entire OSPAR area, or (2) the loss of its typical or natural components in several sub-regions.
Probability of significant decline	There is a high probability that the habitat will decline by 25% or more if no protection or management measures are taken.	There is a high probability that the habitat will significantly decline in quality if no protection or management measures are taken.

If the habitat has some specific *protected status* in the EC Habitats Directive or the UK Biodiversity Action Plan, the corresponding habitat is given (UK Biodiversity Group 1999).

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Appendix Relationship between Annex I marine habitats of the EC Habitats Directive and the habitats described in the Marine Habitat Reviews

The table below gives a correlation of each Annex I type to the habitats described in the Marine Habitat Reviews (taken from the MNCR BioMar classification - Connor *et al.* 1997a, b). Those habitats which may be consistently found within the Annex I type are marked with an *, whilst those which are particularly characteristic of the Annex I type are marked by a #. Note that other habitats (defined in Connor *et al.* 1997a & b but not described in the reviews) may also occur in the Annex I habitats.

		Habitats Directive Annex I type						
Classification code	*Marine habitat review* name	Reefs	Caves	Sand-flats	Sand-banks	Bays	Estua-ries	Lagoons
	Littoral (intertidal) rock							
ELR	Exposed littoral rock	*	*			*	*	
MLR	Moderately exposed littoral rock	*	*			#	*	
MLR.Salv	Littoral *Sabellaria alveolata* (honeycomb worm) reefs	*				*	*	
SLR	Sheltered littoral rock	*	*			#	#	*
SLR.MytX	Littoral *Mytilus edulis* (mussel) beds	*				#	#	
	Littoral (intertidal) sediment							
LGS	Littoral gravels and sands			#		#	#	
LMS	Littoral muddy sands			#		#	#	*
LMS.Znol	Eelgrass *Zostera noltii* beds			#		*	#	*
LMU	Littoral muds			#		*	#	*
	Infralittoral (shallow subtidal) rock							
EIR.KFaR	Exposed infralittoral rock with kelp	#				*		
MIR.KR & MIR.GzK	Moderately exposed infralittoral rock with kelp	#				#	*	*
SIR.K	Sheltered infralittoral rock with kelp	#				#	#	*
	Circalittoral (deep subtidal) rock							
ECR	Exposed circalittoral rock	#	*			*		
MCR	Moderately exposed circalittoral rock	#	*			*	*	
MCR.Csab & CMX.SspiMx	*Sabellaria spinulosa* (honeycomb worm) reefs	#				*	*	
MCR.ModT, SCR.Mod & CMX.ModMx	*Modiolus modiolus* (horse mussel) beds	#				#	*	
MCR.Bri	Subtidal brittlestar beds	#			*	#		
SCR	Sheltered circalittoral rock	#	*			#	*	*
	Sublittoral (subtidal) sediment							
IGS	Infralittoral gravels and sands				#	#	#	*
IGS.Mrl & IMX.MrlMx	Maerl beds				#	#		*
IMS.Zmar	Eelgrass *Zostera marine* beds			*	#	#	*	#
CMU.SpMeg	Seapen and burrowing megafauna communities					*		*

Appendix MNCR SACFOR abundance scales

S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare

GROWTH FORM			SIZE OF INDIVIDUALS / COLONIES				
% COVER	**CRUST / MEADOW**	**MASSIVE / TURF**	**<1 cm**	**1-3 cm**	**3-15 cm**	**>15 cm**	**DENSITY**
>80%	S		S				>1 / 0.0001 m^2 (1x1 cm) >10,000/m^2
40-79%	A	S	A	S			1-9 / 0.001 m^2 1000-9999 / m^2
20-39%	C	A	C	A	S		1-9 / 0.01 m^2 (10x10 cm) 100-999 / m^2
10-19%	F	C	F	C	A	S	1-9 / 0.1 m^2 10-99 /m^2
5-9%	O	F	O	F	C	A	1-9 / m^2
1-5% or density	R	O	R	O	F	C	1-9 / 10 m^2 (3.16x3.16 m)
<1% or density		R		R	O	F	1-9 / 100 m^2 (10x10 m)
					R	O	1-9 / 1000 m^2 (31.6x31.6 m)
						R	>1 / 10,000 m^2 (100x100 m) <1 / 1000 m^2
PORIFERA	Crusts *Halichondria*	Massive spp. *Pachymatisma*		Small solitary *Grantia*	Large solitary *Stelligera*		
HYDROZOA		Turf species *Tubularia* *Abietinaria*		Small clumps *Sarsia* *Aglaophenia*	Solitary *Corymorpha* *Nemertesia*		
ANTHOZOA	*Corynactis*	*Alcyonium*		Small solitary *Epizoanthus* *Caryophyllia*	Med. solitary *Virgularia* *Cerianthus* *Urticina*	Large solitary *Eunicella* *Funiculina* *Pachycerianthus*	
ANNELIDA	*Sabellaria spinulosa*	*Sabellaria alveolata*	*Spirorbis*	Scale worms *Nephtys* *Pomatoceros*	*Chaetopterus* *Arenicola* *Sabella*		
CRUSTACEA	Barnacles Tubiculous amphipods		*Semibalanus* Amphipods	*B. balanus* *Anapagurus* *Pisidia*	*Pagurus* *Galathea* Small crabs	*Homarus* *Nephrops* *Hyas araneus*	
MOLLUSCA	*Mytilus* *Modiolus*		Small gastropod *L. neritoides* Small bivalves *Nucula*	Chitons Med. gastropod *L. littorea* *Patella* Med. Bivalves *Mytilus* *Pododesmus*	Large gastropod *Buccinum* Lge bivalves *Mya, Pecten* *Arctica*		Examples of groups or species for each category
BRACHIOPODA				*Neocrania*			
BRYOZOA	Crusts	*Pentapora* *Bugula Flustra*			*Alcyonidium* *Porella*		
ECHINO-DERMATA				*Echinocyamus* *Ocnus*	*Antedon* Small starfish Brittlestars *Echinocardium* *Aslia, Thyone*	Large starfish *Echinus* *Holothuria*	
ASCIDIACEA	Colonial *Dendrodoa*			Small solitary *Dendrodoa*	Large solitary *Ascidia, Ciona*	*Diazona*	
PISCES					Gobies Blennies	Dog fish Wrasse	
PLANTS	Crusts, Maerl *Audouinella* Fucoids, Kelp *Desmarestia*	Foliose Filamentous			*Zostera*	Kelp *Halidrys* *Chorda* *Himanthalia*	

Exposed littoral rock

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Hill, Burrows, & Hawkins 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A1.1	Littoral rock very exposed to wave action
Wadden Sea	-	Not listed/present
Britain/Ireland (MNCR BioMar 97.06)	ELR	Exposed littoral rock (mussel/barnacle shores)
France (ZNIEFF-MER)	Part of IV.6	Fonds Durs: Cailloutis, Galets et Roches

Description

Extremely exposed to exposed bedrock and boulder shores. Mussels and barnacles dominate these shores, occasionally with robust fucoids in extremely exposed conditions or turfs of red seaweed.

GB distribution

(from MNCR database March 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, although salinity in pools and crevices in the littoral zone can vary considerably with evaporation and dilution by rain.
Wave exposure	Extremely exposed, Very exposed, Exposed The structure of ecological communities on rocky shores is affected by a horizontal gradient of exposure to wave action, from sheltered bays to exposed headlands. The degree of wave action on a particular shore is determined by the aspect of prevailing winds coupled with the 'fetch': the distance over which winds blow. Shores with a long fetch can have strong wave action

	because the wind has a greater distance to generate the height of waves. Such shores may also receive swell on windless days, resulting from distant storms. Exposure to wave action affects the distribution of species, according to their tolerances. Increased exposure favours certain sessile, filter-feeding species. At the same time, increasing exposure carries an increased risk of dislodgement and physical damage, limiting the range of susceptible and physically fragile species.
Substratum	Bedrock; large boulders. Hard rocks provide a more secure anchorage for large plants and animals such as fucoids and limpets.
Height band	Upper shore, Mid shore, Lower shore
Zone	Eulittoral
Temperature	At the interface between land and water, species spend part of their time immersed in the sea, or at least splashed by its spray, and part of their time in contact with the air, with a vertical gradient of emersion up the shore. Air temperatures commonly fluctuate by 10 to 20^{o}C in a 24 hour period whereas sea temperatures usually fluctuate by less than 10^{o}C in a year. Intertidal areas will also be exposed to the rigors of sunlight at low water especially when low water spring tides occur around midday.
Tidal range	Tidal ranges from 0.5 m to 12 m in the British Isles.
Desiccation	In temperate zones, the risk of desiccation due to heat and low humidity is highly significant. The ability of species to tolerate desiccation will effect community structure, as will wave exposure which can modify the extent of the vertical gradient. As wave action increases, so does the amount of spray produced. Waves with greater amplitude break at higher shore levels, showering still higher areas with spray. At very exposed sites, shore levels well above the highest tide level may regularly be wetted by the action of waves. It is not uncommon to find high shore species many tens of meters above the theoretical tidal limiton very exposed cliffs (Lewis 1964).
Slope/shore topography	Rock type influences the slope and topographical complexity of the shore, and slope determines the area available for littoral species. Barnacles and limpets are successful on steep shores, while mussels and seaweeds are more common on gently-sloping or horizontal shores.

Species composition and biodiversity

For ELR in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Actinia equina	●●	●	Occasional
Chthamalus stellatus	●●	●●	Frequent
Semibalanus balanoides	●●●●●	●	Common
Patella vulgata	●●●●	●	Common
Littorina littorea	●●	●	Frequent
Littorina neglecta	●●	●●	Common
Littorina saxatilis	●●	●	Frequent
Nucella lapillus	●●●	●	Frequent
Mytilus edulis	●●●●	●	Frequent
Porphyra umbilicalis	●	●●	Frequent
Palmaria palmate	●●	●	Occasional
Corallinaceae indet. (crusts)	●●	●	Occasional
Corallina officinalis	●●	●	Occasional
Mastocarpus stellatus	●●	●	Occasional
Ceramium sp.	●	●	Occasional
Osmundea pinnatifida	●●	●	Occasional
Himanthalia elongata	●	●●●	Common
Enteromorpha sp.	●	●	Occasional
Verrucaria mucosa	●●	●●	Occasional

Ecological relationships

The wave exposure gradient has a considerable effect on community structure, as a result of the stresses and benefits experienced at different levels of wave energy. Certain species including the barnacles *Semibalanus balanoides* and *Chthamalus montagui* are well adapted to survive on exposed shores. Dogwhelks *Nucella lapillus*, which feed on barnacles, and mussels *Mytilus edulis* are also more abundant on exposed shores. Algae found on these shores tend to be ephemeral or short turf forms.

Habitat complexity

The diversity of species on rocky shores increases towards the lower shore where the habitat is wet for longer periods of the day. Only a limited number of species are able to survive on extremely exposed shores, particularly those shores consisting mainly of steep, smooth rock. Protected microhabitats on exposed shores, such as algal turfs or deep crevices, can however support a surprising variety of species (Raffaelli & Hawkins 1996). A major biological influence on community structure is the presence of algal canopies and shorter algal communities at mid and low shore levels. Macroalgae provide a variety of resources which are not available on bare rock. Most importantly, they increase the amount of space available for attachment, they provide shelter from wave action, desiccation and heat and they are an important food source.

Recruitment processes

Many rocky shore species have a planktonic dispersal phase. These species produce propagules or larvae that spend their early life in the open sea and may eventually settle on shore some distance from where they originated. This strategy allows species to rapidly colonize new areas that become available such as after storms. The level of larval supply and its fluctuations play a considerable role in structuring rocky shore communities and has been appreciated for a long time (Southward & Crisp 1956; Lewis 1964; Kendall *et al*. 1985).

Productivity

Macroalgae exude considerable amounts of dissolved organic carbon which are taken up readily by bacteria and may even be taken up directly by some larger invertebrates. Only about 10% of the primary production is directly cropped by herbivores (Raffaelli & Hawkins 1996). On exposed shores, grazers feed mainly on the microbial film. Dissolved organic carbon, algal fragments and microbial film organisms are continually removed by the sea. This may then enter the food chain of local, subtidal ecosystems, or be exported further offshore. Rocky shores also make a contribution to the food of many marine species through the production of planktonic larvae and propagules which supply essential nutrients to pelagic and benthic species.

Keystone (structuring) species

Semibalanus balanoides, Chthamalus spp., *Mytilus edulis*.

Importance of habitat for other species

Fish and crusteaceans migrating into the intertidal zone to feed as the tide rises, are important predators of rocky shore species. Corkwing wrasse *Crenilabrus melops* rely heavily on the intertidal. Juvenile wrasse are commonly found in rockpools. Shore birds also feed on the rocky shore (Feare & Summers 1985).

Temporal changes

Communities on exposed shores show dynamics caused by physical disturbance events, which create space for recolonization. Stochastic (chance) events contribute greatly to variability in the community. The major cause of variability is the supply of settling planktonic propagules of species in the community (Hawkins & Hartnoll 1982, Hartnoll & Hawkins 1985; Gaines & Roughgarden 1985; Gaines & Bertness 1992). Disturbance due to major climatic events such as storms and cold winters (e.g. Crisp 1964) or small-scale physical damage (Paine & Levin 1981; Shanks & Wright 1986) can have important effects.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Synthetic compound contamination	Uses: boats/shipping (anti-fouling)	Low	The toxic affects of tributyltin (TBT) on molluscs, especially the dog whelk *Nucella lapillus*, are well-documented (Bryan *et al*. 1986, 1987). TBT was extensively used in antifouling paint specifically to kill marine fouling organisms. Unsurprisingly, it therefore had a major ecological impact. Very low concentrations of TBT can lead to the condition known as imposex (the development of male sexual characteristics) in dog whelks. Dog whelks are an important predator on rocky shores and their decline might be expected to have a profound effect on the rest of the community. TBT also affects mussels, an important space-occupying species on rocky shores and may therefore have important effects on community structure.
Synthetic compound contamination	Uses: boats/shipping (oil spills)	Low	Modern dispersants have a low toxicity and are unlikely to do any more harm than the oil. However, since the oil will become dispersed into the water it may contaminate areas below the water level that were previously unaffected, unless it can be trapped and removed.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	The sensitivity of a rocky shoreline to oiling is dependent on its topography and composition as well as its position. For example a vertical rock wall on a wave exposed coast is likely to remain unoiled if an oil slick is held back by the action of the reflected waves. Some shores are well known to act as natural collection sites for litter and detached algae and oil is carried there in the same way. On exposed coasts these sites are usually boulder/cobble beaches at the backs of bays or gullies which act as traps for the oil. As on all types of shoreline, most of the oil is concentrated along the high tide mark while the lower parts are often untouched. It is not long before the waves and tides that carried the oil onto the shore are gradually removing it again, but the rate of such weathering is dependent on weather conditions and shore characteristics. On a shore exposed to strong wave action a patch of oil will usually not remain there for long.
Changes in nutrient levels	Waste: sewage discharge	Not sensitive	The effects of sewage discharge on high-energy rocky shores are negligible.
Abrasion	Recreation: popular beach/resort	Intermediate	The effect of people simply walking on the shore can be damaging. This is particularly apparent when the topography of the shore causes people to follow a limited number of routes, leading to the appearance of paths characterised by reduced cover of fauna and flora (Fletcher 1997). Light trampling pressure has also been shown to damage and remove barnacles (Bronsan & Crumrine, 1994).

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Part of habitat can be protected as *Submerged or partly submerged sea caves*. Can occur at the exposed entrances to *Large shallow inlets and bays* and *Estuaries;* maybe protected as *Reefs* (where there is subtidal interest*)*.
UK Biodiversity Action Plan	None

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Moderately exposed littoral rock

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al*. 1997a) and a review undertaken for the UK Marine SACs Project (Hill, Burrows, & Hawkins 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A1.2	Littoral rock moderately exposed to wave action
Wadden Sea	-	Not listed/present
Britain/Ireland (MNCR BioMar 97.06)	MLR	Moderately exposed littoral rock (barnacle/fucoid shores)
France (ZNIEFF-MER)	Part of IV.6	Fonds Durs: Cailloutis, Galets et Roches

Description

Moderately exposed rocky shores (bedrock, boulders and cobbles) characterised by mosaics of barnacles and fucoids on the mid and upper shore; with fucoids and red seaweed mosaics or dense red seaweed turfs on the lower shore. Where freshwater or sand-scour affects the shore ephemeral green or red seaweeds can dominate. Other shores support communities of mussels and fucoids in the mid to lower shore. Where there is a plentiful supply of suspended sand in the water *Sabellaria* reefs can develop (see separate habitat review).

GB distribution

(from MNCR database March 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, although salinity in pools and crevices in the littoral zone can vary considerably with evaporation and dilution by rain.
Wave exposure	Moderately exposed

	The structure of ecological communities on rocky shores is affected by a horizontal gradient of exposure to wave action, from sheltered bays to exposed headlands. The degree of wave action on a particular shore is determined by the aspect of prevailing winds coupled with the 'fetch': the distance over which winds blow. Shores with a long fetch can have strong wave action because the wind has a greater distance to generate the height of waves. Such shores may also receive swell on windless days, resulting from distant storms. Exposure to wave action affects the distribution of species, according to their tolerances. Increased exposure favours certain sessile, filter feeding species. At the same time, increasing exposure carries an increased risk of dislodgement and physical damage, limiting the range of susceptible and physically fragile species.
Substratum	Bedrock; boulders; cobbles Hard rocks provide a more secure anchorage for large plants and animals such as fucoids and limpets.
Height band	Strandline; Upper shore, Mid shore, Lower shore
Zone	Eulittoral
Temperature	At the interface between land and water, species spend part of their time immersed in the sea, or at least splashed by its spray, and part of their time in contact with the air, with a vertical gradient of emersion up the shore. Air temperatures commonly fluctuate by 10 to 20°C in a 24-hour period whereas sea temperatures usually fluctuate by less than 10°C in a year. Intertidal areas will also be exposed to the rigors of sunlight at low water especially when low water spring tides occur around midday.
Tidal range	Tidal ranges from 0.5 m to 12 m in the British Isles. Greater tidal ranges result in more extensive littoral zones.
Desiccation	In temperate zones, the risk of desiccation due to heat and low humidity is highly significant. The ability of species to tolerate desiccation will effect community structure, as will wave exposure, which can modify the extent of the vertical gradient. As wave action increases, so does the amount of spray produced. Waves with greater amplitude break at higher shore levels, showering still higher areas with spray.
Slope/shore topography	Rock type influences the slope and topographical complexity of the shore, and slope determines the area available for littoral species. Barnacles and limpets are successful on steep shores, while mussels and seaweeds are more common on gently- sloping or horizontal shores.

Species composition and biodiversity

For MLR in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Halichondria panicea	••	••	Occasional
Actinia equina	••	•	Occasional
Semibalanus balanoides	•••	•	Frequent
Carcinus maenas	••	•	Occasional
Patella vulgata	•••	•	Frequent
Littorina littorea	••	•	Frequent
Nucella lapillus	•••	•	Occasional
Mytilus edulis	••	•	Occasional
Palmaria palmata	••	•	Frequent
Corallinaceae (indet.) crusts	••	•	Frequent
Corallina officinalis	••	•	Occasional
Mastocarpus stellatus	•••	•	Frequent
Chondrus crispus	••	•	Occasional
Osmundea pinnatifida	••	••	Frequent
Porphyra purpurea	•	•	Occasional
Rhodothamniella floridula	•	••	Present
Fucus serratus	•••	••	Common
Fucus vesiculosus	••	••	Frequent

Enteromorpha sp.	•••	•	Frequent
Ulva sp.	••	•	Occasional

Ecological relationships

The wave exposure gradient has a considerable effect on community structure, as a result of the stresses and benefits experienced at different levels of wave energy. The general patterns of zonation on rocky shores can be explained in terms of physical factors affecting the outcome of biological interactions. Steeper moderately exposed shores generally have stable patterns of zonation over time. Flatter moderately exposed shores are often characterised by highly dynamic communities with patches of one species giving way to another over time.

Habitat complexity

As mentioned above, moderately exposed rocky shores are often made up of a mosaic of communities, each cycling through a number of successional stages and structured by a number of positive and negative interactions between the main species but with fluctuations generated by recruitment variation. The communities are each dominated by a particular group of species, which may give way to others and sometimes to bare rock over time. These have been particularly well studied on the Isle of Man (Burrows & Lodge 1950; Hawkins & Hartnoll 1983, 1985; Hawkins *et al*. 1992) where the following effects on the mid shore have been shown: The limpet *Patella vulgata* is an important grazer, feeding on the young *Fucus vesiculosus* plants. Mature *F. vesiculosus* plants dislodge settling barnacles *Semibalanus balanoides* as their fronds sweep over the rock. Juvenile limpets, which dislodge newly-settled barnacles as they move, and dogwhelks *Nucella lapillus*, which are predators of barnacles, aggregate under mature clumps of *F. vesiculosus*. Thus, barnacles are scarce in patches dominated by mature *F. vesiculosus*; however, these patches last for only about 3 to 4 years. The sweeping action of *F. vesiculosus* fronds and the presence of limpets minimise the successful settlement of young fucoids. However, limpet grazing is inefficient amongst mature barnacles; as a result, some fucoids are able to settle and survive. *Fucus vesiculosus* clumps appear amongst the barnacles, reducing barnacle recruitment and encouraging the aggregation of limpets.

Recruitment processes

Many rocky shore species have a planktonic dispersal phase. These species produce propagules or larvae that spend their early life in the open sea and may eventually settle on shore some distance from where they originated. This strategy allows species to rapidly colonise new areas that become available. The level of larval supply and its fluctuation plays a considerable role in structuring rocky shore communities and has been appreciated for a long time (Southward & Crisp 1956; Lewis 1964; Kendall *et al*. 1985).

Productivity

Macroalgae exude considerable amounts of dissolved organic carbon which are taken up readily by bacteria and may even be taken up directly by some larger invertebrates. Only about 10% of the primary production is directly cropped by herbivores (Raffaelli & Hawkins 1996). Dissolved organic carbon, algal fragments and microbial film organisms are continually removed by the sea. This may then enter the food chain of local, subtidal ecosystems, or be exported further offshore. Rocky shore organisms also make a contribution to the food of many marine species through the production of planktonic larvae and propagules which supply essential nutrients to pelagic and benthic food chains.

Keystone (structuring) species

Limpet *Patella vulgata*, barnacle *Semibalanus balanoides* & the fucoids *Fucus vesiculosus*, *F.spiralis* and *F.serratus*

Importance of habitat for other species

Fish and crustaceans, migrating into the intertidal to feed as the tide rises, are important predators of rocky shore species. Corkwing wrasse *Crenilabrus melops* rely heavily on the intertidal. Juvenile wrasse are commonly found in rockpools. Shore birds also feed on the rocky shore (Feare & Summers 1985) e.g. the invertebrates attracted to seaweed on the strandline are a particularly important food source. Rich pickings can also be had under macroalgae canopies.

Temporal changes

Communities on moderately exposed shores show dynamics caused by physical disturbance events, which create space for recolonization. Stochastic (chance) events contribute greatly to variability in the community and the major cause of this is the supply of settling planktonic propagules of key species in the community (Hawkins & Hartnoll 1982,1985; Gaines & Roughgarden 1985; Gaines & Bertness 1992). Disturbance due to major climatic events, such as storms and cold winters (e.g. Crisp 1964) or small-scale physical damage (Paine & Levin 1981; Shanks & Wright 1986) can also have important effects.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Synthetic compound contamination	Uses: boats/shipping (anti-fouling)	Intermediate	The toxic affects of tributyltin (TBT) on molluscs, especially the dog whelk *Nucella lapillus*, are well-documented (Bryan *et al.* 1986, 1987). TBT was extensively used in antifouling paint specifically to kill marine fouling organisms. Unsurprisingly, it therefore had a major ecological impact. Very low concentrations of TBT can lead to the condition known as imposex (the development of male sexual characteristics) in dog whelks. Dog whelks are an important predator on rocky shores and their decline might be expected to have a profound effect on the rest of the community. TBT also affects mussels, an important space occupying species on rocky shores and may therefore have important effects on community structure.
Synthetic compound contamination	Uses: boats/shipping (oil spills)	Low	Modern dispesants have a low toxicity and are unlikely to do any more harm than the oil. However, since the oil will become dispersed into the water it may contaminate areas below the water level that were previously unaffected, unless it can be trapped and removed.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	The sensitivity of a rocky shoreline to oiling is dependent on its topography and composition as well as its position. For example a vertical rock wall on a wave exposed coast is likely to remain un-oiled if an oil slick is held back by the action of the reflected waves. Some shores are well known to act as natural collection sites for litter and detached algae and oil is carried there in the same way. On moderately exposed coasts these sites are usually boulder/cobble beaches at the backs of bays or gullies which act as traps for the oil. As on all types of shoreline, most of the oil is concentrated along the high tide mark while the lower parts are often untouched. It is not long before the waves and tides that carried the oil onto the shore are gradually removing it

			again, but the rate of such weathering is dependent on weather conditions and shore characteristics.
Changes in nutrient levels	Waste: sewage discharge	Low	The effect of sewage discharge on a moderately exposed rocky shore is low. Water movement limits the build up of particulates and prevents eutrophication.
Abrasion	Recreation: popular beach/resort	Intermediate	The recreational use of the shore can have adverse effects on the biological community. The effect of people simply walking on the shore can be damaging. This is particularly apparent when the topography of the shore causes people to follow a limited number of routes, leading to the appearance of paths characterised by reduced cover of fauna and flora (Fletcher 1997).
Substratum change	Coastal defence: seawalls/ breakwaters Development: land claim	Intermediate	Natural shorelines are replaced with artificial substrata for a variety of reasons. Colonisation of virgin artificial substrata and subsequent succession is similar to that observed on natural substrata (Hawkins, Southward & Barrett 1983; Cannon 1997). The time for a 'mature' community to develop is therefore expected to depend on the scale of the development.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Large shallow inlets and bays* and *Estuaries*; may be protected as *Reefs* (where there is subtidal interest); part of habitat can be protected as *Submerged or partly submerged sea caves*.
UK Biodiversity Action Plan	Chalk shores are included in the *Littoral* and *sublittoral chalk* Habitat Action Plan.

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Littoral *Sabellaria alveolata* reefs

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Holt *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A1.2/B –MLR.Sab	*Sabellaria* reefs on littoral rock
Wadden Sea	-	Not listed / present
Britain/Ireland (MNCR BioMar 97.06)	MLR.Salv	*Sabellaria alveolata* reefs on sand-abraded eulittoral rock
France (ZNIEFF-MER)	II.5.6	Récifs d'Hermelles à *Sabellaria alveolata*

Description

Many wave-exposed boulder scar grounds in the eastern basin of the Irish Sea (and as far south as Cornwall), are characterised by reefs of *Sabellaria alveolata*, the tubes of which are built from the mobile sand surrounding the boulders and cobbles. The tubes formed by *Sabellaria alveolata* form large reef-like hummocks, which serve to stabilise the boulders. Other species in this biotope include the barnacles *Semibalanus balanoides*, *Balanus crenatus* and *Elminius modestus* and the molluscs *Patella vulgata*, *Littorina littorea*, *Nucella lapillus* and *Mytilus edulis*. Low abundances of algae tend to occur in areas of eroded reef. The main algal species include *Porphyra* spp., *Mastocarpus stellatus*, *Ceramium* spp., *Fucus vesiculosus*, *Fucus serratus*, *Enteromorpha* spp. and *Ulva* spp. On exposed surf beaches in the south-west *Sabellaria* forms a crust on the rocks, rather than the classic honeycomb reef, and may be accompanied by the barnacle *Balanus perforatus* (typically common). On wave-exposed shores in Ireland, the brown alga *Himanthalia elongata* can also occur.

Note: *Sabellaria alveolata* reefs may also form in the subtidal (e.g. in the Severn estuary), but these are not considered here.

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full
Wave exposure	Exposed, moderately exposed
Substratum	Bedrock; cobbles; boulders; pebbles; sand *Sabellaria alveolata* requires a hard substratum on which to form and these areas must have a good supply of suspended coarse sediment. *S .alveolata* reefs can form on a range of substrata from pebble to bedrock (Cunningham *et al.* 1984). Reefs therefore commonly form on areas of rock or boulders surrounded by sand.
Height band	Mid shore, Lower shore Reefs form mainly on the bottom third or so of the shoreline and in the shallow subtidal. Reefs have been recorded subtidally in the Severn Estuary and have been assigned a new MNCR biotope code – SalvMx (Moore *et al.* 1998)
Zone	Eulittoral-mid, Eulittoral-lower
Temperature	Gruet (1982) reported that growth of *S. alveolata* is severely restricted below 5°C. Crisp (1964) noted severe losses of *S. alveolata* due to the severe winter of 1962-63, especially in south and north Wales, and in Lyme Bay where some colonies were depleted by half and others lost completely. Survival was best at lower shore levels.
Water quality	A supply of suspended coarse sediment is a requirement for the development of reefs, but the species has been reported to penetrate into areas such as the Severn Estuary where finer suspended sediments occur (Cunningham *et al.* 1984). Suspended sediment supply is affected by both the local availability of sediment and the amount of water movement for its suspension.

Species composition and biodiversity

Characterising species

For MLR.Salv in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Sabellaria alveolata	•••••	•••	Common
Semibalanus balanoides	••••	•	Frequent
Balanus crenatus	•••	•	Occasional
Balanus perforatus	•	••	Common
Elminius modestus	••	••	Frequent
Patella vulgata	••••	•	Occasional
Littorina littorea	••••	•	Frequent
Nucella lapillus	••••	•	Frequent
Mytilus edulis	•••	•	Occasional
Porphyra sp.	•••	••	Occasional
Palmaria palmata	••	•	Frequent
Mastocarpus stellatus	•••	•	Occasional
Ceramium sp.	•••	•	Occasional
Cladostephus spongiosus	••	••	Occasional
Fucus serratus	••••	••	Occasional
Fucus vesiculosus	•••	••	Occasional
Enteromorpha sp.	••	•	Occasional
Ulva sp.	•••	•	Occasional

Littoral *S. alveolata* reefs are not particularly diverse communities, they do nevertheless provide some increased diversity of habitat, and older reefs have somewhat more diverse associated communities than younger ones. Sheets of *S. alveolata* appear to enhance algal diversity, apparently by providing barriers to limpet grazing (Cunningham *et al.* 1984). Wilson (1971) noted that *Fucus serratus, Fucus vesiculosus*, *Palmaria palmata*, *Polysiphonia* sp., *Ceramium* sp., and *Ulva lactuca* are frequently associated with older *Sabellaria* colonies, and small polychaetes such as *Fabricia sabella* and syllids have been found living on colonies. Cunningham *et al.* (1984) noted up to eighteen associated animal species and twenty associated plant species, mainly on older colonies. The important animal species were all epifauna, including barnacles *Cthalamus montagui*, *C. stellata* and *Semibalanus balanoides,* limpets *Patella vulgata*, *P. depressa* and *P. aspera*, mussel *Mytilus edulis*, dogwhelk *Nucella lapillus* and serpulid worms. No rare or uncommon species have been reported to be associated with *S. alveolata* reefs.

Ecological relationships

Habitat complexity

Cunningham *et al.* (1984) noted that placages (sheet-like structure) might impede the drainage of the shore, creating pools of standing water where there would otherwise be none. Further habitat modification, they noted, included stabilisation of mobile sand, shingle, pebbles, small boulders and an increased habitat heterogeneity of exposed barnacle dominated shores and sand scoured rocks.

Recruitment processes

Sabellaria alveolata larvae spend anything between 6 weeks and 6 months in the plankton (Wilson 1968, 1971) so that dispersal could potentially be widespread. Settlement occurs mainly in existing colonies or their dead remains; chemical stimulation seems to be involved, and this can come from *S. spinulosa* tubes as well as *S. alveolata* (Cunningham *et al.* 1984; Gruet 1982; Wilson 1971).

Productivity

No information available.

Keystone (structuring) species

Sabellaria alveolata

Importance of habitat for other species

There is little detailed mention in the literature of predation on *S. alveolata*, although *Carcinus maenas* was a troublesome predator of transplanted portions of reefs in Somerset (Bamber & Irving 1997). Herdman (1919) mentioned that flatfish such as plaice *Pleuronectes platessa* and sole *Solea solea* could easily obtain the worms by crunching up the brittle sand tubes. Worms are known to be able retract considerable distances down their tubes (Cunningham *et al.* 1994; Wilson 1971); it would therefore appear to be difficult for predators to extract worms easily from compact reef masses.

Temporal changes

There is evidence to suggest that littoral reefs are, at least in many cases, unstable and there frequently appears to be a cycle of development and decay over periods of up to five years (Gruet 1985, 1986, 1989; Perkins 1986, 1988). Exceptionally, Wilson (1976) observed one small reef from its inception as three small individual colonies in 1961, through a period between 1966 and 1975 where it existed as a reef rather greater than 1 meter in extent and up to

60 cm thick, with major settlement of worms occurring in 1966 and 1970. This reef finally 'died' in the autumn of 1975, ironically a period of intense new settlement elsewhere on the same beach (Wilson 1976). In the long term, areas with good *Sabellaria* reef development tend to remain so.

Time for community to reach maturity

A typical life span for worms in colonies forming reefs on bedrock and large boulders in Duckpool was 4-5 years (Wilson 1971), with a likely maximum of around 9 years (Gruet 1982; Wilson 1971). However, it is suspected that there are many colonies on littoral cobble and small boulder scars on moderately exposed shores where shorter lifespans are likely due to the unstable nature of the substratum. Wilson (1971) reported that it was possible to age worms to some degree by measuring the diameter of the tube.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Coastal defence: seawalls/breakwaters	Intermediate	*Sabellaria alveolata* is sensitive to changes in sediment regime. In the Mediterranean Gulf of Valencia, Spain *S. alveolata* populations were lost as a result of sand level rise brought about as a consequence of the construction of seawalls and marinas/harbours, and beach nourishment projects. Long term burial by sand has been shown to kill *S. alveolata* reefs (Perkins 1967). On more open coasts, shore defences on one stretch of coast may lead to a reduced sand supply to neighbouring areas and therefore reduced development of *S. alveolata* reefs.
Changes in temperature	Waste: cooling water (power stations)	Not sensitive*	Studies at Hinkley Point, Somerset, found that growth of the tubes in the winter was considerably greater in the cooling water outfall where the water temperature was raised by around 8-10°C, than at a control site, although the size of the individual worms themselves seemed to be unaffected (Bamber & Irving 1997).
Synthetic compound contamination	Waste: industrial effluent discharge	Low	There is little evidence to suggest sensitivity to chemical contaminants, though this has been suggested as one of the possible causes of loss of *S. alveolata* in the Dee estuary (Craggs 1982).
Abrasion	Recreation: popular beach/resort	Intermediate	Cunningham *et al.* (1984) showed rapid recovery from single trampling events of a light or moderate nature. More extensive damage to colonies (i.e. chunks being removed) was less evident in the short term, but some such damage did occur and was subsequently enlarged by wave action. *Sabellaria alveolata* reefs in the vicinity of intensive mussel aquaculture are vulnerable to damage from trampling by commercial collection of the mussels.
Removal of target species	Collecting: bait digging	Intermediate	Damage to colonies by people opening tubes with knives and removing the worms for use as fishing bait has been observed, though nowhere has this been seen on any intensive scale (Hawkins pers. obs.).

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed

Wadden Sea	Not present
UK	Not significantly declined in quality or extent
Other sub-regions	Not assessed

Protected status

Protection mechanism	***Habitat***
EC Habitats Directive	Can be protected as *Reefs* (where there is subtidal interest), *Estuaries* and *Large shallow inlets and bays.*
UK Biodiversity Action Plan	*Sabellaria alveolata* reefs

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Sheltered littoral rock

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Hill, Burrows, & Hawkins 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A1.3	Littoral rock sheltered from wave action
Wadden Sea	-	Not present/listed
Britain/Ireland (MNCR BioMar 97.06)	SLR	Sheltered littoral rock (fucoid shores)
France (ZNIEFF-MER)	Part of IV.6	Fonds Durs: Cailloutis, Galets et Roches

Description

Sheltered rocky shores, of bedrock or stable boulders and cobbles, are typically characterised by a dense cover of fucoid algae which form distinct zones (channelled wrack *Pelvetia canaliculata* on the upper shore through to the serrated wrack *Fucus serratus* on the lower shore). Where salinity is reduced (such as at the head of a sealoch or where streams run across the shore) *Fucus ceranoides* may occur. Fucoids also occur on less stable, mixed substrata (cobbles and pebbles on sediment) although in less abundance and with fewer associated epifaunal species; beds of mussels *Mytilus edulis* are also common. In summer months, dense blankets of ephemeral green and red seaweeds can dominate these mixed shores.

NB. *Mytilus edulis* beds are considered in a separate habitat review.

GB distribution

(from MNCR database March 1999)

Habitat requirements

Habitat factor	Range of conditions
Salinity	Full, Variable, Reduced / low Salinity in pools and crevices in the littoral zone can vary considerably with evaporation and dilution by rain.
Wave exposure	Sheltered, Very sheltered, Extremely sheltered The structure of ecological communities on rocky shores is affected by a horizontal gradient of exposure to wave action, from sheltered bays to exposed headlands. The degree of wave action on a particular shore is determined by the aspect of prevailing winds coupled with the 'fetch': the distance over which winds blow. Exposure to wave action affects the distribution of species, according to their tolerances. With decreasing exposure the risk of dislodgement and physical damage decreases, resulting in a greater preponderance of fragile species. Morphological differences can be observed between members of the same species from wave-exposed and sheltered sites. For example, dogwhelks from wave-exposed shores have thinner shells with larger apertures than those from sheltered shores.
Substratum	Bedrock; boulders; cobbles; pebbles; mixed substrata on sand and mud. Hard rocks provide a more secure anchorage for large plants and animals such as fucoids and limpets. Sheltered rocky shores can consist mainly of bedrock or they may be a mixture of bedrock and boulders, cobbles or pebbles intermixed with sediment..
Height band	Strandline, Upper shore, Mid shore, Lower shore
Zone	Eulittoral
Temperature	At the interface between land and water, species spend part of their time immersed in the sea and part of their time in contact with the air, with a vertical gradient of emersion up the shore. Air temperatures commonly fluctuate by 10 to 20^{o}C in a 24-hour period whereas sea temperatures usually fluctuate by less than 10^{o}C in a year. Intertidal areas are also exposed to the rigors of sunlight at low water especially when low water spring tides occur around midday.
Tidal range	Tidal ranges from 0.5 m to 12 m in the British Isles. Greater tidal ranges result in more extensive littoral zones.
Desiccation	In temperate zones, the risk of desiccation due to heat and low humidity is highly significant. The ability of species to tolerate desiccation will effect community structure, as will wave exposure, which can modify the extent of the vertical gradient. The elevation in the zonation pattern observed on exposed shores will not be found on sheltered shores, as 'wave splash' will be minimum.
Slope/shore topography	Rock type influences the slope and topographical complexity of the shore, and slope determines the area available for littoral species. Barnacles and limpets are successful on steep shores, while mussels and seaweeds are more common on gently- sloping or horizontal shores.

Species composition and biodiversity

For SLR in the UK	% Frequency	Faithfulness	Typical abundance
Semibalanus balanoides	●●●	●	Frequent
Elminius modestus	●	●●	Occasional
Amphipoda indet.	●		Frequent
Gammaridae indet.	●		Occasional
Patella vulgata	●●	●	Occasional
Littorina littorea	●●	●	Frequent
Littorina obtusata	●	●	Frequent
Littorina saxatilis	●●	●	Frequent
Nucella lapillus	●	●	Occasional
Mytilus edulis	●●	●	Occasional
Corallinaceae indet. (crusts)	●	●	Occasional
Polysiphonia lanosa	●	●●●	Frequent
Ascophyllum nodosum	●●	●●	Common

Fucus ceranoides	•	•••	Frequent
Fucus serratus	••	••	Frequent
Fucus spiralis	••	•••	Frequent
Fucus vesiculosus	•••	•	Common
Pelvetia canaliculata	••	••	Common
Enteromorpha sp.	••	•	Frequent
Ulva sp.	•	•	Occasional
Cladophora rupestris	•	•	Occasional
Verrucaria maura	•	••	Common
Verrucaria mucosa	•	••	Frequent

Ecological relationships

Habitat complexity

The general patterns of zonation on rocky shores can be explained in terms of physical factors affecting the outcome of biological interactions. The diversity of species on rocky shores increases towards the lower shore where conditions are damper. A major biological influence on community structure is the presence of algal canopies and shorter algal communities at mid and low shore levels. Macroalgae provide a variety of resources that are not available on bare rock. Most importantly, they increase the amount of space available for attachment, they provide shelter from wave action, desiccation and heat, and they are an important food source.

Recruitment processes

Many rocky shore species have a planktonic dispersal phase. These species produce propagules or larvae that spend their early life in the open sea and may eventually settle on shore some distance from where they originated. This strategy allows species to rapidly colonize new areas that become available. The level of larval supply and its fluctuation plays a considerable role in structuring rocky shore communities and has been appreciated for a long time (Southward & Crisp 1956; Lewis 1964; Kendall *et al*. 1985)

Productivity

Macroalgae exude considerable amounts of dissolved organic carbon which are taken up readily by bacteria and may even be taken up directly by some larger invertebrates. Only about 10% of the primary production is directly cropped by herbivores (Raffaelli & Hawkins 1996). Dissolved organic carbon, algal fragments and microbial film organisms are continually removed by the sea. This may enter the food chain of local, subtidal ecosystems, or be exported further offshore. Rocky shores also make a contribution to the food of many marine species through the production of planktonic larvae and propagules which supply essential biochemicals to pelagic food chains.

Keystone (structuring) species

Pelvetia canaliculata, *Fucus spiralis*, *Fucus vesiculosus*, *Ascophyllum nodosum*, *Fucus serratus*

Importance of habitat for other species

Fish and crustaceans migrating into the intertidal to feed as the tide rises, are important predators of rocky shore species. Juveniles are commonly found in rockpools. Shore birds also feed on the rocky shore (Feare & Summers 1985). The invertebrates attracted to seaweed on the strandline are a particularly important food source. Rich pickings can also be had under macroalgae canopies. Otters *Lutra lutra* often use rocky shores and will feed on animals such as shore crabs *Carcinus maenas* which, in turn feed on rocky shore species.

Temporal changes

Rocky shore communities are often highly variable in time, due to the combined effects of physical disturbance, competition, grazing, predation and variation in recruitment. However sheltered shores tend to be less variable than exposed or moderately exposed shores and are therefore more stable.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Development: docks, ports & marinas	High	Natural shorelines are replaced with artificial substrata for a variety of reasons. On sheltered shores waterfront developments including harbours, marinas and even residential complexes are common place. Colonisation of virgin artificial substrata and subsequent succession is similar to that observed on natural substrata (Hawkins, Southward & Barrett 1983; Cannon 1997). The time for a 'mature' community to develop is therefore expected to depend on the scale of the development.
Synthetic compound contamination	Uses: boats/shipping (anti-fouling)	Intermediate	The toxic affects of tributyltin (TBT) on molluscs, especially the dog whelk *Nucella lapillus*, are well-documented (Bryan *et al.* 1986, 1987). TBT was extensively used in antifouling paint specifically to kill marine fouling organisms. Unsurprisingly, it therefore had a major ecological impact. Many shallow coastal waters escape the pollution associated with busy harbours and industrialisation. However, the expansion of recreational boating exposed previously clean areas to the effects of TBT. The use of TBT paints on small boats was banned in the late 1980s. TBT is still used on ships and its impact is greatest in areas with heavy boat traffic and close to ports and marinas where boat mooring and maintenance activities are concentrated. Very low concentrations of TBT can lead to the condition known as imposex (the development of male sexual characteristics) in dogwhelks. Dogwhelks are an important predator on rocky shores and their decline might be expected to have a profound effect on the rest of the community. TBT also affects mussels, an important space-occupying species on rocky shores and may therefore have important effects on community structure.
	Uses: boats/shipping (oil spills)	Low	Modern dispersants have a lower toxicity and are unlikely to do any more harm than the oil.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	High	The sensitivity of a rocky shoreline to oiling is dependent on its topography and composition as well as its position. A gradually sloping boulder shore in a calm backwater of a sheltered inlet can trap enormous amounts of oil which may penetrate deep down through the any available substratum. Some shores are well known to act as natural collection sites for litter and detached algae and oil is carried there is the same way. As on all types of shoreline, most of the oil is concentrated along the high tide mark while the lower parts are often untouched. It is not long before the waves and tides that carried the oil onto the shore gradually remove it again, but the rate of such weathering is dependent on weather conditions and shore characteristics. On a sheltered shore it may take years for the limited water movement to remove oil trapped under boulders or in gullies and crevices. Gradual leaching of this oil could result in constant low level pollution of, for example; a rockpool.
Abrasion	Recreation: popular beach/resort	Intermediate	The recreational use of the shore can have adverse effects on the biological community. The effect of people simply walking on

			the shore can be damaging. This is particularly apparent when the topography of the shore causes people to follow a limited number of routes, leading to the appearance of paths characterised by reduced cover of fauna and flora (Fletcher 1997). Community structure can be affected by even light trampling. Fletcher & Frid (1996) found light trampling sufficient to reduce the abundance of fucoids which in turn reduced the microhabitat available for epiphytic species. Light trampling pressure has also been shown to damage and remove barnacles (Brosnan & Crumrine 1994).
Changes in nutrient levels	Waste: sewage discharge	Intermediate	The most severe effects of sewage effluent discharge occur in semi-enclosed areas such as estuaries and sheltered bays. The ecological effects of large sewage outfalls may stretch to a few hundred metres while the effects of smaller discharges are usually confined to within about 10 m of the pipe (Raffaelli & Hawkins, 1996). Effluent discharges can encourage the growth of ephemeral green algae in the affected area. Sewage outfalls may introduce plastics and other solids to the marine environment which may be deposited on to the foreshore of sheltered stretches of coastline.
Removal of target species	Collecting: kelp/wrack harvesting	High	Several rocky shore species are exploited by man in the UK. The main commercial species are the seaweeds knotted wrack *Ascophyllum nodosum* and *Laminaria* spp. Seaweeds are responsible for much of the primary production on rocky shores and are important providers of microhabitat for other species. The recovery of any species will depend on the degree of exploitation. Clumps of *Ascophyllum* on the other hand, can regrow after careful hand cutting. Such careful harvesting is necessary since *Ascophyllum* is slow to recruit after it is completely lost.
	Collecting: shellfish (winkles, mussels)	Intermediate	Other species, which are commercially harvested, include winkles *Littorina littorea*, mussels *Mytilus edulis* and peeler crabs *Carcinus maenas*. The removal of these species can have unforeseen effects on other members of the community (Wells & Alcala 1987).
	Collecting: bait digging	Intermediate	Disturbance is also associated with harvesting and bait collection. Rocks turned over during the collection of peeler crabs might not be replaced and the removal of mussels can destabilise neighbouring animals. The impact of any harvesting or collecting activity will vary depending on the species exploited, how it is done and to what extent.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Probability of significant decline in extent and quality
Other sub-regions	Not assessed

A wide variety of activities can have a detrimental effect on sheltered rock communities and will, in the long term, lead to significant damage of this habitat unless there is due consideration of its extent and quality at a UK level.

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* (where there is subtidal interest), *Large shallow inlets and bays, Reefs, Estuaries, Lagoons* and *Submerged or partly submerged sea caves.*
UK Biodiversity Action Plan	None

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Littoral *Mytilus edulis* beds

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Holt *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A1.3/B-SLR.MX	Mussel beds on sheltered littoral mixed substrata
Wadden Sea	05.01.07	Eulittoral (old) blue mussel beds
Britain/Ireland (MNCR BioMar 97.06)	SLR.MytX	*Mytilus edulis* beds on eulittoral mixed substrata
France (ZNIEFF-MER)	II.5.5	Moulière médiolittorale à *Mytilus* sp.

Description

Sheltered to very sheltered mid and lower eulittoral mixed substrata (mainly cobbles and pebbles on muddy sediments) with dense aggregations of the mussel *Mytilus edulis*. In high densities the mussels bind the substratum and provide a habitat for many species more commonly found on rocky shores. *Fucus vesiculosus* is often found attached to either the mussels or the cobbles and it frequently occurs at high abundance. The mussels are usually encrusted with the barnacle *Semibalanus balanoides* (and/ or *Elminius modestus* in areas of reduced salinity). *Littorina littorea* and small *Carcinus maenas* are common amongst the mussels, whilst areas of sediment may contain *Arenicola marina*, *Lanice conchilega*, *Cerastoderma edule* and other infaunal species. In contrast with the mussel beds found on rocky shores (MLR.MF) this biotope contains few limpets or red algae. This biotope is also found in lower shore tide-swept areas, such as in the tidal narrows of Scottish sealochs.

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	***Range of conditions***
Salinity	Full, variable. *Mytilus edulis* is tolerant of a wide range of salinity compared to other biogenic reef species and may penetrate quite far up estuaries. However, it may stop feeding during short-term exposure to low salinities (Almada-Villela 1984; Bohle 1972) and the most well-developed beds therefore usually occur low on the shore in the mid to lower reaches of estuaries. Almada-Villela (1984) reported greatly- reduced shell growth for a period of up to a month or so upon exposure to 16‰ compared to 26‰ or 32‰, while exposure to 22‰ caused only a small drop in growth rate. In the longer term (in the order of weeks) *M. edulis* adapts well to low salinities (Almada-Villela 1984; Bohle 1972) and hence can even grow as dwarf individuals in the inner Baltic where salinities can be as low as 4-5‰ (Kautsky 1982).
Wave exposure	Sheltered, Very sheltered, Extremely sheltered
Substratum	Mixed boulders, cobbles and pebbles on muddy sediment. In sheltered areas infaunal beds may occur on gravel or even quite sandy areas, although it is likely that some harder substratum embedded within the more sandy areas is required. Dense settlement also occurs on cockle shells in the Wash and Loughor Estuary where the byssus of the embedded mussels seem to serve a stabilising function. It has long been suggested that larval *Mytilus* will settle on most substrata provided they are firm and have a rough, discontinuous surface (Mass Geesteranus 1942). Settlement is in any case a two-stage process; initial settlement occurs primarily on filamentous substrata such as sublittoral hydroids and algae, with subsequent secondary dispersal and reattachment later in areas with adult beds.
Zone	Eulittoral-mid, Eulittoral-lower
Height	Reef areas are normally found on the lower third of the intertidal, and in shallow subtidal, but can occur down to 10 m in some places such as the Wash and on Caernarfon Bar. Lower zonational limits for *M. edulis* are usually set by biological factors, normally predation by starfish, crabs and gastropods, and by physical factors. Sand burial has been shown to limit lower regions of *M. edulis* zonation patterns in New Hampshire, USA (Daly & Mathieson 1977). This is probably important in some British locations, particularly in the case of cobble and boulder scars in areas of shifting sands such as Morecambe Bay and the Solway Firth. Upper limits of distribution are set by physical factors, but growth and therefore size of animals is also affected by reduced feeding time at higher levels. It has been estimated that growth would be zero at approximately 55% aerial exposure (Baird 1966), although clearly this will vary somewhat with local conditions.
Temperature	*Mytilus edulis* is widely distributed throughout the cooler waters of the world. The most limiting factor for distribution world-wide is thought to be temperature (Stubbings 1954). Damage by extreme low temperatures is minimised in *Mytilus* by the use of nucleating agents in the haemolymph (Aunaas, Denstad & Zachariassen 1988). Even in more temperate sites *M. edulis* is periodically subject to potentially lethal freezing conditions periodically, but they can survive even when tissue temperatures fall below $-10^{o}C$ (Williams 1970). Tolerance of high temperatures and desiccation can explain the upper limit of *M. edulis* on the high shore (Seed & Suchanek, 1992). British *M. edulis* have an upper sustained thermal tolerance limit of about $29^{o}C$ (Almada-Villela, Davenport & Gruffydd 1982; Read & Cumming 1967). Recruitment or movement to cracks is known to afford better thermal protection on the upper shore (Suchanek 1985). It can therefore be speculated that dense reef structures might afford some protection from extremes of temperature to the lower animals. In general, however, given the wide temperature tolerance of *Mytilus*, reefs, which are generally found quite low on the shore, are unlikely to be very sensitive to changes in temperature.
Water quality	*Mytilus edulis* is widely recognised as being tolerant of a wide variety of environmental variables including salinity and oxygen tension as well as temperature and desiccation (Seed & Suchanek 1992). It is capable of responding to wide fluctuations in food quantity and quality, including variations in inorganic particle content of the water, with a range of morphological, behavioural and physiological responses (Hawkins & Bayne 1992). Excessive levels of silt and inorganic detritus are thought to be damaging to *Mytilus* once they accumulate too heavily within the reef matrix (Seed & Suchanek 1992), although the degree to which this might be influenced directly by water quality rather than production of faeces and pseudofaeces is unclear.

Species composition and biodiversity

Characterising species

For SLR.MytX in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Arenicola marina	••	•	Occasional
Lanice conchilega	••	•	Occasional
Semibalanus balanoides	••••	•	Frequent
Elminius modestus	••	•	Frequent
Carcinus maenas	•••	•	Occasional
Littorina littorea	••••	•	Common
Mytilus edulis	•••••	•	Abundant
Cerastoderma edule	••	••	Occasional
Fucus vesiculosus	•••	••	Occasional

Ecological relationships

Habitat complexity

The associated biota of *Mytilus* beds has been little studied, but does not appear generally to be particularly rich or diverse in comparison with stable subtidal biogenic reefs. Nevertheless, the *Mytilus* beds often represent the only hard substrate communities in an area (e.g. an estuary), so they may be regarded as important in terms of increased habitat heterogeneity. A variety of small infaunal invertebrates are found within the accumulations of mussel mud, with some larger mobile animals such as *Littorina littorea*, *Gammarus* spp., polychaetes and small *Carcinus maenas* in between the mussels and dead shells. These are hunted by foraging birds such as turnstones, curlews, redshank and gulls. The shells themselves may support encrusting fauna such as barnacles, and algae, particularly *Fucus vesiculosus* and sometimes green algae such as *Enteromorpha* spp., may be frequent. It has been suggested that the high rate of suspension feeding in the mussel mounds favours species that reproduce with cocoons, brood their young or which disperse as juveniles rather than as planktonic larvae (Commito 1987).

Recruitment processes

Larval growth to metamorphosis during spring and early summer, at around 10^{o}C, normally takes about 2-4 weeks (Lane, Beaumont & Hunter 1985; Seed 1976; Seed & Suchanek 1992; Widdows 1991). *Mytilus edulis* has a two-stage extended dispersal strategy. A primary settlement of post-larvae usually occurs on sublittoral filamentous substrata such as hydroids and algae. Then, after growing to around 1-2 mm in length, the spat detach and move to the adult beds, aided by the secretion of long byssus threads which help the young mussels to drift in the water until a secondary settlement site is found. Spatfall and recruitment in some beds of mussels is very variable year-to-year, and unlike some other invertebrates, high densities of the adults do not inhibit the settlement of spat (Commito 1987).

Productivity

No information available.

Keystone (structuring) species

Mytilus edulis

Importance of habitat for other species

A number of invertebrate predators, particularly crabs and starfish, can be important in regulating *Mytilus* populations. Other important predators include flatfish; in Morecambe Bay, flounders were found to contain the remains of up to 570 (average 150) small mussels per fish, and plaice and dabs were similarly important (Dare 1976). Bird predation on mussels may significantly affect the development of reefs (see reviews in Seed & Suchanek 1992; Meire 1993). Oystercatchers and eider ducks are very widely reported as feeding extensively on *Mytilus*, and may be responsible for heavy mortalities in wave-protected bays and estuaries (Seed & Suchanek 1992). In addition to the species already mentioned, a wide variety of other organisms have been found to be important predators on *Mytilus* and include limpets, predatory gastropods, crabs, lobsters, urchins, fish, otters and seals.

Temporal changes

Surveys of intertidal mussel beds in the German part of the Wadden Sea showed that the distribution of the beds remained rather constant, although the abundance of mussels varied considerably due to irregular spatfalls, ice drift, storm surges and parasitism (Obert & Michaelis 1991). During the 1980s the mussel populations declined due to increasing eider predation. In the Danish part of the Wadden Sea Jensen (1992) showed that there were no obvious differences between macrobenthos populations present in the 1930s and in the 1980s.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Synthetic compound contamination	Uses: boats/shipping (anti-fouling)	Intermediate	A number of studies have demonstrated toxic effects of TBT, including mortalities, at concentrations in water of 0.4 ug/l-1 or less (Widdows & Donkin 1992).
Heavy metal contamination	Waste: industrial effluent discharge	Intermediate	Mussels were missing from a wider area of a Cumbrian shore than were other organisms around a large, phosphate-rich outfall, the effluent from which was contaminated by a number of heavy metals (Pope et al. 1997). On the other hand, distribution of shore organisms around other industrial or mixed outfalls has shown mussels to be among the least sensitive shore organisms (McKenzie & Perkins 1979). The bioaccumualtion of environmental contaminants and their effects on the physiology of mussels was reviewed by Widdows & Donkin (1992). Bokn, Moy & Murray (1993) found Mytilus to be the most sensitive to diesel fuel when compared with other intertidal organisms.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	It is known that phytoplankton blooms can sometimes cause problems, including mortalities in *Mytilus*. Long-term nutrient enrichment and increasing phytoplankton production have been reported in the southern North Sea (De Jonge 1997; Smayda 1990). An associated problem is that of enrichment which often appears to be associated with changes in the species composition of phytoplankton, often favouring smaller groups at the expense of diatoms (Smayda 1990) and this could have

			consequences for all filter feeding organisms including *Mytilus*.
Removal of target species	Collecting: shellfish (winkles, mussels)	Intermediate	In virtually every cSAC location around Britain where mussel beds form mud-mound reefs, the mussels have been fished or are now fished. When fished by hand at moderate levels by persons with traditional skills, the biogenic reefs will probably retain most of their intrinsic biodiversity. Mussels are also taken on quite a large scale by hand for use as angling and long-line bait, although the latter is now less in demand. Anglers tend to have most impact where the beds are adjacent to roads leading to favoured shore fishing locations. A small mussel bed adjacent to a road causeway in Anglesey has virtually been eliminated over the years.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Heavily endangered
UK	Not significantly declined in extent or quality (requires further assessment)
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* (where there is subtidal reef interest) and occurs within *Estuaries* and *Large shallow inlets and bays*.
UK Biodiversity Action Plan	None

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Littoral gravels and sands

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Elliott *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A2.1	Littoral gravels and coarse sands
Wadden Sea	05.01.03	Sandflat, free of vegetation
Britain/Ireland (MNCR BioMar 97.06)	LGS	Littoral gravels and sands
France (ZNIEFF-MER)	II.3.2	Sables moyens dunaires
	II.3.4	Biocénose des sables

Description

Clean gravel and/or sand in the littoral zone (the area between high and low tides) with a particle diameter range from 16 mm to 0.063 mm; shingle shores comprising mobile cobbles, pebbles and coarse gravel are also included. The shore and substratum type can range from steep mobile shores that are typically of coarse material (gravel and coarse sand), through less steep shores of coarse, medium or fine sand to level sandflats of fine sand that remain water-saturated throughout the tidal cycle. Mud (particle diameter less than 0.063 mm) does not exceed 10%, and is usually totally absent.

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable, Reduced / low
Wave exposure	Very exposed, Exposed, Moderately exposed, Sheltered, Very sheltered
Substratum	Shingle; gravel; sand
	Intertidal sandflats may contain all grades of sand and to a lesser extent silt and clay. The settling velocity of particles is dependent on particle size and water characteristics such that sands and coarse materials settle rapidly and particles >15 ìm will settle out within one tidal cycle (King 1975). The gradient of the shore reflects the energy conditions and those of sandy shores tend to be dynamic. Steeper shores are associated with larger grains and shallow profiles with fine sediment (Pethick 1984). Most shores have a range of grain sizes in the swash zone and they are usually composed of fine to medium sand. On a shore with plunging breakers, there is often a concentration of coarser sediment around the plunge at mean water.
Height band	Strandline, Upper shore, Mid shore, Lower shore. Intertidal areas by definition have low, middle and high tidal heights and the productivity of these areas differ with respect to the tidal elevation and shore slope (Gray 1981). On sandy shores most of the infaunal community is found on the lower shore. Any increase in height will result in greater exposure to air and thus desiccation of the organisms. Changes in tidal height over the intertidal zone create a less predictable environment where there may be more extreme changes in temperature, salinity, dissolved oxygen and water content than in the sublittoral zone (Hayward 1994).
Zone	Supralittoral, Littoral fringe, Eulittoral
Porosity	Particle size, mixture and compaction influence the permeability or percolation rate of sands and gravels (Pethick 1984) especially those with a mixture of particles. Porosities in different-sized material may be similar depending on interaction (Taylor Smith & Li 1966).
Water content	The water content of sandflats is influenced by the porosity and compaction of the sediment, the shore slope and the potential for draining. The permanent water content in an intertidal sand flat may be low as the interstices between the particles drain during exposure to air, although draining is inversely related to organic and silt content.
Organic content	Sand typically has low levels of organic matter and is well oxygenated in the surface layers (Eagle 1973), the organic matter being derived from decaying seaweed, the faeces and remains of animals and terrigenous sources (as wind-blown material).
Oxygen content	Oxygen content is a function of the degree of oxygenation (aeration) and the inherent oxygen demand of organic matter. Sands are usually sufficiently oxygenated by seawater which, at high tide, percolates from a few mm in fine, sheltered sandflats to several metres in coarse sand (Eagle 1983). Interstitial oxygenation may be poor below the surface layer particularly where the sand is fine or in cases of high concentrations of organic material such as decaying seaweed on the strand line (Hayward 1994).
Microbial activity	Microbial activity is low in areas of higher energy as there is limited organic detritus available for bacterial degradation, coupled with the particles' comparatively low surface area to volume ratio that provides a surface for microbial populations.

Species composition and biodiversity

For LGS in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Nermetea indet.	•	••	Present
Nephtys cirrosa	••	•••	Frequent
Pygospio elegans	•	•	Frequent
Scolelepis squamata	••	•••	Frequent
Arenicola marina	••	•	Occasional
Pontocrates arenarius	•	•••	Frequent
Bathyporeia pelagica	••	••	Common
Bathyporeia pilosa	•	••	Common
Eurydice pulchra	••	•••	Frequent
Angulus tenuis	••	•••	Common

Ecological relationships

Habitat complexity

The shrimp *Crangon crangon* is a significant predator of the smallest sizes of plaice during and immediately after the fish settle on sandy beaches. Predation rate is strongly dependent on the size of both the predator and the prey (Gibson, Yin & Robb 1995). Polychaete worms are dominant predators within the substratum and tend to be opportunistic and actively pursue prey (although they may have size preferences); their numbers may be closely related to those of their prey, which includes other worms and crustaceans (Meire *et al.* 1994). Many infaunal species also scavenge e.g. *Nephtys* and the isopod *Eurydice pulchra* and quantity of food available determines the density of scavengers (Hayward 1994; Ansell *et al.* 1972).

Recruitment processes

The presence of high densities of adult invertebrates in the sand may inhibit the recruitment of potential colonising stages from the water column (Olafsson, Peterson & Ambrose 1994). This may account for juveniles occupying less favourable parts of the intertidal areas, for example juvenile *Arenicola* and *Nephtys* settle in areas outside the optimal distribution for the adults (usually higher on the shore).

Productivity

Sandflat communities tend to be relatively poor in species but may have very high abundances of those species which are present.

Keystone (structuring) species

None.

Importance of habitat for other species

Intertidal areas are well defined as juvenile fish-feeding areas (Costa & Elliott 1991). Sheltered sandflats are important nursery areas for plaice (Lockwood 1972; Marshall 1995; Marshall & Elliott 1997), as well as feeding areas for sea bass *Dicentrarchus labrax* and flounder *Platichthys flesus* (Elliott & Taylor 1989). Fish such as sole *Solea solea* and gadoids frequent sandy areas, but many also occur on coarser and mixed grades of sediment. The most important marine predators on intertidal sandflats are the sole *Solea solea*, dab *Limanda limanda*, flounder *Platichthys flesus* and plaice *Pleuronectes platessa* plaice which feed on polychaetes (for example *Arenicola* and *Nereis*) and tidally active crustaceans such as *Bathyporeia* and *Eurydice* species (Croker & Hatfield 1980; McDermott 1983; McLachlan 1983). In summer, large numbers of juvenile plaice and dab move over flats at high tide to feed on mobile epifauna, sedentary infauna and protruding siphons and tentacles (Elliott & Taylor 1989). On sandflats many demersal fish are opportunistic predators and the prey choice will reflect the infaunal species distribution of the area (Costa & Elliott 1991). Migratory species of fish such as salmon and shad can be found on sandflats when on passage to other wetlands e.g. saltmarshes and freshwater areas, although they appear to have no particular requirement for the sandflats.

The littoral gravel and sand biotopes are also used by important wintering and passage birds for feeding. Shorebirds are important predators on north-west European intertidal sandflats during long migrations from breeding to wintering grounds. Intertidal sandflats also support microphytobenthos in the interstices between the sand grains. Mucilagenous secretions produced by these algae may stabilise fine substrata (Tait & Dipper 1998). Macrophytes are usually sparse on intertidal sand unless there are some stones or shells for the attachment of species. The community may include mats of *Enteromorpha* spp. and *Ulva* spp., possibly in large aggregates to form the so-called ‘green tides’ (Piriou, Menesguen & Salomon 1991).

Temporal changes

No information available.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Development: land claim	High	Extensive areas of intertidal sandflats have been removed through land claim coupled in some areas with rising sea levels (Davidson *et al.* 1991; Burd 1992). Some estuaries have lost up to 80% of the area, most of which has been the land claim of intertidal mud and sandflats. The greatest impact of land claim is due to depletion of the main prey rather than simply the area loss and each prey and predator species will differ in their response (McLusky, Bryant & Elliott 1992).
Changes in temperature	Climate change/global warming	Intermediate	Many intertidal species have wide tolerances for temperature and can also alter metabolic activity, or simply burrow deeper in the sediment or move seaward to combat temperature change (Brown 1983). Severe changes in temperature in intertidal areas will result in a seasonal reduction in benthic species richness and abundance, although the species are well adapted to such changes.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	Oil-spills can cause large-scale deterioration of communities in intertidal and shallow sub-tidal sediment systems (Majeed 1987). Tidal-pulsing will push oil into intertidal sands. Oil pushed into coarse sands will destabilise the sediment and produce an oxygen demand where oxygen is available but little degradation at depth where aeration does not occur.
Synthetic compound contamination/ **Heavy metal contamination/** **Hydrocarbon contamination**	Waste: industrial effluent discharge	Intermediate	Industrialised and urbanised estuaries and coastlines may receive effluent discharges which contain conservative contaminants i.e. those with a long half-life, are likely to bioaccumulate (remain within the food chain) and thus have a toxic effect (Clark 1997). Such contaminants include heavy metals, radionucleides and synthetic organic compounds. The lethal and sub-lethal effects of these pollutants vary according to the state and availability of the compound and its characteristics and the organism it affects. Some effects may be lethal, by removing individuals and species and thus leaving pollution-tolerant and opportunistic species. Other effects may be sub-lethal, in affecting the functioning of organisms such as their reproduction, physiology, genetics and health, which will ultimately reduce their fitness for survival (Nedwell 1997). In contrast to low energy areas (e.g. mudflats), the higher energy sediment biotopes are less likely to receive and/or retain these contaminants. The coarser sediments of exposed intertidal sandflats and the hydrodynamic characteristics, including high dispersion, dictates that there are few cases of severe pollution in such habitats. However, chemical pollution of intertidal sands can occur and will remove elements of the fauna.
Changes in nutrient levels	Waste: sewage discharge Aquaculture: fin-fish	Intermediate	High organic inputs coupled with poor oxygenation lead to conditions of slow degradation and produces anaerobic conditions in the sediments. In turn this increases microbial activity and reduces the redox potential of the sediments (Fenchel & Reidl 1970). Ultimately this increases the production of toxic substances such as hydrogen sulphide and methane. Moderate enrichment provides food to increase the species abundance and a mixing of organisms with different responses increases diversity (Elliott 1994). With greater enrichment, the diversity declines and the community becomes

			increasingly dominated by a few pollution-tolerant, opportunistic species such as the polychaete *Capitella capitata*. In grossly polluted environments, the anoxic sediment is defaunated and may be covered by sulphur-reducing bacteria. Such a change will affect the palatability of any remaining prey and thus impair functioning of marine areas.
Removal of non-target species	Collecting: bait digging	Intermediate	The effect of bait digging is to reduce community diversity and species richness, especially by commercial digging for worms and other macrofauna on intertidal sandflats (Brown & Wilson 1997). This removal of target species leading to community and population changes at the ecological and genetic levels will effect predators e.g. the removal of bait organisms such as *Arenicola* from intertidal sandflats will effect shorebird predation.

Conservation and protection status

Conservation status

Region	***Status***
OSPAR area	Not assessed
Wadden Sea	Endangered
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	***Habitat***
EC Habitats Directive	*Mudflats and sandflats not covered by seawater at low tide*; occurs within *Estuaries* and *Large shallow inlets and bays.*
UK Biodiversity Action Plan	None

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Littoral muddy sands

Compiled by: Leigh Jones, Joint lNature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope cla ssification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Elliott *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A2.2	Littoral sands and muddy sands
Wadden Sea	05.01.02	Mixed flats, free of vegetation
Britain/Ireland (MNCR BioMar 97.06)	LMS	Littoral muddy sands
France (ZNIEFF-MER)	III.3	Sables fins plus ou moins envasés

Description

Shores of muddy sand, typically consisting of particles less than 4 mm in diameter, where the mud fraction (less than 0.063 mm diameter particles) makes up between 10% and 30% of the sediment. Typically, the sand fraction is medium (particle diameter 0.25-1 mm) or fine (particle diameter 0.063-0.25 mm) sand. Muddy sand usually forms gently-sloping flats that remain water-saturated throughout the tidal cycle. They support communities predominantly of polychaetes and bivalves, including the lugworm *Arenicola marina*, the cockle *Cerastoderma edule* and the Baltic tellin *Macoma balthica* but may also have eelgrass *Zostera noltii* beds (LMS.Znol) (Not included in this review, see 'Eelgrass *Zostera noltii* beds' review).

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable
Wave exposure	Sheltered, Very sheltered
Substratum	Muddy sand Littoral muddy sands are predominantly sand (particles 63-125 µm) and to a lesser extent a mud fraction (4-63 µm). The settling velocity of particles is dependent on particle size and water characteristics such that sands and coarse materials settle rapidly and particles >15 mm will settle out within one tidal cycle (King 1975). The type, direction and speed of the currents and the size of the particles control sediment deposition within an area. Fine-grained material such as clay and silt will follow the residual waterflow, although there may be deposition at periods of slack water. Coarser-grained material will travel along the bed in the direction of the maximum current and will be affected most by high velocities (Postma 1967).
Height band	Strandline, Upper shore, Mid shore, Lower shore
Zone	Supralittoral, Littoral fringe, Eulittoral
Porosity	Porosity denotes the amount of pore space in a sediment and is related to the permeability of a sediment. Particle size, its mixture and compaction influence the permeability (Pethick 1984) especially those with a mixture of particles. Porosities in different sized material may be similar (Taylor Smith & Li 1966) due to interaction between grain shape, the degree of sorting, the length of time since deposition and therefore the degree of settling and compaction.
Water content	The porosity and compaction of the sediment, the shore slope and the potential for draining influence the water content of mud and sandflats. Muddy sands retain water at low tide as a result of their shallow gradient and the capillary attraction of closely-packed particles (Gray 1981). However, muddy sands tend to be more freely-draining than mud alone owing to the greater average particle size.
Organic content	Intertidal muddy sands contain a high proportion of organic matter, which is deposited and accumulates in low-energy areas due to its small and low specific gravity. Allochthonous organic material is derived from both anthropogenic sources (effluent, run-off) and natural sources (settlement of plankton, detritus). Autochthonous organic material on these sediment areas is restricted to benthic microalgae (microphytobenthos) such as diatoms and euglenoids and heterotrophic microorganism production, although mats of opportunistic green macroalgae such as *Enteromorpha* spp. and *Ulva* spp. will also develop. The organic matter (measured as organic carbon and nitrogen) is degraded by the microorganisms and the nutrients recycled (Newell 1965; Trimmer *et al.* 1998). In addition, the high surface area to volume ratio of fine particles acts as a surface for the development of microfloral populations. These features coupled with poor oxygenation of muds and hence low degradation rates, lead to an accumulation of organic matter.
Oxygen content	Oxygen content is a function of the degree of oxygenation (aeration) and the inherent oxygen demand of organic matter. Mud tends to have lower oxygen levels because their lower permeability leads to the trapping of detritus which, together with the large surface area for microbial colonisation, leads to higher oxygen uptake (Eagle 1983). Much of the organic detritus therefore undergoes anaerobic degradation, with hydrogen sulphide, methane or ammonia produced, as well as dissolved organic carbon compounds which can be utilised by aerobic micro-organisms living on the surface (McLusky 1989; Libes 1993).

Species composition and biodiversity

Muddy sand habitats tend to support a relatively poor diversity of species, which are usually found in high abundances. Species present are predominately sessile tube-dwelling polychaetes with bivalves also well represented (Atkins 1983). Some species characteristic of subtidal areas may also occur.

Characterising species

For LMS in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Eteone longa	••	••	Common
Hediste diversicolor	•	••	Occasional
Nephtys hombergii	••	••	Occasional
Scoloplos armiger	•••	•••	Abundant
Pygospio elegans	•••	•	Common
Spio filicornis	•	•••	Frequent
Capitella capitata	••	••	Frequent
Arenicola marina	•••	•	Common
Oligochaeta indet.	••	••	Common
Bathyporeia pilosa	•	••	Common
Bathyporeia sarsi	••	••	Frequent
Corophium arenarium	••	••	Common
Corophium volutator	•	••	Common
Crangon crangon	••	••	Common
Hydrobia ulvae	••	••	Common
Cerastoderma edule	••••	••	Common
Macoma balthica	••••	••	Common

Ecological relationships

Habitat complexity

Intertidal areas by definition have low, middle and high tidal heights and the productivity of these areas differs with respect to the tidal elevation and shore slope (Gray 1981). Most of the infaunal community is found in the mid-tidal region, with any decrease in tidal height taking the area towards greater current speed near channels and any increase in height will result in greater exposure to air and thus desiccation of the organisms. Changes in tidal height over the intertidal zone create a less predictable environment where there may be more extreme changes in temperature, salinity, dissolved oxygen and water content than in the sublittoral zone (Hayward 1994). The gradient of the shore reflects the energy conditions – that of muddy sands being gently-sloping and reflecting low-medium energy conditions. Microbial activity has a valuable role in stabilising estuarine organic fluxes by reducing the seasonal variation in primary production, ensuring a relatively constant food supply, and allowing the re-absorption of dissolved nutrients. (Robertson 1988). The bacteria living on particulate or dissolved organic matter makes the primary production more readily available for animal consumption (McLusky 1989).Intertidal sandflats also support microphytobenthos in the interstices of the sand grains. Mucilagenous secretions produced by these algae may stabilise fine substrata (Tait & Dipper 1998). Macrophytes of intertidal sand are few unless there are some stones or shells for attachment. The community may include mats of *Enteromorpha* and *Ulva,* possibly in large aggregations to form so-called 'green tides' (Piriou, Menesguen & Salomon 1991).

Recruitment processes

The presence of high densities of adult invertebrates may inhibit the recruitment of potential colonising stages from water (Olafsson, Peterson & Ambrose 1994). This may account for juveniles occupying less favourable parts of the intertidal areas, for example juvenile *Arenicola* settles in areas outside the optimal distribution for the adults.

Productivity

Coastal mudflats have a very poor productivity (McLachlan 1983).

Keystone (structuring) species

None.

Importance of habitat for other species

Intertidal areas are well defined as juvenile fish feeding areas (Costa & Elliott 1991). Sandflats are important nursery areas for plaice (Lockwood 1972; Marshall 1995; Marshall & Elliott 1997), as well as feeding areas for sea bass and flounder (Elliott & Taylor 1989). Fish such as sole *Solea solea* and gadoids frequent sandy areas, but many also occur on coarser and mixed grades of sediment. The most important marine predators on intertidal sandflats are the flatfish sole *Solea solea*, dab *Limanda limanda*, flounder *Platichthys flesus* and plaice *Pleuronectes platessa* which feed on polychaetes and their tails (e.g. *Arenicola*), bivalve young and siphons (e.g. of *Macoma* and *Angulus*) and tidally active crusteaceans such as *Bathyporeia* and *Eurydice* species (Croker & Hatfield 1980; McDermott 1983; McLachalan 1983). In summer, large numbers of plaice and dab juveniles move over the sand at high tide to feed on mobile epifauna, sedentary infauna and protruding siphons and tentacles (Elliott & Taylor 1989). The muddy sand biotopes are used by important wintering and passage birds for feeding and roosting. Shorebirds form important predators on north-west European intertidal mudflats during long migrations over long distances from breeding to wintering grounds. Particularly dependant species are Brent geese, shelduck, pintail, oystercatcher, ringed plover, grey plover, bar-tailed and black-tailed godwits, curlew, redshank, knot, dunlin and sanderling, whilst grey geese and whooper swan may use this habitat for roosting (Jones & Key 1989; Davidson *et al*. 1991). In comparison to mudflats, muddy sands tend to support a more extensive bird population.

Temporal changes

No information available.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Development: land claim	High	Extensive areas of intertidal sand/mudflats have been removed through land claim coupled in some areas with rising sea levels (Davidson *et al*. 1991; Burd 1992). Some estuaries have lost up to 80% of their area, most of which has been the land claim of intertidal sand and mudflats. The greatest impact of land claim is the reduction in area and biological integrity of this habitat, which will reduce the carrying capacity for supporting bird and fish predator populations.
Changes in temperature	Climate change/global warming	Intermediate	Many intertidal species have wide tolerances for temperature and can also alter metabolic activity, or simply burrow deeper in the sediment or move seaward to combat temperature change (Brown 1983). Severe changes in temperature in intertidal areas will result in a seasonal reduction in benthic species richness and abundance, although the species are well adapted to such changes.

Changes in wave exposure	Development: land claim	High	Land claim may also disrupt the hydrophysical regime in an area resulting in changes in wave action. Increased wave action causes stress to the infauna by disrupting feeding and burrowing activities and reduces species richness, abundance and biomass. The appearance of the intertidal region may also alter as the top 20cm of sand may be removed by storm events (Dolphin, Hume & Parnell 1995). Infauna will be sensitive to this change in sediment as they are adapted to burrow through only certain grades of sediment (Trueman & Ansell 1969).
Synthetic compound contamination/ **Heavy metal contamination**	Waste: industrial effluent discharge	High	Industrialised and urbanised estuaries and coastlines may receive effluent discharges which contain conservative contaminants i.e. those with a long half-life, are likely to bioaccumulate (remain within the food chain) and thus have a toxic effect (Clark 1997). Such contaminants include heavy metals, radionuclides and synthetic organic compounds. The lethal and sub-lethal effects of these pollutants vary according to the state and availability of the compound, its characteristics and the organisms. Some effects may be lethal, by removing individuals and species and thus leaving pollution-tolerant and opportunistic species. Other effects may be sub-lethal, in affecting the functioning of organisms such as their reproduction, physiology, genetics and health, which will ultimately reduce their fitness for survival (Nedwell 1997). Sheltered, low-energy areas in enclosed bays will be most susceptible to these pollutants as dispersion is low and the finer substrata in these areas will act as a sink (McLusky 1982 ; Somerfield, Gee & Warwick 1994; Ahn, Kang & Coi 1995; Nedwell 1997). The pollutants will enter the food chain and be accumulated by predators, as shown by the seasonal loading of heavy metals in tissues of wading birds in the Wash (Parslow 1973). Silt which is often associated with industrial pollution may be deposited onto the mudflats thus raising their height and therefore increasing the exposure time of infaunal communities at low tide.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	High	Oil-spills can cause large-scale deterioration of communities in intertidal and shallow sub-tidal sedimentary systems (Majeed 1987). Oil covering intertidal muddy sand prevents oxygen transport to the substratum and produces anoxia resulting in the death of infauna.
Changes in nutrient levels	Waste: sewage discharge	High	High organic inputs coupled with poor oxygenation leading to conditions of slow degradation will produce anaerobic conditions in the sediments. In turn this increases microbial activity and reduces the redox potential of the sediments (Fenchel & Reidl 1970). Ultimately this increases the production of toxic chemicals such as hydrogen sulphide and methane. The changed status to anaerobiosis will limit the sediment macroinfauna to species which can form burrows or have other mechanisms to obtain oxygen from overlying water. Moderate enrichment provides food to increase the abundance and a mixing of organisms with different responses increases diversity (Elliott 1994). With greater enrichment, the diversity declines and the community becomes increasingly dominated by a few pollution-tolerant, opportunistic species such as the polychaete *Manayunkia aestuarina*. Organic enrichment may result in increased coverage by opportunistic green macroalgae such as *Ulva* sp. and *Enteromorpha* sp. resulting in the formation of 'green tide' mats. Anoxic conditions form below the mats, reducing the diversity and abundance of infauna (Simpson 1997).
Removal of non-target species	Collecting: bait digging	Intermediate	The effects of bait diggers are to reduce community diversity and species richness, especially by commercial digging for worms and other macrofauna on intertidal muddy sand (Brown & Wilson 1997). This removal of target species leading to community and population changes at the ecological and genetic levels will affect predators e.g. the removal of bait organisms such as *Arenicola* from intertidal mudflats will effect shorebird predation.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Endangered
UK	Significantly declined in extent and quality (needs further assessment to confirm)
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	*Mudflats and sandflats not covered by seawater at low tide water,* occurs within *Estuaries* and *Large shallow inlets and bays*
UK Biodiversity Action Plan	Mud flats

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Littoral muds

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997a) and a review undertaken for the UK Marine SACs Project (Elliott *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A2..3	Littoral muds
Wadden Sea	05.01.01	Mud flats, free of vegetation
Britain/Ireland (MNCR BioMar 97.06)	LMU	Littoral muds
France (ZNIEFF-MER)	III.2	Vases

Description

Shores of predominately fine particulate sediment with a particle size less than 0.063 mm in diameter that typically forms extensive mudflats. Dry compacted mud can form steep and even vertical structures, particularly at the top of the shore adjacent to saltmarshes. Also included in this suite of biotopes are sandy muds, which have between 20% and 70% sand. Small amounts of gravel or pebbles may be found within the mud, having little effect upon the structure of the associated communities. Littoral muds support infaunal communities characterised by polychaetes, certain bivalves and oligochaetes. The majority of littoral muds are under variable or reduced-salinity conditions in coastal inlets. The ragworm *Hediste diversicolor*, the Baltic tellin *Macoma balthica* and the furrow shell *Scrobicularia plana* are conspicuous members of muddy freshwater-influenced shore communities. Fully marine littoral muds typically have a richer infauna of polychaetes and bivalves.

Saltmarshes (LMU.Sm) are not considered here.

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable, Reduced / low
Wave exposure	Sheltered, Very sheltered, Extremely sheltered
Substratum	Sandy mud, mud
Height band	Strandline, Upper shore, Mid shore, Lower shore
Zone	Supralittoral, Littoral fringe, Eulittoral
Substratum	Littoral mudflats are predominantly clay (particles <4 m), silt (4-63 m) and to a lesser extent very find sand (63-125 m). The settling velocity of particles is dependent on particle size and water characteristics such that clay and silt particles are unlikely to settle within one tidal cycle. The type, direction and speed of the currents and the size of the particles control sediment deposition within an area. Fine-grained material such as clay and silt will follow the residual waterflow, although there may be deposition at periods of slack water.
Porosity	Clays can have porosity's ranging from 65-82% and silts 45-88% (Taylor Smith & Li 1966). However, in extreme cases a mudflat that is composed largely of clay can become sufficiently compacted to support sessile fauna and even rock-borers such as the burrowing bivalve piddock *Pholas* (Eltringham 1971).
Water content	The porosity and compaction of the sediment, the shore slope and the potential for draining influence the water content of mudflats. Mudflats may be extensive yet retain water at low tide as a result of their shallow gradient and the capillary attraction of closely-packed particles (Gray 1981). The sediments may be thixotropic due to the high water content (Chapman 1949), thus allowing easier burrowing by infauna applying pressure to the sediment which becomes softer and easier to penetrate.
Organic content	Intertidal mudflats contain a high proportion of organic matter which is deposited and accumulates in low energy areas due to its small and low specific gravity. Allochthonous organic material is derived from both anthropogenic sources (effluent, run-off) and natural sources (settlement of plankton, detritus). Autochthonous organic material on these sediment areas is restricted to benthic microalgae (microphytobenthos) such as diatoms and euglenoids and heterotrophic microorganism production, although mats of opportunistic green macroalgae such as *Enteromorpha* and *Ulva* will also develop. The organic matter (measured as organic carbon and nitrogen) is degraded by the micro-organisms and the nutrients recycled (Newell 1965; Trimmer *et al.* 1998). In addition, the high surface area-to volume ratio of fine particles acts as a surface for the development of microfloral populations. These features coupled with poor oxygenation of muds and hence low degradation rates, lead to an accumulation of organic matter.
Oxygen content	Oxygen content is a function of the degree of oxygenation (aeration) and the inherent oxygen demand of organic matter. Mud tends to have lower oxygen levels than other sediment types because their lower permeability leads to the trapping of detritus which, together with the large surface area for microbial colonisation, leads to higher oxygen uptake (Eagle 1983). Much of the organic detritus therefore undergoes anaerobic degradation, with hydrogen sulphide, methane or ammonia produced, as well as dissolved organic carbon compounds which can be utilised by aerobic micro-organisms living on the surface (McLusky 1989; Libes 1993).
Microbial activity	It has been calculated that the biomass of bacteria within mudflats may be of the same order of magnitude as the biomass of animals living in the sediment. Breakdown of organic matter to sulphides and sulphates by bacteria forms the sulphur cycle, which determines the redox potential and pH of the sediment.

Species composition and biodiversity

Littoral mud communities tend to be relatively poor in species but have very high abundances of those species which are present. Sheltered shores are found in areas of low energy and have poorly-sorted sediments with high levels of organic matter and an increased silt content (Dyer 1979). Extreme shelter favours the establishment of a predominantly sessile tube-dwelling community of polychaetes which are often numerically dominant, with bivalves also well represented (Atkins 1983). Some species characteristic of subtidal areas may also occur. Many infaunal species e.g. *Nephtys* scavenge on littoral mud and the quantity of food determines the density of scavengers (Ansell *et al.* 1972; Hayward 1994). There are few macrophytes on intertidal mud unless there are some stones or shells for attachment of species. Those may include mats of *Enteromorpha* and *Ulva*, possibly in large aggregations to form so-called 'green tides' (Piriou, Menesguen & Salomon 1991).

Characterising species

For LMU in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Nematoda indet.	•	••	Common
Eteone longa	••	••	Abundant
Hediste diversicolor	••••	••	Abundant
Nephtys hombergii	••	••	Common
Pygospio elegans	••	•	Common
Streblospio shrubsolii	••	•••	Common
Capitella capitata	•	•	Common
Arenicola marina	•	•	Frequent
Manayunkia aestuarina	•	•••	Common
Oligochaeta indet.	••	••	Abundant
Tubificoides benedii	••	•••	Common
Corophium volutator	••	••	Common
Hydrobia ulvae	•••	••	Common
Cerastoderma edule	••	••	Common
Macoma balthica	•••	••	Common
Scrobicularia plana	•	•••	Abundant

Ecological relationships

Habitat complexity

Intertidal areas by definition have low, middle and high tidal heights and the productivity of these areas differs with respect to the tidal elevation and shore slope (Gray 1981). Most of the infaunal community is found in the mid-tidal region, with any decrease in tidal height taking the area towards greater current speed near channels and any increase in height will result in greater exposure to air and thus desiccation of the organisms. Changes in tidal height over the intertidal zone create a less predictable environment where there may be more extreme changes in temperature, salinity, dissolved oxygen and water content than in the sublittoral zone (Hayward 1994). The gradient of the shore reflects the energy conditions – that of mudflats are shallow reflecting the low energy conditions. Microbial activity has a valuable role in stabilising estuarine organic fluxes by reducing the seasonal variation in primary production, ensuring a relatively more-constant food supply, and allowing the re-absorption of dissolved nutrients (Robertson 1988). The bacteria living on particulate or dissolved organic matter makes the primary production more readily available for animal consumption (McLusky 1989).

Recruitment processes

The presence of high densities of adult invertebrates may inhibit the recruitment of potential colonising stages (planktonic larvae) from the water column (Olafsson, Peterson & Ambrose 1994). This may account for juveniles occupying less favourable parts of the intertidal areas, for example juvenile *Arenicola* and *Nephtys* settle in areas outside the optimal distribution for the adults. Mudflats are important nursery areas for plaice (Lockwood 1972; Marshall 1995; Marshall & Elliott 1997).

Productivity

Intertidal mudflats are important in the functioning of estuarine systems and may have a disproportionately high productivity compared to subtidal areas (Elliott & Taylor 1989). Estuarine mudflats receive primary production from benthic microalgae and water-column phytoplankton but production may be light-limited in these turbid environments.

Keystone (structuring) species

None.

Importance of habitat for other species

Intertidal areas are well defined as juvenile fish-feeding areas (Costa & Elliott 1991). The most important marine predators on intertidal mudflats are the flatfish sole *Solea solea*, dab *Limanda limanda*, flounder *Platichthys flesus* and plaice *Pleuronectes platessa* which feed on polychaetes and their tails (e.g. of *Arenicola* and *Nereis*), bivalve young and siphons (e.g. of *Macoma*) (Croker & Hatfield 1980; McDermott 1983; McLachlan 1983). In summer, large numbers of juvenile plaice and dab move over flats at high tide to feed on mobile epifauna, sedentary infauna and protruding siphons and tentacles (Elliott & Taylor 1989). Within estuaries and on mud, however, many demersal fish are opportunistic predators and the prey choice will reflect the infaunal species distribution of the area (Costa & Elliott 1991).

The littoral mud habitat is used by important wintering and passage birds for feeding and roosting. Shorebirds form important predators on north-west European intertidal mudflats during long migrations over long distances from breeding to wintering grounds. Particularly dependant species are Brent geese, shelduck, pintail, oystercatcher, ringed plover, grey plover, bar-tailed and black-tailed godwits, curlew, redshank, knot, dunlin and sanderling, whilst grey geese and whooper swan may use this habitat for roosting (Jones & Key 1989; Davidson *et al.* 1991). Migratory species of fish such as salmon and shad can be found on mudflats when on passage to other wetlands e.g. saltmarshes and freshwater areas, although they appear to have no requirement for the mud and sandflats

Temporal changes

No information available.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Development: land claim	High	Extensive areas of intertidal mudflats have been removed through land-claim coupled in some areas with rising sea levels (Davidson *et al.* 1991; Burd 1992). Some estuaries have lost up to 80% of the available area, most of which has been the land-claim of intertidal mudflats. The greatest impact of land reclamation is due to depletion of the main prey rather than simply to area loss and each prey and predator species will differ in their response (McLusky, Bryant & Elliott, 1992). Although the area of intertidal mudflats in estuaries is smaller than the subtidal area, it provides the dominant feeding area for the fish populations (Elliott & Taylor 1989). For example, land claim in the Forth Estuary has removed 24% of the natural fish habitats but 40% of their food supply (McLusky, Bryant & Elliott 1992). The greatest effect of land claim is on flatfish such as flounder and juvenile plaice.
Siltation	Waste: industrial effluent discharge	Intermediate	Silt, which is often associated with industrial pollution, may be deposited onto the mudflats thus raising their height and therefore increasing the exposure time of infaunal communities at low tide.
Heavy metal contamination/ **Synthetic compound contamination/** **Radionuclide contamination**	Waste: industrial effluent discharge	Intermediate	Industrialised and urbanised estuaries and coastlines receive effluent discharges which contain conservative contaminants i.e. those with a long half-life, are likely to bioaccumulate (remain within the food chain) and thus have a toxic effect (Clark 1997). Such contaminants include heavy metals, radionucleides and synthetic organic compounds. The lethal and sub-lethal effects of these pollutants vary according to the state and availability of the compound, its characteristics and the organisms. Some effects may be lethal, by removing individuals and species and thus leaving pollution-tolerant and opportunistic species. Other effects may be sub-lethal, in affecting the functioning of organisms such as the reproduction, physiology, genetics and health, which will ultimately reduce the fitness for survival (Nedwell 1997). Sheltered, low-energy areas such as intertidal mudflats in enclosed bays or estuaries will be most susceptible to these pollutants as dispersion is low and the finer substrata in these areas will act as a sink (McLusky 1982; Somerfield, Gee & Warwick 1994; Ahn, Kang & Coi, 1995; Nedwell 1997). The pollutants will enter the food chain and be accumulated by predators, as shown by the seasonal loading of heavy metals in tissues of wading birds in the Wash (Parslow 1973).
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	High	Oil spills resulting from tanker accidents can cause large-scale deterioration of communities in intertidal and shallow subtidal sediment systems (Majeed 1987). Oil covering intertidal muds prevents oxygen transport to the substratum and produces anoxia resulting in the death of infauna. In sheltered low-energy areas such as intertidal mudflats pollutant dispersion will be low and the finer substrata in these areas will act as a sink (McLusky 1982; Somerfield, Gee & Warwick 1994; Ahn, Kang & Coi, 1995; Nedwell 1997). The pollutants will then enter the food chain and be accumulated by predators.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	High organic inputs coupled with poor oxygenation leading to conditions of slow degradation will produce anaerobic conditions in the sediments. In turn this increases microbial activity and reduces the redox potential of the sediments

			(Fenchel & Reidl 1970). Ultimately this increases the production of toxic chemicals such as hydrogen sulphide and methane. The changed status to anaerobiosis will limit the sediment macroinfauna to species which can form burrows or have other mechanisms to obtain oxygen from overlying water. Moderate enrichment provides food to increase the abundance and a mixing of organisms with different responses increases diversity (Elliott 1994). With greater enrichment, the diversity declines and the community becomes increasingly dominated by a few pollution-tolerant, opportunistic species such as the polychaete *Manayunkia aesturina*. Such a symptom on intertidal mudflats is an increased coverage by opportunistic green macroalgae such as *Ulva* sp. and *Enteromorpha* sp. resulting in the formation of 'green tide' mats. Anoxic conditions form below the mats, reducing the diversity and abundance of infauna (Simpson 1997). In grossly polluted environments, the anoxic sediment is defaunated and may be covered by sulphur-reducing bacteria. Such a change will affect the palatability of any remaining prey and thus impair functioning of marine areas.
Removal of non-target species	Collecting: bait digging	Intermediate	The potential effects of bait digging are to reduce community diversity and species richness, especially by commercial digging for worms and other macrofauna on intertidal mudflats (Brown & Wilson 1997). This removal of target species, leading to community and population changes at the ecological and genetical levels, will affect predators.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Heavily endangered
UK	Significantly declined in extent and quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	*Mudflats and sandflats not covered by seawater at low tide water*, occurs within *Estuaries* and *Large shallow inlets and bays*
UK Biodiversity Action Plan	Mudflats

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Eelgrass *Zostera noltii* beds

***Compiled by**: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.*

***Derived, in part, from**: the UK marine biotope classification (Connor* et al. *1997a) and a review undertaken for the UK Marine SACs Project (Davison 1998).*

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A2.71/B-LMS.Zos.Znol	*Zostera noltii* beds in upper to mid shore muddy sand
Wadden Sea	05.02.01	Intertidal seagrass beds
Britain/Ireland (MNCR BioMar 97.06)	LMS.Znol	*Zostera noltii* beds in upper to mid shore muddy sand
France (ZNIEFF-MER)	II.3.3	Herbiers de *Zostera marina*, *Zostera noltii* (= *Z. nana pro parte*) du médiolittoral inférieur
	III.3.7	Biocenose des sables vaseux superficiels de mode calme (SVMC)

Description

Mid and upper shore wave-sheltered muddy fine sand or sandy mud with narrow-leafed eel grass Zostera noltii *at an abundance of frequent or above. This is similar to polychaetes and* Cerastoderma edule *(LMS.PCer) since it is most frequently found on lower estuary and sheltered coastal muddy sands with a similar infauna. Exactly what determines the distribution of the* Zostera noltii *is, however, not entirely clear.* Zostera noltii *is often found in small lagoons and pools, remaining permanently submerged, and on sediment shores where the muddiness of the sediment retains water and stops the roots from drying out. A black layer is usually present below 5 cm sediment depth. The infaunal community is characterised by polychaetes* Pygospio elegans *and* Arenicola marina*, mud amphipods* Corophium volutator *and bivalves* Cerastoderma edule*,* Macoma balthica *and* Scrobicularia plana*. Typically an epifaunal community is found that includes the mud snail* Hydrobia ulvae*, shore crabs* Carcinus maenas *and the green alga* Enteromorpha *sp. This biotope should not be confused with IMS.Zmar, which is a* Zostera marina *bed on the lower shore or shallow sublittoral clean or muddy sand.*

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Fully marine and variable
Wave exposure	Sheltered, Very sheltered, Extremely sheltered
Substratum	Muddy fine sand; sandy mud
Height band	Upper shore, Mid shore
Zone	Eulittoral
Temperature	Although *Z. noltii* is adapted to intertidal conditions and can tolerate broad temperatures ranges, the upper shore habitat exposes the species to extremes of cold or heat at low tide or in very shallow bays. Den Hartog (1987) suggested that cold winters could result in significant losses. In extreme winter conditions, the formation of ice amongst the sediments of exposed intertidal eelgrass beds can lead to the erosion of surface sediments and the uprooting of rhizomes, as well as direct frost damage to the plant. Covey & Hocking (1987) observed in the Helford River that, during exceptionally cold weather in January 1987, ice formed in the upper reaches of the mudflats and led to the defoliation of *Z. noltii* (the rhizomes survived).
Water quality	Like all plants, *Zostera* requires a particular light regime to photosynthize and grow. Turbidity affects light penetration thus influencing *Zostera* growth by restricting the amount of photosynthetically active radiation available to the submerged plants. Increases in turbidity are a commonly cited factor in the declin e of eelgrass beds. Jimenez, Niell & Algarra (1987) found that *Z. noltii* is better adapted to high light intensities than *Z. marina* and this is probably one of several adaptations that allows *Z. noltii* to occur higher up the shore.
Nutrients	Nutrient uptake by *Zostera* from the water column occurs through the leaves and from the interstitial water via the rhizomes. Nitrogen is usually the limiting element and is most easily absorbed as ammonium. In sandy sediments, phosphate may become a limiting factor due to its adsorption onto sediment particles (Short 1987).

Species composition and biodiversity

Characterising species

For IMS.Znol in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Pygospio elegans	•••	•	Common
Arenicola marina	••••	•	Frequent
Tubificoides spp.	•••	•	Common

Corophium volutator	••	•	Frequent
Carcinus maenas	•••	•	Occasional
Littorina littorea	••	•	Frequent
Hydrobia ulvae	•••	•	Abundant
Cerastoderma edule	••••	•	Abundant
Macoma balthica	•••	•	Frequent
Scrobicularia plana	••	•••	Common
Enteromorpha spp.	•••	•	Common
Zostera noltii	•••••	•••	Common

Ecological relationships

Habitat complexity

Community composition will depend upon a combination of factors, including the stability of the bed, the substratum type, salinity, tidal exposure and location. Of the three species of Zostera, *diversity tends to be lowest in the intertidal, estuarine, annual beds of* Z. noltii *(Jacobs & Huisman, 1982). Wildfowl (ducks and geese) are among the few animals which graze directly upon* Zostera *and are able to digest its leaves. Eelgrasses provide shelter and hiding places. The leaves and rhizomes provide substrata for the settlement of epibenthic species which in turn may be grazed upon by other species.*

Recruitment processes

Eelgrass beds are widely recognised to be important spawning and nursery areas for many species of fish, including commercial species.

Sediment stabilisation

Dense meadows of eelgrass leaves increase rates of sedimentation, and the rhizome and root networks bind the sediment, thereby reducing erosion. The roots also allow oxygen to penetrate into otherwise impermeable sediments. The penetration of Zostera *roots into the sediment aerates the upper layers and provides a more favourable habitat for burrowing animals.*

Productivity

Eelgrass primary production supports a rich, resident fauna and as a result, the beds are used as a refuge and nursery area by many species. The decomposition of dead eelgrass tissue by bacteria drives detritus-based food chains within the Zostera *bed. High numbers of heterotrophic protists are found in the water column over eelgrass meadows and take up both the dissolved organics leaching from the eelgrasses and the rapidly multiplying bacteria.*

Keystone (structuring) species

Zostera noltii

Importance of habitat for other species

Since the occurrence of the wasting disease which led to the widespread loss of Zostera marina *beds throughout Europe and North America in the 1920s-30s, the relative importance of the different* Zostera *species in Brent geese diet has shifted. As a result of the decline of* Z. marina *and its slow recovery, Brent geese were forced to migrate to other feeding areas and to switch their feeding to intertidal beds of* Z. angustofolia *and* Z. noltii. Zostera noltii *has replaced* Z. marina *as the preferred food and currently provides the main source of energy for Brent geese overwintering in Britain. Burton (1961) studied the dark-bellied Brent geese on the Essex coast* *in the late 1950s and early 1960s and found that they fed almost entirely on* Z. noltii *and the alga* Enteromorpha *sp. This shift in eelgrass abundance from* Z. marina *to* Z. noltii *has also affected wigeon. Wigeon numbers have declined dramatically in recent years and the reduced availability of eelgrass is considered to be one of the contributory factors. Grazing wigeon are very vulnerable to human disturbance. Where wildfowling is popular, wigeon appear to avoid the* Z. noltii *beds near the top of the shore and only begin to feed there when the* Z. angustifolia *and* Z. marina *lower down the shore are exhausted (Percival & Evans 1997).*

Temporal changes

New leaves appear in spring and the eelgrass meadows develop over the intertidal flats in the summer. Leaf growth ceases around September or October (Brown 1990), and leaf cover begins to decline during the autumn and over the winter. Plants may experience a complete loss of foliage, dying back to the buried rhizomes.

Time for community to reach maturity

In perennial populations, the rhizomes survive the winter to produce new leaves the following spring, while in annual populations, both the leaves and rhizomes die.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	High	A number of studies have suggested that, in general, it is the associated faunal communities that are more sensitive to oil pollution that the *Zostera* plants themselves (Jacobs 1980; Zieman *et al.* 1984; Fonseca 1992). Epiphyte grazers such as *Hydrobia ulvae* can contribute to the health of *Zostera* plants by removing the algae that foul the leaves. Any factors (natural or anthropogenic) such as oil pollution which reduce grazer populations may therefore have an indirect adverse impact on the *Zostera* bed. As *Z. noltii* occurs highest up the shore, it is likely to be most vulnerable to covering by oil, compared with sublittoral *Zostera* species, which are protected from direct contact with oil. Since *Zostera* generally occurs in sheltered, low energy sites, natural weathering of oil will be slow.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	Nutrient enrichment encourages rapid growth of blanket algae. Some opportunistic species such as *Enteromorpha* spp. may cause severe shading of *Zostera* (Den Hartog 1987). Den Hartog (1994) reported that at Langstone Harbour, S. England the growth of a dense blanket of *E. radiata* in 1991 resulted in the loss of 10 ha of *Z. marina* and *Z. noltii*, and that by the summer of 1992, *Zostera* spp. were entirely absent. Eutrophication may have a detrimental affect on grazer populations.
Abrasion	Recreation: popular beach /resort	Intermediate	Trampling is usually caused by recreational activities such as walking, horse-riding and off-road driving. Trampling damage may also be caused by environmental mitigation work. Thom (1993) reported that *Z. marina* beds in Washington State were damaged by trampling when mitigation work was being carried out in response to crab mortalities. Trampling damage resulting from oil clean-up attempts has also been reported. After the *Sea Empress* oil spill near Milford Haven in Wales, damage to *Zostera* appeared to be limited to those plants living on areas of shore traversed by clean-up vehicles. Abrasion may also be caused by boat anchoring, beaching and launching.
	Uses: boats/shipping (anchoring, mooring,	Intermediate	

	beaching & launching)		
Displacement	Collecting: bait digging	Intermediate	Eelgrasses are generally not physically robust. Their root systems are typically located within the top 20 cm of the sediment and so can be dislodged easily by a range of activities, including trampling, anchoring, digging, dredging and powerboat wash (Fonesca 1992).

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Heavily endangered
UK	Significantly declined in extent (subject to review)
Other sub-regions	Not known

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	A named component of *Mudflats and sandflats not covered by seawater at low tide.* May also occur in *Estuaries* and *Large shallow inlets and bays.*
UK Biodiversity Action Plan	Seagrass beds (Habitat Action Plan)

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Exposed infralittoral rock with kelp

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Birkett *et al.*1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.1	Infralittoral rock very exposed to wave action and/or currents and tidal streams.
Wadden Sea	-	Not present
Britain/Ireland (MNCR BioMar 97.06)	EIR.KFaR	Kelp with cushion fauna, foliose red seweeds or coralline crusts (exposed rock)
France (ZNIEFF-MER)	III.9.3.3	Faciès à *Laminaria hyperborea-Laminaria ochroleuca*: sous-faciès à *L. hyperborea* en population pure (eau claire, mode battu à très battu)

Description

Rocky habitats in the infralittoral zone subject to exposed to extremely exposed wave action or strong tidal streams. Typically the rock supports a community of kelp *Laminaria hyperborea* with foliose seaweeds and animals, the latter tending to become more prominent in areas of stongest water movement. The depth to which the kelp extends varies according to water clarity, exceptionally (e.g. St Kilda) reaching 45 m. The sublittoral fringe is characterised by dabberlocks *Alaria esculenta*, or occasionally by the kelp *Saccorhiza polysichides*. In very strong wave action the sublittoral fringe *Alaria* zone extends to 5 to 10 m, whilst at Rockall *Alaria* replaces *L. hyperborea* as the dominant kelp in the infralittoral. In some areas, there may be a band of dense foliose seaweeds (reds or browns) below the main kelp zone.

(see also habitat reviews for moderately exposed infralittoral kelp and sheltered infralittoral kelp.)

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full. Kelps are stenohaline in that they do not tolerate wide fluctuations in salinity.
Wave exposure	Extremely exposed, Very exposed, Exposed. *Laminaria hyperborea* is unable to survive where wave action is extreme, since its stiff stipe, topped with a large lamina, is prone to being snapped. In some areas, wave action depresses the upper limit of the *L. hyperborea* habitat to several metres below MLWS and under very severe wave conditions, the species may be absent. In such areas (e.g. Rockall) *Alaria esculenta* will be found in the infralittoral zone owing to its flexible stipe and thickened mid-rib which acts as reinforcement.
Tidal streams	Very strong, Strong, Moderately strong, Weak, Very weak
Substratum	Bedrock; stable boulders
Zone	Sublittoral fringe; Infralittoral
Depth range	0-50 m
Temperature	The kelp species of western Europe have relatively limited geographical ranges, which suggests that they are stenothermal and as such unable to tolerate large fluctuations in temperature. *Laminaria hyperborea* grows in a temperature range of $0^{o}C – 15^{o}C$ (Kain 1964), whereas *Saccorhiza polyschides* grows between $3^{o}C-24^{o}C$ (Norton 1970). *Alaria esculenta* is tolerant of temperatures up to $16^{o}C$ (Sundene 1962). Seasonal adaptions to temperature tolerance do occur though increased temperatures during the winter months are less well tolerated than increased temperatures during the summer months (Luning 1990).
Water quality	The light quantity and quality that is available to a kelp plant is dependent on the depth of water above the plant and its clarity. Absorption of light in coastal waters is influenced by the amount of particulate matter in suspension as well as by the dissolved oxygen components. Wavelengths of light are attenuated differentially as a result of these factors, altering the spectrum of wavelengths available at different depths. These effects may have a strong influence on kelp distribution and density within a kelp biotope.
Nutrients	All kelp species are thought to be efficient absorbers of nitrate and phosphate from seawater. However the quantities of these nutrients in seawater vary throughout the year, with maximum levels being attained during the winter months. In spring when the nitrate concentration of the water is almost zero kelps continue to grow by means of their own internal reserves. However, after depletion of all reserves the growth rates decline in late spring and early summer, then external supply governs growth activity (Conolly & Drew 1985 a, b).

Species composition and biodiversity

Characterising species

For EIR.KFaR in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Mytilus edulis	••	•	Common
Echinus esculentus	••	•	Frequent
Palmaria palmata	••	••	Frequent
Corallinaceae indet.	•••	•	Common
Corallina officinalis	••	••	Frequent
Laminaria digitata	••	••	Common
Laminaria hyperborea	••••	•	Common
Alaria esculenta	•••	•••	Common

Ecological relationships

Habitat complexity

Kelp communities contain a large number of habitats available for colonization by other species. The faunal diversity of kelp biotopes is extremely rich owing to the available primary, secondary and microbally-recycled production and also to the structural diversity within the biotope with many and various exploitable niches available. The floral diversity within kelp communities can also be great with colonisation occurring epiphytically on kelp plants or less independently on the surrounding substrata. Drach (1949) pointed out the importance of this and calculated that the rugose stipes of *Laminaria hyperborea* provide a settlement area of one-and-a-half times that of the rock surface. Epiflora recorded for *Laminaria hyperborea* stipes include *Palmaria palmata*, *Phycodrys rubens*, *Membranoptera alata*, *Ptilota gunneri* and *Cryptopleura ramosa* (Marshall 1960). Stipes of *Laminaria digitata*, although smooth, can support a considerable epiphytic flora, mainly of smaller species (Gayral & Cosson 1973).

Kelp beds are dynamic ecosystems where competition for light, space and food result in the species rich but patchy distribution patterns of flora and fauna on the infralittoral reefs. Kelp plants themselves support a diverse epiflora and epifuana, with their holdfasts forming a sheltered habitat for a diverse assemblage of animals.

Recruitment processes

Kelp biotopes, with their large numbers of species, high biomass and high rates of productivity are an important nursery area for a diverse range of species. It is likely that juvenile forms of all the animals that are present as adults in the kelp bed make use of the habitat as a nursery area. Other species may make use of the kelp beds during only parts of their life cycles.

Productivity

Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone (from high water to the depth of light penetration) kelps produce nearly 75% of the net carbon fixed.

Keystone (structuring) species

Laminaria hyperborea, *Alaria esculenta*, *Echinus esculentus.*

Importance of habitat for other species

Although kelp species often dominate their environment, they also supply extra substrate available for other organisms. Holdfasts provide refuge to a wide variety of animals. Jones (1971) listed upto 53 macrofaunal invertebrate species obtained from an individual holdfast. A few meiofaunal species may actively burrow into kelp. Benwell (1981) showed how the nematode *Monhystera disjuncta* may help weaken the distal areas of the kelp where it feeds on decomposition-associated microbiota.

Urchin predators such as lobsters *Homarus gammarus* and wolfish *Anarhichas lupus* may also be found amongst kelp forests.

Temporal changes

A very obvious change that has been noted in kelp forests throughout the world is that of either at a certain depth (Kain 1971) or in an area of kelp at a certain time, the kelp plants are lost and the bedrock becomes covered with encrusting coralline algae. The populations of the local species of sea urchin were found to increase at the same time. The resulting kelp-free areas within or adjacent to kelp forests are frequently referred to as “urchin barrens” and may remain kelp-free for years. Large-scale overgrazing of *Laminaria hyperborea* forests by the green sea urchin *Strongylocentrotus droebachiensis* has occurred off the coast of northern Norway (Hagen 1987). The resulting overgrazed ‘Isoyake’ bottoms dominated by crustose coralline algae and sea urchins persisted for more than five years in the Vestfjord area.

Long-term fluctuations or permanent shifts in the biodiversity of kelp forests may occur in the UK; however long-term monitoring has not been undertaken. Long-term studies on kelp beds on the Atlantic coast of Canada have continued since the original study in the late 1960s (Mann 1972). Temporal changes within kelp beds seem to be on a decadal scale, making long term monitoring projects necessary.

Time for community to reach maturity

Leinaas & Christie (1996) examined re-colonisation of a kelp forest after severe reductions in urchin numbers. The succession of algal growth followed a predictable pattern. The substratum was colonised initially by filamentous algae, then *Laminaria saccharina*. Only after 3-4 years after urchin removal did the slower growing, long-lived kelp *Laminaria hyperborea* become dominant.

Kain (1963) determined the age of individual plants by counting the number of growth rings or lines in the stipe. *Laminaria digitata* was reported as having no more than three growth lines (Kain 1979). Gayral & Cosson (1973) estimated the life expectancy of *L. digitata* to be approximately 4-6 years. *Laminaria hyperborea* is the longest-living species with plants as old as 15 years being recorded off the Outer Hebrides (Kain 1977). A plant with 18 rings was found in Norway by Grenager (1956). Many populations are limited by conditions to a life span of less than half of these extremes (Kain 1971). *Alaria esculenta* was estimated to live for between 4-7 years (Baardseth 1956) and *Saccorhiza polyschides* plants between 8-16 months.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Change in temperature	Climate change/global warming	Intermediate	This would affect the biogeographical distribution of kelp according to their temperature tolerances. Unfortunately, global warming effects span multiple generations of scientists and governments and the need for very long term monitoring research has only recently been appreciated.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	The mucilaginous slime covering kelps is thought to act as a protective device (O'Brien & Dixon 1976). *Laminaria digitata* showed reduced photosynthetic rates when emersed in crude oil (Schramm 1972). *Laminaria hyperborea* however would probably not come into contact with freshly released crude oil because of its continual emersion.
Removal of target species	Collecting: kelp/wrack harvesting	High	Svendensen (1972) examined kelp beds over periods of up to 3 years after harvesting and found the *Laminaria* population to be dense after one year. He regarded the beds as completely regenerated in terms of biomass after 3-4 years. Sivertsen (1991) compared the regrowth of kelp in areas trawled 1-5 years previously with areas freshly trawled and also control areas. Large canopy-forming plants were absent until 4 years after harvesting, but the structure of the kelp population was beginning to stabilise with little change in plant density from years 4-5. A further interesting observation was the replacement (for one year only) of the *L. hyperborea*-dominated forest with a population of *S. polyschides* as in the clearance experiments by Kain (1975). Harvesting may also affect those species associated with the kelp biotope. Rinde *et al.* (1992) carried out a survey to establish the affects of kelp harvesting on common organisms within the kelp biotope. They found the forest structure to recover to almost normal after 3-4 years, but argued that the forest did not provide the same physical environment for the other organisms which it shelters. The dredged areas tended to have growth of other kelps on the bottom, e.g. *Alaria esculenta*, while the bottom between the young *L. hyperborea* plants was uniformly covered with coralline algae after 3 years. In the control areas there was a more diverse bottom community.
Removal of non-target species	Collecting: shellfish (winkles, mussels)	Intermediate	The removal of predators such as lobsters and crayfish could result in an unchecked urchin population, which could in turn destroy kelp populations and form 'urchin barrens'.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Heavily endangered
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* and may occur within *Large shallow inlets and bays*.
UK Biodiversity Action Plan	None

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Moderately exposed infralittoral rock with kelp

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al*. 1997b) and a review undertaken for the UK Marine SACs Project (Birkett *et al*., 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov 1999)	A3.2	Infralittoral rock moderately exposed to wave action and/or currents and tidal streams
Wadden Sea	03.02.06	Benthic zone of the shallow coastal waters with hard bottom and rich macrophytes
Britain/Ireland (MNCR BioMar 97.06)	MIR.KR	Kelp with red seaweeds (moderately exposed)
	MIR.GzK	Grazed kelp with algal crusts
France (ZNIEFF-MER)	III.9.3.3	Faciès à *Laminaria hyperborea*-*Laminaria ochroleuca*: sous-faciès à *L. hyperborea* en population pure (eau claire, mode battu à très battu)

Description

MIR.KR. Infralittoral rock subject to moderate wave exposure, or moderately strong tidal streams on more sheltered coasts. On bedrock and stable boulders there is typically a narrow band of kelp *Laminaria digitata* in the sublittoral fringe which lies above the *Laminaria hyperborea* forest and park. Associated with the kelp are communities of seaweeds, predominantly reds and including a greater variety of more delicate Filamentous types than found on more exposed coasts (EIR.KFaR). The faunal component of the understorey is also less prominent than in EIR.KFaR.

MIR.GzK. Infralittoral rock, typically dominated by the kelp *Laminaria hyperborea* but where the rock beneath is intensely grazed by urchins giving a barren algal-encrusted rock surface. In some areas the upper parts of the kelp stipes may be free from grazing pressure and support a typical kelp stipe flora. Under intense grazing pressure, erect algae are absent and animals are confined to crevices and under-boulder habitats where urchins cannot penetrate. Where grazing is less severe, some erect algae, such as *Desmarestia aculeata*, and a certain animals (eg. *Alycyonium digitatum* and *Nemertesia antennina*) may occur. Dense aggregations of brittlestars (*Ophiothrix fragilis* and *Ophiocomina nigra*) produce a similarly barren community, through their smothering effect.

GB distribution

(from MNCR database in March 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Fully marine. Kelps are stenohaline in that they do not tolerate wide fluctuations in salinity. Laboratory studies have shown Norwegian species to tolerant salinities as low as 15 ‰ although 25 ‰ to 30 ‰ was found to be favourable (Sundene 1964b). Sporophytes of *Laminaria hyperborea* grew optimally from 20-35‰ but did not survive at 6‰ (Hopkin & Kain 1978).
Wave exposure	Moderately exposed, Sheltered
Tidal streams	Very strong, Strong, Moderately strong, Weak, Very weak
Substratum	Bedrock; stable boulders and cobbles
Zone	Sublittoral fringe; Infralittoral
Depth range	0-20m
Temperature	The kelp species of western Europe have relatively limited geographical ranges, which suggests that they are stenothermal and as such unable to tolerate large fluctuations in temperature. *Laminaria digitata* found in cold temperate waters have a range of 0°C – 20°C (Kain 1969). *Laminaria hyperborea* shows a narrower range of temperature tolerance for growth 0°C – 15°C (Kain 1964). Seasonal adaptations to temperature tolerance do occur though increased temperatures during the winter months are less well tolerated than increased temperatures during the summer months (Luning 1990).
Water quality	The critical depth for *Laminaria* corresponds roughly to the depth at which irradiance levels, averaged over the whole year, fall to about 1% of their values at the surface. If light penetration is good and kelp plants can grow at greater depths. For example, kelps are found below 100m in the clear waters of the Mediterranean but are restricted to around 35m in the coastal waters off the far western coasts of Europe. In the turbid waters of Helgoland and Norway, kelps are found at depths of only 6-7m. Light is also used as an environmental signal by *Laminaria hyperborea*. New frond growth is induced in winter when the daylength falls below a certain value (Luning 1986).
Nutrients	All kelp species are thought to be efficient scavengers of nitrate and phosphate from seawater. However the quantity of these nutrients in seawater varies throughout the year, with maximum levels being attained during the winter months. In spring when the nitrate concentration of the water is almost zero kelps continue to grow by means of their own internal reserves. However, after depletion of all reserves the growth rates decline in late spring and early summer, then external supply governs growth activity (Conolly and Drew 1985a, b).

Species composition and biodiversity

Characterising species

For MIR.KR. in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Obelia geniculata	••	••	Frequent
Pomatoceros triqueter	•••	•	Occasional
Gibbula cineraria	•••	•	Occasional
Asterias rubens	•••	•	Occasional
Palmaria palmata	••	••	Frequent
Corallinaceae indet.	•••	•	Common
Corallina officinalis	••	••	Frequent
Phycodrys rubens	•••	•	Frequent
Laminaria digitata	•••	••	Abundant
Laminaria hyperborea	••••	•	Common

For MIR.GzK. in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Obelia geniculata	••	••	Frequent
Alcyonium digitatum	•••	•	Occasional
Pomatoceros triqueter	•••	•	Frequent
Gibbula cineraria	•••	•	Occasional
Calliostoma zizyphinum	•••	••	Occasional
Antedon bifida	•••	•	Frequent
Asterias rubens	••••	•	Occasional
Ophiocomina nigra	••	•	Frequent
Ophiura albida	••	••	Occasional
Echinus esculentus	•••••	•	Common
Corallinaceae indet. (crusts)	••••	•	Abundant
Phycodrys rubens	•••	•	Frequent
Aglaozonia (asexual *Cutleria*)	••	••	Frequent
Laminaria hyperborea	••••	•	Common

Ecological relationships

Any kelp-bearing area will contain a number of habitats available for other biota. The faunal diversity of kelp biotopes is extremely rich owing to the available primary, secondary and microbally-recycled production and also to the structural diversity within the habitat with many and various exploitable niches available. The floral diversity within kelp communities is also great with colonization occurring epiphytically on kelp plants or less independently on the surrounding substrata. Drach (1949) pointed out the importance of this and calculated that the rugose stipes of *Laminaria hyperborea* provide a settlement area of one and a half times that of the rock surface. Epiflora recorded for *Laminaria hyperborea* stipes includes *Palmaria palmata*, *Phycodrys rubens*, *Membranoptera alata*, *Ptilota gunneri* and *Cryptopleura ramosa* (Marshall 1960; Whittick 1969). Stipes of *Laminaria digitata* although smooth, can support a considerable epiphytic flora, mainly of smaller species (Gayral & Cosson 1973).

A very obvious change that has been noted in kelp forests throughout the world is that either at a certain depth (Kain 1971a) or in an area of kelp at a certain time, the kelp plants are lost and the bedrock becomes covered with encrusting coralline algae. The populations of the local species of sea urchin were found to increase at the same time. The resulting kelp-free area within or adjacent to kelp forests are frequently referred to as "urchin barrens" and may remain kelp free for years. Large-scale overgrazing of *Laminaria hyperborea* beds by the green sea urchin *Strongylocentrotus droebachiensis* has recently occurred off the coast of northern Norway (Hagen 1987). The resulting overgrazed 'Isoyake' bottoms dominated by crustose coralline algae and sea urchins persisted for more than five years in the Vestfjord area.

Habitat complexity

Kelp beds are dynamic ecosystems where competition for light, space and food result in the species rich but patchy distribution patterns of flora and fauna on the infralittoral reefs. Kelp plants themselves support a diverse epiflora and epifauna with their holdfasts forming a sheltered habitat for a diverse assemblage of animals.

Recruitment processes

Kelp biotopes are important nursery areas for a diverse range of species. It is likely that juvenile forms of all the animals that are present as adults in the kelp bed make use of the habitat as a nursery area. Other species may only make use of the kelp beds during only parts of their lifecycles.

Productivity

Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone (from high water to the depth of light penetration) kelps produce nearly 75% of the net carbon fixed.

Keystone (structuring) species

Laminaria hyperborea, Laminaria digitata, Echinus esculentus, Paracentrotus lividus and *Strongylocentrotus droebachiensis*

Importance of habitat for other species

Although kelp species often dominate their environment, they also supply extra substrate available for other organisms. Holdfasts also provide refuge to a wide variety of animals. Jones (1971) listed upto 53 macrofaunal invertebrate species obtained from an individual holdfast. A few meiofaunal species may actively burrow into kelp. Benwell (1981) has shown how the nematode *Monhystera disjuncta* may help weaken the distal areas of the kelp where it feeds on decomposition-associated microbiota.

Urchin predators such a lobsters *Homarus gammarus* and wolffish *Anarhichas lupus* may also be found amongst kelp forests.

Temporal changes

Long-term fluctuations or permanent shifts in the biodiversity of kelp beds may occur in the UK; however long term monitoring has not been undertaken. Long term studies on kelp beds on the Atlantic coast of Canada have continued since the original study in the late 1960's (Mann 1972). Temporal changes within kelp beds seem to be on a decadal scale, making monitoring projects of very long term a necessity.

Time for community to reach maturity

Leinaas & Christie (1996) examined re-colonisation of a barren kelp forest after severe reductions in urchin numbers. The succession of algal growth followed a predictable pattern. The substratum was colonised initially by filamentous algae, then *Laminaria saccharina*. Only after 3-4 years after the removal experiment did the slower growing, long-lived kelp *Laminaria hyperborea* become dominant.

The age of individual plants has been determined by Kain (1963b) by counting the number of growth rings or lines in the stipe. *Laminaria digitata* was reported as having no more than three growth lines (Kain 1979). *Laminaria hyperborea* is the longest living species with plants as old as 15 years being recorded off the Outer Hebrides (Kain 1977). A plant with 18 rings was found in Norway by Grenager (1956). Many populations are limited by conditions to a life span of less than half of these extremes (Kain 1971a).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Waste: sewage discharge	Intermediate	Silt deposition may occur in the vicinity of sewage outfalls and this can exert a number of detrimental influences on marine benthic algal communities (Fletcher 1996). The sediment can cover all available substrata interfering with the processes of spore attachment. They can smother young germlings and inhibit their growth and development. Combined with water movement sediments can abrasively scour surfaces of settled spores.
Changes in temperature	Climate change/global warming	Intermediate	This would affect the biogeographical distribution of kelp according to their temperature tolerances.
Changes in turbidity	Extraction: navigational/ maintenance dredging	Intermediate	Dredging results in the suspension of the fine silt and clay fractions of the sediment which is deposited by inshore currents. This will increase turbidity and decrease the amount of penetrating light.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	The mucilaginous slime covering kelps is thought to act as a protective device (O'Brien & Dixon 1974). *Laminaria digitata* showed reduced photosynthetic rates when emersed in crude oil (Schramm 1972). *Laminaria hyperborea* however would never come into contact with freshly released crude oil as a result of its continual emersion.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	The increase in levels of macronutrients in European coastal waters results in the excessive growth of ephemeral macroalgal species. Increased turbidity in coastal waters may also occur as a result of prolific phytoplankton growth.
Changes in oxygenation	Aquaculture: fin - fish	Intermediate	Plumes of waste could stream over kelp forests leading to anaerobiosis as a result of the oxygen demand of the decomposing material. Detrital rain could also smother the surfaces of plants. Anti-microbial agents could be particularly harmful to kelp biotopes because of the importance of bacteria in detrital cycling.
Removal of target species	Collecting: kelp/wrack harvesting	High	Svendsen (1972) examined kelp beds over periods of up to 3 years after harvesting and found the Laminaria population to be dense after one year. Although he regarded the beds as completely regenerated in terms of biomass only after 3-4 years. Sivertsen (1991) has compared the regrowth of kelp in areas trawled 1-5 years previously with areas freshly trawled and control areas. Large canopy-forming plants were absent until 4 years after harvesting, but the structure of the kelp population was beginning to stabilize with little change in plant density from years 4-5. Harvesting may also affect those species associated with the kelp biotope. Rinde *et al.*, (1992) studied the effects of kelp harvesting on other common organisms within the kelp biotope and found

			the forest structure to recover after 3-4 years. Persistent differences from undisturbed forests were however found.
Removal of non-target species	Collecting: shellfish (winkles, mussels)	Intermediate	The removal of predators such as lobsters and crayfish could result in an unchecked urchin population, which could in turn destroy kelp populations in the formation of 'urchin barrens'.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not known
Wadden Sea	Heavily endangered
UK	Not significantly declined in extent or quality
Other sub-regions	Not known

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs*; may occur within *Estuaries*, *Lagoons* and *Large shallow inlets* and *bays*.
UK Biodiversity Action Plan	None

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Sheltered infralittoral rock with kelp

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Birkett *et al.*, 1998).

Classification

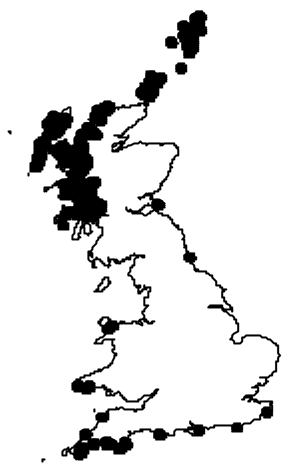
Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.3/B-SIR.K	Silted kelp communities on sheltered infralittoral rock
Wadden Sea	03.02.06	Benthic zone of the shallow coastal waters with hard bottom and rich macrophytes
Britain/Ireland (MNCR BioMar 97.06)	SIR.K	Silted kelp (stable rock)
France (ZNIEFF-MER)	III.9.3.5	Faciès à *Laminaria hyperborea-Laminaria ochroleuca* : sous-faciès à algues filamenteuses (mode abrite).
	III.9.4.1	Facies à Cystoseires et *Laminaria saccharina* en mode abrité.

Description

Infralittoral rock in wave and tide-sheltered conditions, supporting silty communities with *Laminaria hyperborea* and /or *Laminaria saccharina*. Associated seaweeds are typically silt-tolerant and include a high proportion of delicate filamentous types. Some areas, particularly in the lower infralittoral zone, are subject to intense grazing by urchins and chitons and may have poorly developed seaweed communities.

GB distribution

(from MNCR database in February 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable.
Wave exposure	Sheltered, Very sheltered, Extremely sheltered
Tidal streams	Moderately strong, Weak, Very weak
Substratum	Bedrock, boulders, cobbles and mixed substrata
Zone	Sublittoral fringe; Infralittoral
Depth range	0-20m
Temperature	The kelp species of western Europe have relatively limited geographical ranges, which suggests that they are stenothermal and as such unable to tolerate large fluctuations in temperature. *Laminaria hyperborea* grows in a temperature range of $0^oC – 15^oC$ (Kain 1964), whereas *L. saccharina* has a slightly wider range of between 0^oC-18^oC. Seasonal adaptations to temperature tolerance do occur though increased temperatures during the winter months are less well tolerated than increased temperatures during the summer months (Luning 1990).
Water quality	The light quantity and quality that is available to a kelp plant is dependent on the depth of water above the plant and its clarity. Absorption of light in coastal waters is influenced by the amount of particulate matter in suspension as well as by the dissolved oxygen components. Wavelengths of light are attenuated differentially as a result of these factors, altering the spectrum of wavelengths available at different depths. These effects probably have little influence on sheltered infralittoral kelp biotopes, as component species tend to be silt-tolerant.
Nutrients	All kelp species are thought to be efficient absorbers of nitrate and phosphate from seawater. However the quantity of these nutrients in seawater varies throughout the year, with maximum levels being attained during the winter months. In spring when the nitrate concentration of the water is almost zero kelps continue to grow by means of their own internal reserves. However, after depletion of all reserves the growth rates decline in late spring and early summer, then external supply governs growth activity (Conolly & Drew 1985 a, b).

Species composition and biodiversity

Characterising species

The flora and fauna of kelp beds varies with depth and geographical location and may be depauperate in silted habitats.

For SIR.K in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Pomatocerous triqueter	•••	•	Frequent
Gibbula cineraria	•••	•	Frequent
Asterias rubens	•••	•	Occasional
Echinus esculentus	•••	•	Occasional
Ascidia mentula	••	••	Occasional
Corallinaceae indet.	•••	•	Common
Laminaria hyperborea	••	•	Common
Laminaria saccharina	••••	•	Common

Ecological relationships

Habitat complexity

Kelp *Laminaria hyperborea* plants support a diverse epiflora and epifauna with their holdfasts forming a sheltered habitat for a diverse assemblage of animals. However *L. saccharina* forests are subject to intense grazing by urchins and chitons and tend to have poorly developed seaweed communities. Those species which are present are typically silt-tolerant and include a high proportion of delicate filamentous types.

Recruitment processes

Kelp biotopes are important nursery areas for a diverse range of species. It is likely that juvenile forms of all the animals that are present as adults in the kelp bed make use of the habitat as a nursery area. Rinde *et al.* (1992) states that the kelp beds in Norway are nursery areas for gadoid species. Other species may make use of the kelp beds during only parts of their life cycles. Specific information on the extent to which UK kelp biotopes are used as nursery areas for animal species is not known.

Productivity

Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone (from high water to the depth of light penetration) kelps produce nearly 75% of the net carbon fixed.

Keystone (structuring) species

Laminaria saccharina, L. hyperborea, Echinus esculentus

Importance of habitat for other species

Although kelp species often dominate their environment, they also supply extra substrate available for other organisms. Holdfasts also provide refuge to a wide variety of animals. Jones (1971) listed upto 53 macrofaunal invertebrate species obtained from an individual holdfast. A few meiofaunal species may actively burrow into kelp. Benwell (1981) has shown how the nematode *Monhystera disjuncta* may help weaken the distal areas of the kelp where it feeds on decomposition-associated microbiota.

Temporal changes

Long-term fluctuations or permanent shifts in the biodiversity of kelp beds may occur in the UK; however long-term monitoring has not been undertaken. Long-term studies on kelp beds on the Atlantic coast of Canada have continued since the original study in the late 1960's (Mann 1972). Temporal changes within kelp beds seem to be on a decadal scale, making monitoring projects of very long term a necessity.

Time for community to reach maturity

Leinaas & Christie (1996) examined re-colonisation of a barren kelp forest after severe reductions in urchin numbers. The succession of algal growth followed a predictable pattern. The substratum was colonised initially by filamentous algae and then by *Laminaria saccharina*.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Waste: sewage discharge	Low	Although sheltered infralittoral kelp is tolerant of siltation, excessive siltation which occurs in the vicinity of sewage outfalls can exert a number of detrimental influences on marine benthic algal communities (Fletcher 1996). The sediment can cover all available substrata interfering with the processes of spore attachment. They can smother young germlings and inhibit their growth and development.
Changes in temperature	Climate change/global warming	Intermediate	This would affect the biogeographical distribution of kelp according to their temperature tolerances. Unfortunately, global warming effects span multiple generations of scientists and governments and the need for very long term monitoring

			research has only recently been appreciated.
Changes in turbidity	Extraction: navigational/ maintenance dredging	Intermediate	Dredging results in the suspension of the fine silt and clay fractions of the sediment that is deposited by inshore currents. This will increase turbidity and decrease the amount of penetrating light.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	The mucilaginous slime covering kelps is thought to act as a protective device (O'Brien & Dixon 1976). However, *Laminaria hyperborea* would probably never come into contact with freshly released crude oil as a result of its continual emersion.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	The increase in levels of macronutrients in European coastal waters results in the excessive growth of ephemeral macroalgal species. Increased turbidity in coastal waters may also occur as a result of prolific phytoplankton growth. The localised increase in nutrient levels as a result of marine aquaculture could produce local eutrophication effects, particularly at slack tide.
Changes in oxygenation	Aquaculture: fin-fish	Intermediate	Plumes of waste could stream over kelp forests leading to anaerobiosis as a result of the oxygen demand of the decomposing material. Detrital rain could also smother the surfaces of plants. Anti-microbial agents could be particularly harmful to kelp biotopes because of the importance of bacteria in detrital cycling.
Removal of target species	Collecting: kelp/wrack harvesting	Intermediate	Svendensen (1972) examined kelp beds over periods of up to 3 years after harvesting. He found the *Laminaria* population to be dense after one year but in terms of biomass considered the population to have completely regenerated after 3-4 years. Sivertsen (1991) has compared the re-growth of kelp in areas trawled 1-5 years previously with areas freshly trawled and control areas. Large canopy-forming plants were absent until 4 years after harvesting, but the structure of the kelp population was beginning to stabilize with little change in plant density from years 4-5. A further interesting observation was the replacement (for one year only) of the *L. hyperborea*-dominated forest with a population of *S. polyschides* as in the clearance experiments by Kain (1975). Harvesting may also affect those species associated with the kelp biotope. Rinde *et al*. (1992) carried out a survey to establish the affects of kelp harvesting on common organisms within the kelp biotope. They found the forest structure to recover to almost normal after 3-4 years, but argue that the forest does not provide the same physical environment for the other organisms that it shelters.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Heavily endangered
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs*; may occur within *Estuaries*, *Lagoons* and *Large shallow inlets and bays*.
UK Biodiversity Action Plan	None

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Whittick, A. 1969. M.Sc. Thesis, Durham University.

Exposed circalittoral rock

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Hartnoll 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.5	Circalittoral rock very exposed to wave action or currents and tidal streams
Wadden Sea	-	Not present
Britain/Ireland (MNCR BioMar 97.06)	ECR	Exposed circalittoral rock
France (ZNIEFF-MER)	IV.6	Part of Fonds durs : cailloutis, galets et roches.

Description

Circalittoral rocky habitats subject to strong wave action or tidal currents and supporting animal communities which are robust enough to survive in such strong water movement. The fauna is generally low-lying faunal crusts, cushions and turfs but also includes communities of the large soft coral *Alcyonium digitatum*. Included here are habitats which occur in very strong tidal streams (ECR.BS) in tidal channels (sounds, sealochs) as well as those found on wave exposed coasts (ECR.EFa, ECR.Alc), as there are strong similarities in species composition in some cases.

GB Distribution

(from MNCR database March 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable The majority of exposed circalittoral rock habitats occur on the open coast in full salinity, however some occur in the tide-swept sounds of sealochs and in a few cases are subject to more variable salinities (e.g. Loch Etive, Scotland).
Wave exposure	Extremely exposed, Very exposed, Exposed, Moderately exposed, Sheltered, Very sheltered Water movement is the prime factor influencing community composition. Wave action generates extreme forces, and is basically a result of wind blowing across the sea and transferring energy to the sea surface. Wave action will be modified by local topography and the severity of wave effects decrease with depth. Under gale conditions the bottom water velocity may be > 200 $cm.sec^{-1}$ at 20 m, but reduced to about 60 $cm.sec^{-1}$ at 40 m and 9 $cm.sec^{-1}$ at 80 m (Hiscock 1983).
Tidal streams	Very strong, Strong, Moderately strong, Weak, Very weak Tidal streams flow to and fro with the tidal cycle, and they do not attenuate with depth as rapidly as does wave action. The presence or absence of water movement will alter the balance of competition between species which might be otherwise able to survive across a wide range of exposure. The end result is that there are very different circalittoral biotopes in different conditions of current exposure. The distribution of species will result from a balance between their ability to withstand vigorous water movement, and their need for water flow to assist their feeding processes. Exposed areas tend to be dominated by cnidarians and massive sponges.
Substratum	Bedrock; stable boulders Surface texture, erosion and rock hardness are factors of marked relevance to circalittoral communities. Substratum stability is determined by whether it is comprised of bedrock, or of loose boulders or stones. The mobility of boulders and stones is a function of wave exposure, and mobility of the substratum will selectively impact faunal turf species. Marked differences between the communities of bedrock and adjacent loose rocks has been recorded (Knight-Jones & Jones 1955). Mobile substrata under exposed conditions have a community characterised by serpulid worms, barncales and bryozoan crusts (Hiscock 1981; Dipper 1983; Mitchell, Earll & Dipper 1983; Bunker & Hiscock 1987; Howson 1988) rather than by the larger more delicate species which feature on the adjacent bedrock.
Depth band	5-50 + m
Zone	Circalittoral
Temperature	Localised short-term fluctuations in seawater temperature, resulting from heat loss or gain to the air or the substratum, can occur in the shallow surface layer in inshore water. Circalittoral faunal turf communities are largely insulated from such transient influences by their depth and in many cases also by their prevalence in high-energy systems.
Light	Light is the environmental factor which determines the depth distribution of the circalittoral – the decrease of light with depth defines the upper limit of the zone as the limit of kelp or dense algal growth.. In areas where enough incident light reaches the seabed rocky habitats the community tends to be dominated by large macroalgae in what is defined as the infralittoral zone. When light levels decline with depth there is a progressive shift to faunal-dominated communities. Areas of the infralittoral dominated by animal biotopes occur as a result of steep slopes, intense grazing, and sometimes extreme physical conditions (such as surge gulleys); however they are very much the exception.
Slope	The slope of the rock influences faunal turf communities as it affects the amount of incident light, and consequently the abundance of algal growth.
Water quality	Transparency and water clarity are affected by dissolved material and suspended particles in the water, and are important because they influence the penetration of light. In exposed conditions temporarily suspended material, such as coarse bottom material, may cause scour. Settlement of suspended material is not usually a problem in exposed situations.
Scour	Scour is a factor in more exposed areas where the rock substratum is in proximity to sediment. Typically such situations are found where boulders lie on a sandy bottom, or in the regions where the bedrock merges with the level seabed.

Species composition and biodiversity

For ECR in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Pachymatisma johnstonia	••	••	Occasional
Cliona celata	••	••	Occasional
Tubularia indivisa	••	••	Frequent
Nemertesia antennina	•••	••	Occasional
Alcyonium digitatum	••••	•	Frequent
Urticina felina	•••	•	Occasional
Sagartia elegans	••	•	Occasional
Corynactis viridis	••	••	Frequent
Caryophyllia smithii	•••	•	Frequent
Pomatoceros triqueter	••	•	Frequent
Balanus crenatus	••	•	Frequent
Cancer pagurus	•••	•	Occasional
Calliostoma zizyphinum	•••	••	Occasional
Parasmittina trispinosa	••	•	Frequent
Antedon bifida	••	•	Occasional
Securiflustra securifrons	•	••	Frequent
Asterias rubens	••••	•	Occasional
Echinus esculentus	••••	•	Occasional
Clavelina lepadiformis	••	•	Occasional
Corallinaceae indet. (Crusts)	••	•	Frequent

Ecological relationships

Environmental factors determine which circalittoral rock species can inhabit a given location and this will depend on the biological characteristics of each species – such as size, habit, feeding method and reproductive mode. However, not every species occurs throughout its potential range – its realised distribution is moderated by biological interactions such as competition, grazing and predation. Circalittoral communities have been poorly studied in respect to biological interactions because in order to determine the real role of species in a community experimental manipulation in the field is required. This has been carried out extensively in the intertidal and infralittoral but rarely in the circalittoral owing to the logistics of working at such depths.

Habitat complexity

Circalittoral rock provides a firm attachment in areas of strong wave action or tidal currents such that the sessile habit of many species is advantageous. Firm attachment prevents the species from being swept away to what might be unfavourable conditions, and prevents them from being damaged by impact on rocks. In terms of being prostrate or erect there is a conflict of interest for circalittoral rock species. They are mostly filter feeders, and they frequently live in vigorous water movement. A prostrate habit protects them from the worst of the water movement, as well as giving them a very robust morphology. However, it tends to place them in the boundary layer with limited water movement, and it is the water which carries their food. Conversely, erect species are more prone to damage by turbulence or currents and more fully exposed to them; but they are in a position to maximise food intake. Under conditions of extreme exposure robust low-growing forms predominate – barnacles, massive sponges, short hydroids, bryozoans and tube-building polychaetes. As exposure moderates the taller erect forms come into prominence – the sea fans, soft corals and the like. These erect forms still tolerate considerable exposure as they have a tough yet flexible structure which enables them to withstand turbulence and strong currents without damage.

Recruitment processes

Whilst most exposed circalittoral rock species spend their larval life in the plankton, there are a few planktonic species which spend their early stages within the circalittoral rock biotopes. This is true, in rather different degrees, of the hydroids and the jellyfish. Hydroids are common and conspicuous members of circalittoral rock biotopes, but the attached hydroids are only the juvenile stages. The sexually reproducing mature stages are small medusae which are released into the plankton, where they produce larvae which settle again. In contrast, for jellyfish the large adult medusae in the plankton are the prominent phase. The juvenile stages live attached to rocks as an inconspicuous scyphistoma stage in which the jellyfish overwinters. In spring this buds off a series of juvenile medusae, or ephyrae, which grow rapidly in the plankton to form the adult.

Productivity

Although not primary producer's circalittoral rock communities are important secondary producers. They accumulate and concentrate the primary production from a large water mass, and make this readily available to higher trophic levels.

Keystone (structuring) species

Circalittoral rock biotopes typically are not dominated by single species, accepting *Alcyonium digitatum* in some biotopes, but support a diverse mosaic of species.

Importance of habitat for other species

Circalittoral rock communities interact with others by the provision of food and /or temporary shelter to mobile species which are not permanent faunal turf fauna. Shelter is important to juvenile fish, which can find refuge (and food) amongst the dense turf of sessile species. A food source is provided to large mobile crustaceans and fish which are attracted by the rich and stationary food supply available on circalittoral rock.

Temporal changes

One of the features of circalittoral faunal turf communities is their fine-scale spatial variation which tends to be very patchy. Whilst the infralittoral tends to be more predictable, circalittoral rock tends to be a mosaic of different species patches; The different assemblages may represent 'alternate stable states' (Sutherland 1974; Sebens 1985a, b). In most of these biotopes substratum space is very fully occupied and the availability of space is a controlling resource for the settlement and growth of species. According to when free space is made available, and on which species are recruiting at that time, different assemblages of species may develop under the same physio-chemical conditions. Once established, often following a succesional sequence (Hextall 1994), these assemblages are stable for long periods and different assemblages may co-exist in close proximity.

Time for community to reach maturity

Information is restricted, but it is clear that a number of the more prominent members of the circalittoral rock communities are relatively long lived, and fairly slow growing, some with life spans ranging from 6-100 years. The soft coral *Alcyonium digitatum* is a very prominent member of the circalittoral rock community and observations have shown that colonies of 10-15 cm in height are between five and ten years old (Hartnoll unpubl.).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Fishing: benthic trawling	Low	Although towed gear may not directly cross circalittoral faunal turf biotopes (see above), the activities of dredging and trawling on nearby level bottoms with softer sediments could have effects on neighbouring communities. Towed gear results in the suspension of fine sediment (Jones 1992), which can affect the efficiency of filter feeding (Sherk 1971; Morton 1977) and in exposed situations can cause scour (see 'Habitat requirements').
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Low	Untreated oil is not a risk to circalittoral communities as it is concentrated mainly at the surface. If oil is treated by dispersant the resulting emulsion will penetrate the water column, especially under the influence of turbulence.
Changes in nutrient levels	Waste: sewage discharge	Low	The primary effect of increased nutrient levels is to stimulate algal growth, both of benthic macroalgae and microscopic phytoplankton. Since by definition circalittoral faunal turf communities are essentially animal dominated, the effects of eutrophication will be indirect. Changes in the phytoplankton are more likely to produce impacts. Increased phytoplankton densities will change the food supply for the predominantly filter-feeding communities. Blooms of toxic algae may affect survival of circalittoral rock communities, perhaps particularly in their planktonic larval stages.
Abrasion	Fishing: benthic trawling	Intermediate	Towed gear is potentially the most destructive impact, and has been the subject of the most intensive study (MacDonald *et al.* 1996). However, most circalittoral rock biotopes will not generally be threatened since the generally steep and rocky substrata are unsuitable for both trawls and dredges. However there are types of towed gear designed for rocky areas – the rockhopper otter trawl, and the Newhaven scallop dredge and these could pose a risk to circalittoral rock communities on gently-sloping or level rock.
	Fishing: potting/creeling	Low	Static gear is deployed regularly on rocky grounds, either in the form of pots or creels, or as bottom set gill or trammel nets. Whilst the potential for damage is lower per unit deployment compared to towed gear, there is a risk of cumulative damage to sensitive species if use is intensive. Damage could be caused during the setting of pots or nets and their associated ground lines and anchors, and by their movement over the bottom during rough weather and during recovery.
	Fishing; angling	Low	Rod and line angling is the least likely activity to produce incidental damage from the fishing itself – the main risk is damage from the anchoring of the angling boats. Frequent anchoring in areas which often experience strong tidal flow is an obvious problem.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in area or extent
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* and *Submerged or partially submerged sea caves*. May also occur in *Large Shallow Inlets and bays* and more rarely in *Estuaries*.
UK Biodiversity Action Plan	None

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Moderately exposed circalittoral rock

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Hartnoll 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.6	Circalittoral rock moderately exposed to wave action or currents and tidal streams.
Wadden Sea	-	Not present/listed
Britain/Ireland (MNCR BioMar 97.06)	MCR	Moderately exposed circalittoral rock
France (ZNIEFF-MER)	IV.6	Part of Fonds durs : cailloutis, galets et roches.

Description

Circalittoral rock subject to moderate wave exposure or some degree of tidal currents in more sheltered conditions. Such habitats occur very widely around the coast and are highly variable in their character, depending on quite subtle differences in water quality (e.g. the degree of suspended silt or sand), tidal current strength, rock topography and rock type. A wide range of biotopes are currently defined, but these may require expansion to fully account for all parts of Britain and Ireland.

(*Sabellaria spinulosa* reefs [MCR.Csab], *Modiolus* beds [MCR.ModT] and brittlestar beds [MCR.Bri] are considered seperately. This review considers the remainder of MCR).

GB Distribution

(from MNCR database March 1999)

Habitat requirements

Habitat factor	Range of conditions
Salinity	Full The majority of moderately exposed circalittoral rock habitats occur on the open coast in full salinity.
Wave exposure	Moderately exposed, Sheltered Water movement is the prime factor influencing community composition. Wave action generates extreme forces, and is basically a result of wind blowing across the sea and transferring energy to the sea surface. Wave action is modified by local topography and the severity of wave effects decrease with depth. Under gale conditions the bottom water velocity may be > 200 $cm.sec^{-1}$ at 20 m, but reduced to about 60 $cm.sec^{-1}$ at 40 m and 9 $cm.sec^{-1}$ at 80 m (Hiscock 1983).
Tidal streams	Moderately strong, Weak, Very weak Tidal streams flow to and fro with the tidal cycle, and they do not attenuate with depth as rapidly as does wave action. The presence or absence of water movement will alters the balance of competition between species, which might be otherwise able to survive across a wide range of exposure. The end result is that there are very different circalittoral biotopes in different conditions of current exposure. The distribution of species results from a balance between their ability to withstand vigorous water movement, and their need for water flow to assist their feeding processes.
Substratum	Bedrock; stable boulders and cobbles Surface texture, erosion and rock hardness are factors of obvious relevance to circalittoral communities. Substratum stability is determined by whether it is comprised of bedrock, or of loose boulders or stones. The mobility of boulders and stones will be a function of wave exposure, and mobility of the substratum will selectively impact faunal turf species. Marked differences between the communities of bedrock and adjacent loose rocks have been recorded (Knight-Jones & Jones 1955). Mobile substrata under exposed conditions have a community characterised by serpulid worms, barnacles and bryozoan crusts (Howson 1988; Bunker & Hiscock 1987; Dipper 1983; Mitchell, Earll & Dipper 1983, Hiscock 1981) rather than by the larger more delicate species which feature on the adjacent bedrock.
Depth band	5-30 m
Zone	Circalittoral
Temperature	Localised short-term fluctuations in seawater temperature, resulting from heat loss or gain to the air or the substratum, can occur in the shallow surface layer in inshore water. Circalittoral faunal turf communities are largely insulated from such transient influences by their depth and in many cases also by their prevalence in high-energy systems.
Light	Light is the environmental factor which determines the depth distribution of the circalittoral – the decrease of light with depth defines the upper limit of the zone. In areas where enough incident light reaches the seabed rocky habitats the community tends to be dominated by large macroalgae in what is defined as the infralittoral zone. When light levels decline with depth there is a progressive shift to faunal-dominated communities. Areas of the infralittoral dominated by animal biotopes occur as a result of steep slopes, intense grazing, and sometimes extreme physical conditions (such as surge gullies), however they are very much the exception.
Slope	The slope of the rock influences faunal turf communities as it affects the amount of incident light, and consequently the abundance of algal growth.
Water quality	Transparency and water clarity are affected by dissolved material and suspended particles in the water, and are important because they influence the penetration of light.

Species composition and biodiversity

For MCR in the UK	% Frequency	Faithfulness	Typical abundance
Phakellia ventilabrum	•	••	Frequent
Phakellia vermiculata	•	••	Occasional
Ciocalypta penicillus	•	•••	Occasional
Nemertesia antennina	•••	••	Occasional
Hydrallmania falcata	••	••	Occasional
Sertularia argentea	••	••	Occasional

Sertularia cupressina	•	•••	Occasional
Alcyonium digitatum	••••	•	Occasional
Swiftia pallida	•	••	Frequent
Eunicella verrucosa	•	•••	Occasional
Urticina felina	•••	•	Occasional
Caryophyllia smithii	••	••	Frequent
Sabellaria spinulosa	•	••	Frequent
Pomatoceros triqueter	•••	•	Frequent
Pagurus bernhardus	••	•	Occasional
Cancer pagurus	••	••	Occasional
Calliostoma zizyphinum	••	•	Occasional
Modiolus modiolus	•	•	Occasional
Alcyonidium diaphanum	••	••	Occasional
Pentapora foliacea	•	•••	Occasional
Crossaster papposus	••	••	Rare
Asterias rubens	••••	•	Occasional
Ophiothrix fragilis	•••	•	Frequent
Echinus esculentus	•••	•	Occasional
Clavelina lepadiformis	••	••	Occasional
Polyclinum aurantium	•	••	Frequent
Molgula manhattensis	•	••	Occasional
Corallinaceae indet. (Crusts)	••	•	Frequent

Ecological relationships

Environmental factors determine which circalittoral rock species can inhabit a given location and this will depend on the biological characteristics of each species – such as size, habit, feeding method and reproductive mode. However, not every species occurs throughout its potential range – its realised distribution is moderated by biological interactions such as competition, grazing and predation. Circalittoral communities have been poorly studied in respect to biological interactions because in order to determine the real role of species in a community experimental manipulation in the field is required. This has been carried out extensively in the intertidal and infralittoral but rarely in the circalittoral owing to the logistics of working at such depths.

Habitat complexity

Circalittoral rock provides a firm attachment in areas of moderate wave action or tidal currents such that the sessile habit of many species may be advantageous. Firm attachment will prevent the species from being swept away to what might be unfavourable conditions, and will prevent them from being damaged by impact on rocks. Under conditions of moderate exposure the taller erect forms such as sea fans, soft corals and the like are prominent. These species still tolerate considerable exposure though they have a tough yet flexible structure, which enables them to withstand turbulence and strong currents without damage and also allows individuals to maximise food intake.

Recruitment processes

Whilst most moderately exposed circalittoral rock species spend their larval life in the plankton, there are a few planktonic species which spend their early stages within the circalittoral rock biotopes. This is true, in rather different degrees, of the hydroids and the jellyfish. Hydroids are common and conspicuous members of circalittoral rock biotopes, but the attached hydroids are only the juvenile stages. The sexually reproducing mature stages are small medusae, which are released into the plankton, where they produce larvae, which settle again. In contrast, for jellyfish the large adult medusae in the plankton are the prominent phase. The juvenile stages live attached to rocks as an inconspicuous scyphistoma stage in which the jellyfish overwinters. In spring this buds off a series of juvenile medusae, or ephyrae, which grow rapidly in the plankton to form the adult.

Productivity

Although not primary producer's circalittoral rock communities are important secondary producers. They accumulate and concentrate the primary production from a large water mass, and make this readily available to higher trophic levels.

Keystone (structuring) species

Circalittoral rock biotopes in moderately exposed conditions typically are not dominated by single species, but support a diverse mosaic of species. The biotopes where single species dominate (e.g. *Modiolus*, *Sabellaria* and brittlestars) are described separately.

Importance of habitat for other species

Circalittoral rock communities interact with others by the provision of food and /or temporary shelter to mobile species which are not permanent faunal turf fauna. Shelter is important to juvenile fish, which can find refuge (and food) amongst the dense turf of sessile species. A food source is provided to large mobile crustaceans and fish, which are attracted by the rich and stationary food supply available on circalittoral rock.

Temporal changes

One of the features of circalittoral faunal turf communities is their fine-scale spatial variation, which tends to be very patchy. Whilst the infralittoral tends to be more predictable, circalittoral rock tends to be a mosaic of different species patches such mosaicing is particularly pronounced in moderately exposed circalittoral communities compared with exposed and sheltered communities. The different assemblages may represent 'alternate stable states' (Sutherland 1974; Sebens 1985a, b). In most of these biotopes substratum space is very fully occupied and the availability of space is a controlling resource for the settlement and growth of species. According to when free space is made available, and on which species are recruiting at that time, different assemblages of species may develop under the same physio-chemical conditions. Once established, often following a successional sequence (Hextall 1994), these assemblages are stable for long periods and different assemblages may co-exist in close proximity.

Time for community to reach maturity

Information is restricted, but it is clear that a number of the more prominent members of the circalittoral rock communities are relatively long lived, and fairly slow growing, some with life spans ranging from 6-100 years. The soft coral *Alcyonium digitatum* is a very prominent member of the circalittoral rock community and observations have shown that colonies of 10-15cm in height are between five and ten years old (Hartnoll unpubl.).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Fishing: benthic trawling	Low	Although towed gear may not directly cross circalittoral faunal turf biotopes (see above), the activities of dredging and trawling on nearby level bottoms with softer sediments could have effects on neighbouring communities. Towed gear results in the suspension of fine sediment (Jones 1992), which can affect the efficiency of filter feeding (Sherk 1971; Morton 1977). Conversely suspended sediment is vital for some species. *Sabellaria spinulosa* requires suspended sand grains in order to form its tubes and will therefore only occur in very turbid areas where sand is placed in suspension by water movement.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Low	Untreated oil is not a risk to circalittoral communities as it is concentrated mainly at the surface. If oil is treated by dispersant the resulting emulsion will penetrate the water column, especially under the influence of turbulence.
Changes in nutrient levels	Waste: sewage discharge	Low	Moderately exposed circalittoral rock biotopes occur in open coast situations, usually in or close to waters of considerable depth. They are therefore not generally near sources of discharge of organic pollutants and even if they were they would be considered as *Higher Natural Dispersion Areas*, and therefore apparently at little risk. The primary effect of eutrophication is to stimulate algal growth, both of benthic macroalgae and microscopic phytoplankton. Since by definition circalittoral faunal turf communities are essentially animal dominated, the effects of eutrophication will be indirect. Changes in the phytoplankton are more likely to produce impacts. Increased phytoplankton densities will change the food supply for the predominantly filter-feeding communities. Blooms of toxic algae may affect survival of circalittoral rock communities, perhaps particularly in their planktonic larval stages.
Abrasion	Fishing: benthic trawling	Intermediate	Towed gear is potentially the most destructive impact, and has been the subject of the most intensive study (MacDonald *et al.* 1996). However, most circalittoral rock biotopes will not generally be threatened since the generally steep and rocky substrata are unsuitable for both trawls and dredges. However there are types of towed gear designed for rocky areas – the rockhopper otter trawl, and the Newhaven scallop dredge and these could pose a risk to circalittoral rock communities on gently-sloping or level rock.
	Fishing: potting/creeling	Low	Static gear is deployed regularly on rocky grounds, either in the form of pots or creels, or as bottom set gill or trammel nets. Whilst the potential for damage is lower per unit deployment compared to towed gear, there is a risk of cumulative damage to sensitive species if use is intensive. Damage could be caused during the setting of pots or nets and their associated ground lines and anchors, and by their movement over the bottom during rough weather and during recovery.
	Fishing: angling	Low	Rod and line angling is the least likely activity to produce incidental damage from the fishing itself – the main risk is damage from the anchoring of the angling boats. Frequent anchoring in areas which often experience strong tidal flow is an obvious problem.
Removal of non-target species	Fishing: potting/creeling	Low	The traditional harvesting activity in circalittoral areas has been for crabs, lobsters and crayfish by potting and by bottom-set tangle or gill nets. The latter also target. fish as a by-catch. The obvious effect is the reduction in numbers of the target species, which are an important component of these communities. The reduction in these large predatory species will also have effects on the rest of the community, but these have not been evaluated in British waters. Diving may also damage circalittoral rock communities by the collection of animals either for food, or as souvenirs

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in area or extent
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* and *Submerged or partially submerged sea caves*. May also occur in *Large Shallow Inlets* and *bays* and more rarely in *Estuaries.*
UK Biodiversity Action Plan	None

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Sabellaria spinulosa reefs

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Holt *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.6/B-MCR.Csab	*Sabellaria spinulosa* communities on circalittoral rock
	A4.4/B-CMX.SspiMx	*Sabellaria spinulosa* and *Polydora* spp. on stable circalittoral mixed sediment.
Wadden Sea	03.02.09	Sublittoral *Sabellaria* reef
Britain/Ireland (MNCR BioMar 97.06)	MCR.CSab	Circalittoral *Sabellaria* reefs
	CMX.SspiMx	*Sabellaria spinulosa* and *Polydora* spp. on stable circalittoral mixed sediment
France (ZNIEFF-MER)	III.3.3.1	Faciès à *Sabellaria spinulosa*
	III.5.1.1	Faciès d'épifaune à *Sabellaria spinulosa*

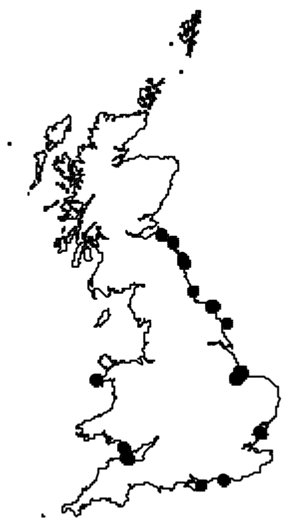
Description

CSab. Circalittoral rock or mixed substrata dominated by a crust of *Sabellaria spinulosa*.

SspiMx. The tube-building polychaete *Sabellaria spinulosa* at high abundances on mixed sediment, with *Polydora* spp. tubes attached. Infauna comprise typical sublittoral polychaete species, together with the bivalves *Abra alba* and *Nucula nitidosa*. Epifauna comprise calcareous tubeworms, pycnogonids, hermit crabs and amphipods.

GB distribution

(from MNCR database March 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full
Wave exposure	Moderately exposed
Tidal streams	Moderately strong, Weak
Substratum	Bedrock; boulders, cobbles, mixed substrata; mixed sediment *Sabellaria spinulosa* reefs or crusts will form on hard substratum but this does not preclude their formation from other substrata (Hiscock 1991). Rees & Dare (1993) describe habitat preference as being typically on shell (especially oyster valves), sandy gravel or rocky substrates with moderate tidal flow. Larsonneur (1994) reported *Sabellaria spinulosa*-dominated communities present on rock/pebble bottoms in the Bay of Mont St. Michael. It is likely that stability of the reefs is to some degree a function of the stability of the substratum. The more transient crusts probably occur principally on relatively unstable substrata, while longer-lasting reefs could be limited to more stable substrata.
Zone	Circalittoral
Depth range	10-30 m (CSab); 30->50 m (SspiMx) Dense reefs reported in the Bristol Channel were found at a depth of 41m (George & Warwick 1985), while recently discovered reefs off the north Norfolk coast were found at 15-25 m (Foster-Smith *et al*, in prep. February 1998).
Temperature	Specific information on temperature tolerance for this species is not available. However, its widespread distribution, from at least north of the Shetlands to the Mediterranean Sea, together with its predominantly subtidal habitat means that *Sabellaria spinulosa* is likely to be much less sensitive to temperature changes than the intertidal *Sabellaria alveolata*, which has been shown to be severely affected by low winter temperatures. Crisp (1964) found that *Sabellaria spinulosa* was less affected by the cold winter of 1963 than *Sabellaria alveolata*, which experienced many mortalities.
Water quality	*Sabellaria spinulosa* requires suspended sand grains in order to form its tubes; reef communities therefore only occur in very turbid areas where sand is placed into suspension by water movement. The relative importance of tidal versus wave-induced movements is unclear. Studies in relation to sewage and other pollution suggest this species is not particularly sensitive to changes in water quality. However, this may not be the case for associated biota.

Species composition and biodiversity

Characterising species

For CSab in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Scypha ciliata	••••	•	Rare
Halichondria panicea	••	•	Frequent
Tubularia indivisa	•••	••	Occasional
Alcyonium digitatum	••	•	Frequent
Urticina felina	••••	•	Occasional
Sabellaria spinulosa	•••••	••	Super abundant
Pomatoceros triqueter	••	•	Frequent
Balanus balanus	•••	••	Occasional
Cancer pagurus	•••	•	Occasional
Gibbula cineraria	•••	•	Occasional
Pododesmus patelliformis	••	•	Frequent
Securiflustra securifrons	••	••	Frequent
Crossaster papposus	•••	•	Rare
Henricia sp.	•••••	•	Occasional
Asterias rubens	•••••	•	Occasional

Ophiothrix fragilis	••••	•	Occasional
Ophiopholis aculeata	••	••	Occasional
Echinus esculentus	•••	•	Occasional
Corallinaceae indet. (crusts)	••	•	Occasional

For SspiMx in the UK	***% Frequency***	***Faithfulness***	***Typical abundance***
Tubulanus sp.	••••	•	Common
Polynoidae indet.	•••••	•	Frequent
Pholoe sp.	•••••	•	Common
Phyllodocidae sp.	••••	•	Abundant
Eteone sp.	••••	•	Frequent
Glycera sp.	•••••	•	Common
Glycinde nordmanni	•••••	•	Common
Syllis sp.	••••	•	Frequent
Exogone naidina	••••	•	Frequent
Exogone verugera	•••••	•	Frequent
Nephtys sp.	•••••	•	Common
Lumbrineris gracilis	•••••	•	Common
Prionospio sp.	•••••	•	Common
Spiophanes bombyx	•••••	•	Frequent
Cirratulidae indet.	•••••	•	Common
Mediomastus fragilis	•••••	•	Frequent
Scalibregma inflatum	•••••	•	Common
Sabellaria spinulosa	•••••	•	Common
Ampharetidae indet.	•••••	•	Common
Ampelisca sp.	•••••	•	Present/Not known
Abra alba	•••••	•	Common
Sphenia binghami	•••••	•	Common
Ophiura sp.	•••••	•	Abundant

Ecological relationships

Habitat complexity

The thicker, and probably more permanent, crusts or reefs seem to have a considerable influence on the benthic community structure. George & Warwick (1985) mentioned that *Sabellaria* reefs contained a more diverse fauna than nearby areas. The National Rivers Authority (1984) found sites in the Wash (eastern England) associated with *Sabellaria spinulosa* to have more than twice as many species and almost three times as many individuals as sites with very few, or no *Sabellaria spinulosa*.

Recruitment processes

Experimental laboratory work by Wilson (1970) showed the *Sabellaria spinulosa* larvae are strongly stimulated to metamorphose and settle by cement secretions of adult or newly settled young *Sabellaria spinulosa*. In the absence of suitable stimulation metamorphosis and settlement sometimes occurs but always more slowly. George & Warwick (1985) suggested that growth and recruitment of *Sabellaria spinulosa* could be inhibited or even prevented by dense populations of the brittle star *Ophiothrix fragilis*, which occur at very high densities, thus preventing adequate food particles from reaching the worms.

Keystone (structuring) species

Sabellaria spinulosa

Importance of habitat for other species

Warren & Sheldon (1967) and Warren (1973) reported that *Sabellaria spinulosa*, probably along with other associated organisms, could be an important food source for pink shrimp *Panadalus montagui.*

Temporal changes

Sabellaria spinulosa is a fast-growing annual, as sheets up to 2.4 cm thick can develop within one growing season. These are definitely seasonal in abundance. Areas where *Sabellaria spinulosa* had been lost due to winter storms appeared to recolonise up to the maximum observed 2.4 cm thickness during the following summer (R. Holt pers comm). George & Warwick (1985) also made seasonal observations in the Bristol Channel and concluded that in the year of the study the settlement of juveniles was low and that the density of adults could not be maintained by the degree of recruitment.

Time for community to reach maturity

George & Warwick (1985) found that the majority of the reef was composed of *Sabellaria spinulosa* over one year old. They also mentioned that most of the species found within the reef matrix are slow growing and long lived with very low turnover rate, suggesting that the reef itself must be relatively old and stable.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Extraction: sand/gravel (aggregate dredging)	Low	The likelihood of damage due to sediment plumes in areas adjacent to gravel extraction is unclear, as there is no knowledge of the effects of differing particle size upon *Sabellaria* . However, it would be surprising if damage was other than very localised given *Sabellaria's* preference for turbid waters.
Changes in temperature	Climate change/global warming	Low	Owing to the sublittoral habitat occupied by *Sabellaria spinulosa* it is not very sensitive to temperature change.
Synthetic compound contamination	Waste: industrial effluent discharge	Low	Hoare & Hiscock (1974) investigated the distribution of marine organisms around the outfall from a bromide extraction plant in North Wales. The effluent has a pH of 4 and contained free halogens. Species richness and diversity was markedly reduced within 150 m of the outfall, but *Sabellaria* was found closer to the outfall than any other organism.
Changes in nutrient levels	Waste: sewage discharge	Not sensitive*	Walker & Rees (1980) reported that in the discharge area and down tide of the area *Sabellaria spinulosa* was present in greater densities and diversities than elsewhere in the bay.
Abrasion	Fishing: benthic trawling	High	Berhahn & Vorberg (1993) have suggested that *Sabellaria spinulosa* is a good indicator of fishing intensity in the Wadden Sea. Subtidal *Sabellaria* reefs are reported to have been lost due to physical damage in at least five areas. In the Wadden Sea, Reisen & Reise (1982) reported that extensive subtidal *Sabellaria spinulosa* reefs were lost from Lister Ley, island of

			Sylt, between 1924 and 1982. They attributed the losses to destruction by "heavy gear" as populations were in the way of shrimp trawling. Reise & Schubert (19870 reported similar losses from Norderau area, and attributed them to similar causes. Trawling still occurs in these areas and as a result Sabellaria has been replaced by Mytilus edulis and sand-dwelling amphipods in these areas (Reise & Schubert 1987). Populations have also been destroyed in Morecambe Bay (England) (Taylor 1993: Mistakidis 1956)
	Extraction: sand/gravel (aggregate dredging)	High	In the short term *Sabellaria spinulosa* reefs would be severely damaged by extensive aggregate dredging activities. The speed of recovery from such damage is currently unknown. Compared to fishing impacts, gravel extraction is likely to be more limited in extent, more controlled, and less likely to continue for very long periods of time. So although direct damage would obviously be severe, recovery from adjacent undamaged areas seems more likely.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not known
Wadden Sea	Threatened by complete destruction
UK	Significantly declined in extent and quality
Other sub-regions	Not known

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* and may also occur within *Estuaries* and *Large shallow inlets and bays*.
UK Biodiversity Action Plan	*Sabellaria spinulosa* reefs (Habitat Action Plan)

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Modiolus modiolus beds

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Holt *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov 1999)	A3.6/B-MCR.M.ModT A3.7/B-SCR.Mod A4.4/B-CMX.ModMx	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata Sheltered *Modiolus* beds *Modiolus modiolus* beds on circalittoral mixed sediment
Wadden Sea	-	Not listed/present
Britain/Ireland (MNCR BioMar 97.06)	SCR.Mod MCR.ModT CMX.ModMx	Sheltered *Modiolus* (horse-mussel) beds *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata *Modiolus modiolus* beds on circalittoral mixed sediment
France (ZNIEFF-MER)	III.6.1.2	Faciès à *Modiolus modiolus*

Description

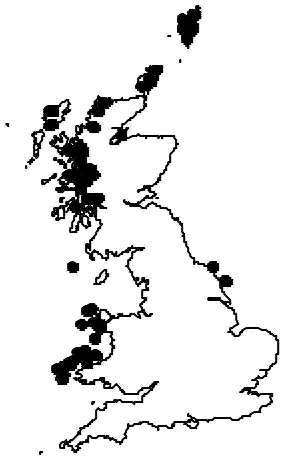
SCR.Mod. Circalittoral mixed substrata, not influenced by significant tidal streams, with clumps or more extensive beds of *Modiolus modiolus.*

MCR.ModT. *Modiolus* beds on mixed substrata (cobbles, pebbles and coarse muddy sediments) in moderately strong currents, typically on the open coast but also in tide-swept channels of marine inlets. Often with sponges such as *Hemimycale columella*, hydroids such as *Sertularia argentea*, *Hydrallmania* and *Abietinaria abietina*, *Alcyonium digitatum*, barnacles, *Alcyonium digitatum*, bryozoans such as *Alcyonidium mytili* and ascidians *Dendrodoa grossularia*. This biotope is typified by examples off the north-west Lleyn Peninsula in North Wales and off Co. Down, Northern Ireland.

CMX.ModMx. Muddy gravels and coarse sands in deeper water of continental seas may contain venerid bivalves with beds of *Modiolus modiolus*. The clumping of the byssus threads of the *M. modiolus* creates a stable habitat that attracts a very rich infaunal community. Brittlestars such as *Ophiothrix fragilis* may also occur with this community. This biotope is very similar to the 'boreal off-shore gravel association' and the 'deep *Venus* community' described by previous workers (Ford 1923; Jones 1951). Similar *Modiolus* beds on open coast stable boulders, cobbles and sediment are described under MCR.ModT.

GB distribution

(from MNCR database March 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full Dense populations of very young *Modiolus modiolus* do occasionally occur subtidally in estuaries, although the species is more poorly adapted to fluctuating salinity than other mussel species (Bayne 1976). Dense populations of adults are not found in low salinity conditions. Pierce (1970) established tolerance limits of 27 – 41 ‰ for *Modiolus modiolus* based on ventilation behaviour and byssus formation.
Wave exposure	Moderately exposed (MCR.ModT & CMX.ModMx), Sheltered, very sheltered (SCR.Mod)
Tidal streams	Strong (MCR.ModT), Moderately strong (MCR.ModT & CMX.ModMx), Weak (SCR.Mod), Very weak (SCR.Mod)
Substratum	Mixed substrata (SCR.Mod), Cobbles, pebbles and *Modiolus* shells (MCR.ModT), Muddy gravel and sand, with shells and stones (CMX.ModMx)
Zone	Infralittoral – lower (MCR.ModT), Circalittoral (all)
Depth range	10-20 m (SCR.Mod), 20- >50 m (CMX.ModMx) Coleman (1973) demonstrated that *Modiolus modiolus* exposed to air has an erratic heart rate, suggesting a lack of physiological adaptation to ariel exposure, and that it loses water rapidly due to an apparent inability to control its gape effectively. Dense populations therefore seem restricted to around 5 – 50 m in British waters, although bioherms have been recorded in over 80m in Nova Scotia (Wildish & Fader, in press). Lack of mobility, thin shell and restricted tolerance to changes in temperature and salinity has been suggested as reasons for the poor ability of *Modiolus* to colonise the intertidal (Davenport & Kjorsvik 1982).
Temperature	*Modiolus modiolus* is clearly a northern species, and the fact that dense aggregations seem to reach their southerly limit around British coasts suggests a possible susceptibility to a long-term rise in summer water temperatures. There is little published information on the temperature tolerance of *Modiolus*, although it is clear that it has a lower upper thermal limit than *Mytilus edulis* (Bayne 1976). Being subtidal it is protected from major short-term fluctuations. It has been suggested that an inability to tolerate temperature changes is one of the factors which prevents *Modiolus* from colonising the intertidal to any extent (Davenport & Kjorsvik 1982). Low winter water temperatures would not pose any threat to *Modiolus modiolus* populations around Britain.
Water quality	*Modiolus modiolus* has been found in a variety of turbid and clear water conditions.
Nutrients	Work in Newfoundland has demonstrated that *Modiolus modiolus* is capable of tolerating intermittent availability of food supplies, reducing feeding activity during periods of low phytoplankton (autumn and winter) and increasing clearance rate during spring and early summer (Navarro & Thompson 1996).

Species composition and biodiversity

Characterising species

For SCR.Mod in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Terebellidae indet.	•••	•	Occasional
Pomatoceros triqueter	••••	•	Frequent
Serpula vermicularis	••	••	Occasional
Protula tubularia	••	••	Occasional
Pagurus bernhardus	••••	•	Occasional
Munida rugosa	•••	••	Frequent
Hyas araneus	•••	••	Occasional
Liocarcinus depurator	•••	••	Occasional
Carcinus maenas	•••	•	Occasional
Buccinum undatum	••••	••	Occasional
Modiolus modiolus	•••••	••	Frequent
Aequipecten opercularis	•••	••	Frequent
Crossaster papposus	•••	•	Rare
Asterias rubens	••••	•	Occasional
Ophiothrix fragilis	••••	•	Frequent
Echinus esculentus	••••	•	Occasional
Ascidiella aspersa	•••	•	Occasional

For MCR.ModT in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Sertularia argentea	•••	••	Frequent
Alcyonium digitatum	•••	•	Frequent
Pomatoceros triqueter	•••	•	Frequent
Balanus crenatus	•••	•	Common
Pagurus bernhardus	•••	•	Occasional
Hyas araneus	•••	••	Frequent
Buccinum undatum	•••	•	Occasional
Modiolus modiolus	••••	••	Abundant
Electra pilosa	•••	•	Frequent
Asterias rubens	••••	•	Occasional
Ophiothrix fragilis	•••	•	Occasional
Corallinaceae indet. (crusts)	•••	•	Frequent
Phycodrys rubens	•••	•	Common

For CMX.ModMx in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Nemertea indet.	••••		Common
Golfingia sp.	•••		Frequent
Harmothoe sp.	••••		Common
Pholoe sp.	••••		Common
Pseudomystides limbata	•••		Present

Protomystides bidentata	●●●●	Common
Eumida sanguinea	●●●	Abundant
Nereiphylla lutea	●●●●	Abundant
Glycera lapidum	●●●●	Common
Syllis sp.	●●●●	Frequent
Eusyllis blomstrandi	●●●	Frequent
Syllides sp.	●●●	Present
Exogone hebes	●●●●	Frequent
Exogone naidina	●●●	Present
Exogone verugera	●●●●	Frequent
Sphaerosyllis sp.	●●●●	Frequent
Sphaerosyllis bulbosa	●●●	Frequent
Sphaerosyllis tetralix	●●●	Frequent
Autolytus sp.	●●●	Present
Nematonereis unicornis	●●●	Common
Lumbrineris gracilis	●●●●●	Common
Paradoneis lyra	●●●●	Common
Aonides paucibranchiata	●●●●	Common
Laonice bahusiensis	●●●●	Common
Polydora caeca sp.	●●●●	Common
Polydora caulleryi	●●●●	Frequent
Spiophanes kroyeri	●●●	Frequent
Caulleriella alata	●●●	Frequent
Mediomastus fragilis	●●●●	Common
Notomastus sp.	●●●●	Present
Clymenura johnstoni	●●●	Abundant
Praxillella affinis	●●●●	Common
Asclerocheilus	●●●	Frequent
Scalibregma inflatum	●●●	Common
Owenia fusiformis	●●●	Common
Sabellaria spinulosa	●●●●	Common
Ampharete sp.	●●●	Common
Lanice conchilega	●●●	Present
Lysilla sp.	●●●	Abundant
Polycirrus sp.	●●●●	Common
Hydroides norvegica	●●●●	Frequent
Grania sp.	●●●●	Common
Ampelisca spinipes	●●●	Frequent
Gammaropsis cornuta	●●●	Frequent
Leptochiton asellus	●●●●	Common
Modiolus modiolus	●●●●●	Abundant
Mysella bidentata	●●●	Frequent
Spisula elliptica	●●●	Common

Abra alba	•••	Common
Timoclea ovata	••••	Common
Hiatella arctica	••••	Abundant
Ophiuroidea indet.	•••	Abundant
Amphipholis squamata	•••	Abundant

Ecological relationships

Modiolus has a strong structuring influence on the sediments in which reef areas usually occur. The communities associated with *Modiolus* are known generally to be extremely rich and diverse. There are clearly variations in composition of associated species. Sponges, ascidians, *Alcyonium digitatum*, *Chlamys varia* , *Aequipecten opercularis*, hydroids and *Ophiothrix fragilis* are all very abundant in some, but not all, *Modiolus* communities. Urchins, starfish and whelks are numerous on most.

Habitat complexity

Apart from the infauna, the *Modiolus* community in Strangford Lough (Northern Ireland) has been described as consisting of mainly three components (Magorrian *et al.* 1995): Very dense aggregations of living and dead *Modiolus* shells which form the framework in single or multiple layers; a rich community of free living and sessile epifauna and predators; a rich and diverse community which seeks shelter in the crevices between the *Modiolus* shells and byssus threads and flourishes on its rich sediment. In the Gulf of Maine it has been found that the diversity of other benthic species increased as *Modiolus* clump size and number increased (Ojeda & Dearborn 1989). From limited data plus subjective observations it seems likely that this would be the case in British waters and moreover that the reef areas would have a more diverse fauna than non-reef areas.

Recruitment processes

The possible role of *Modiolus* reef communities in providing a nursery refuge for other species has not been investigated. Dense growths of bushy hydroids and bryozoans could conceivably provide an important settling area for spats of bivalves such as *Pecten maximus* and *Aequipecten opercularis*, adults of which are often abundant in nearby areas. Established *Modiolus* beds are also very important for the recruitment of juveniles as it is suspected that their survival is greatly enhanced by settling within the mass of adults byssus threads where predators cannot easily attack them.

Keystone (structuring) species

Modiolus modiolus

Importance of habitat for other species

Predators are significant mainly in young *Modiolus*. In the early years predation is probably largely by crabs and starfish, which are very numerous. In shallower areas red seaweeds such as *Phycodrys rubens* and corallines may be present on *Modiolus* beds. Holt & Shalla (unpublished) found several species of fish on the *Modiolus* reef areas to the north-east of the Isle of Man.

Temporal changes

There are very few temporal changes as *Modiolus* beds are slow-growing ,long-lived and static communities.

Time for community to reach maturity

Rates of development of reefs are not known. There would appear to be some potential for spread of existing bioherms where these take the form of very dense raised beds, as off the Lleyn Peninsula, Wales as a result of clumps of mussels dropping off from the edges, which are often quite discrete. This would undoubtedly be a very slow process taking probably many years per meter of spread. Spread or recovery of more infaunal types of reefs would presumably be slower still, although this is purely speculative. Individual mussels are long lived with ages up to 35 years occasionally being reported. Ages in excess of 25 years are very frequent with maximum ages likely to be well in excess of 50 years (Anwar *et al.* 1990).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Waste: spoil dumping	Intermediate	Deposition of capital dredging such as barge loads of boulder clay which will initially settle as a mass, will almost certainly smother the patch it lands on. From such spoil mounds the material usually disperses, but there are no case histories to indicate rates of sediment accretion that *Modiolus* clumps can keep up with. In a *Modiolus* bed off the Humber long-term changes in contaminant loads associated with spoil disposal were detectable in the shells of *Modiolus modiolus*. While this indicates survival of the mussels within a dispersal zone around the disposal ground, information on the loss of condition is not available.
Changes in temperature	Climate change/global warming	Intermediate	*Modiolus modiolus* is a northern species, and the fact that dense aggregations seem to reach their southerly limit around British shores suggests a possible susceptibility to a long-term rise in summer water temperatures.
Hydrocarbon contamination	Uses:boats/ shipping (oil spills)	Intermediate	As *Modiolus modiolus* are filter feeders, depending on suspended particles in the water column for food, they tend to be very sensitive to oil pollution (Dethlefsen, 1978). Lees & Driskell (1981) suggested that suspension feeders such as *Modiolus* would be highly sensitive to the effects of an acute spill.
Abrasion	Fishing: benthic trawling	High	Scallop and queen scallop dredging has been implicated in the dramatic reduction in density and extent of the widespread and often dense areas of *Modiolus* bed, which was described by Jones (1951) off the south east of the Isle of Man. Magorrian *et al.* (1995) observed damage to *Modiolus* clumps in Strangford Lough owing to queen scallop trawling. The scallops and queens are fished using heavy metal dredges, usually with large prominent metal teeth along the leading edge. This fishery practice has also been found to damage many of the epibenthic species found in association with *Modiolus* beds. (Hill *et al.* 1997). It is unlikely that scallop or queen fishing would be very viable over very dense reef areas, and it has therefore been assumed that many years of fishing on adjacent areas have to some extent damaged the edges of the denser beds.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Significantly declined in extent
	Not significantly declined in quality (where still present)
Other sub-regions	Not known

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* and occurs within *Large shallow inlets and bays* and potentially also within *Estuaries*.
UK Biodiversity Action Plan	*Modiolus modiolus* beds Habitat Action Plan

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Subtidal brittlestar beds

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Hughes, D.J. 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.6/B-MCR.Bri	Brittlestar beds on circalittoral rock or mixed substrata
Wadden Sea	-	-
Britain/Ireland (MNCR BioMar 97.06)	MCR.Bri	Brittlestar beds
France (ZNIEFF-MER)	III.6.1.1	Faciès à *Ophiothrix fragilis*

Description

Circalittoral rock or mixed substrata dominated by dense beds of brittlestars. *Ophiothrix fragilis* or *Ophiocomina nigra* may dominate separately or there may be mixed populations of the two species. More rarely *Ophiopholis aculeata* may form dense aggregations (MCR.Oph.Oacu). The brittlestars tend to have a smothering effect on the rock, significantly reducing species diversity and biomass when they are very dense. The brittlestars are mobile and so some areas may appear highly grazed (MCR.GzFa) if they previously had brittlestar populations on them.

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full. Most brittlestars beds exist in fully marine conditions. However, in the Dutch Oosterschelde Estuary, dense *Ophiothrix* aggregations have been recorded in areas where normal salinity is

	only 16.5‰ (Wolff 1968).
Wave exposure	Moderately exposed, Sheltered.
	Beds are usually sheltered from strong wave action, but examples in moderately exposed situations are known (Ball *et al.* 1995).
Tidal streams	Moderately strong, Weak.
	Brittlestar beds can be found in a variety of current regimes. Many sealochs examples experience only weak tidal streams, but on more open coastlines brittlestar beds are generally associated with higher-energy environments. In the Dover Strait, *Ophiothrix* beds experience current speeds of up to 1.5m s^{-1} during average spring tides (Davoult & Gounin 1995b). Similarly strong tidal streams (1.0 – 1.2 m s^{-1}) were also recorded over beds in the Isle of Man (Brun 1969).
Substratum	Bedrock; boulders, cobbles, mixed substrata and sediments.
	Beds on cobbles, gravel and mixed coarse sediments are probably the most common, and these substrata will obviously predominate where strong currents are experienced. In the Bristol Channel, *Ophiothrix* was recorded at high density (up to 838m^{-2}) on reefs formed by tubes of the polychaete worm *Sabellaria spinulosa* (George & Warwick 1985). In Strangford Lough, dense *Ophiothrix* beds overly shells of the horse mussel *Modiolus modiolus* (Magorrian, Service & Clarke 1995).
Zone	Lower Infralittoral, Circalittoral
Depth range	10-30m.
	The upper and lower depth boundaries of beds may be very abrupt.
Temperature	Within the British Isles the distribution of brittlestars is not limited by temperature, although individual species such *as Ophiopholis aculeata* and *Ophiura robusta* do show a latitudinal distribution pattern. In the Oosterschelde Estuary, *Ophiothrix fragilis* was common in areas regularly experiencing winter temperatures down to 3^{o}C, but was eliminated when temperatures fell to 0^{o}C (Wolff 1968). Such extremes are only likely to be found in enclosed situations with very shallow water depths, and will not be experienced by the majority of open-coast brittlestar beds.
Water quality	High rates of sedimentation are probably unfavourable to brittlestar beds due to the fouling of the animals' feeding organs (tube feet and arm spines), and in extreme cases suffocation (Aronson 1992). Beds in current-swept situations will not experience this problem, but it may be a factor in limiting the distribution of beds in semi-enclosed areas such as sealochs.

Species composition and biodiversity

Characterising species

For MCR.Bri in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Alcyonium digitatum	•••	•	Occasional
Pomatoceros triqueter	•••	•	Frequent
Pagurus bernhardus	•••	•	Occasional
Gibbula cineraria	•••	•	Occasional
Crossaster papposus	•••	•	Rare
Asterias rubens	••••	•	Occasional
Ophiothrix fragilis	•••••	•	Common
Ophiocomina nigra	••••	••	Common
Ophiopholis aculeata	••	••	Frequent
Ophiura albida	•••	••	Frequent
Echinus esculentus	•••••	•	Frequent
Ciona intestinalis	•••	•	Occasional
Corallinaceae indet (crusts)	•••	•	Common

Ecological relationships

Aggregations of *Ophiothrix fragilis* result from the active association of animals with their conspecifics (i.e. true social behaviour is displayed), rather than simply from the individual responses of the brittlestars to features of their physical environment. *Ophiocomina nigra* is less tolerant than *Ophiothrix fragilis* of close contact with conspecifics. Individuals of this species often show a dispersed, non-random spatial distribution, this pattern only breaking down at very high local population densities. Individuals of *Ophiocomina nigra* will maintain a dispersed distribution from each other even when mixed with much larger numbers of *Ophiothrix*.

Large mobile animals commonly found on *Ophiothrix* beds include the starfish *Asterias rubens*, *Crossaster papposus* and *Luidia ciliaris*, the urchins *Echinus esculentus and Psammechinus miliaris*, edible crabs *Cancer pagurus*, swimming crabs *Necora puber*, *Liocarcinus* spp., and hermit crabs *Pagurus bernhardus*. Brittlestar beds are not a major habitat for fish, although Warner (1971) recorded poor cod *Trisopterus minutus* shoaling over the beds in Torbay.

There is evidence to suggest that massive aggregations of suspension-feeding brittlestars can have a favourable effect on water quality in coastal environments and may even help counteract some of the potentially harmful effects of eutrophication.

Habitat complexity

Brittlestar beds may appear at first glance to support few animals besides the brittlestars themselves. Where dense *Ophiothrix* aggregations are found on bedrock surfaces they may monopolize the substratum, virtually to the exclusion of other epifauna (Ball *et al.* 1995). In comparison, beds on softer substrata may contain a rich associated fauna (Warner 1971; Allain 1974; Davoult & Gounin 1995). Allain (1974) provided a list of species found by various authors in brittlestar beds in the English Channel and Irish Sea. Large suspension-feeders such as dead man’s fingers *Alcyonium digitatum*, the anemone *Metridium senile* and the hydroid *Nemertesia antennina* are present mainly on rock outcrops or boulders protruding above the brittlestar-covered substratum. The large anemone *Urticina felina* may be quite common. This species lives half-buried in the substratum but is smothered by the brittlestars, usually being surrounded by a ‘halo’ of cleared space (Brun 1969; Warner 1971). *Utricina* will eat brittlestars, hence their avoidance of it.

Recruitment processes

Several species of large, mobile crustaceans and echinoderms can be found on brittlestar beds although it is unclear whether the juvenile forms of these animals make use of the habitat as a nursery area.

Productivity

Brittlestar beds represent major concentrations of benthic biomass and may play an important role in the functioning of their local ecosystems.

It is thought that dense *Ophiothrix* beds may play an important role in local nutrient cycles by filtration and concentration of suspended particulate matter, and by the excretion of nitrogenous waste.

Keystone (structuring) species

Ophiothrix fragilis, *Ophiocomina nigra*, *Ophiopholis aculeata*, *Luidia ciliaris*.

Importance of habitat for other species

Warner (1971) found the *Ophiothrix* was preyed upon by crabs, dragonets *Callionymus lyra* and plaice *Pleuronectes platessa*, but did not seem to be a major food item for any of them. The large starfish *Asterias rubens* and (especially) *Luidia ciliaris* are also brittlestar predators, and are usually actively avoided by them. A starfish moving through an *Ophiothrix* bed is preceded by a 'bow-wave' of brittlestars moving out of the way.

Brittlestars of the genus *Ophiura* are known to be a common prey for flatfish such as plaice (e.g. Downie 1990).

Temporal changes

In the Plymouth area, dense *Ophiothrix* beds were recorded at the turn of the century, but were apparently absent during the 1920s and 30s. Beds were recorded again from the early 1950s onwards, and persisted until the late 1960s. From about 1970 onwards, the extent and density of *Ophiothrix* populations declined rapidly and only scattered individuals were present by the end of the decade. The 1970s decline of *Ophiothrix* was associated with an increased abundance of the predatory starfish *Luidia ciliaris* in the Plymouth area. There are suggestions that the cyclic changes earlier in the century were also related to the abundance of *Luidia* (Holme 1984).

Time for community to reach maturity

Records from several areas suggest that brittlestar beds can persist for years or decades. The life span of *Ophiothrix* individuals is probably 2 – 8 years. *Ophiocomina nigra* grows slowly and lives for upto 14 years.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Waste: spoil dumping	Intermediate	Heavy sedimentation will inhibit bed occurrence by clogging the brittlestar feeding organs. Aronson (1989) refers to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively attributes this to increased sedimentation caused by the localised dumping of construction materials.
Changes in temperature	Climate change/global warming	High	Leewis, Waarenburg & van der Tol (1994) described fluctuations in the abundance of *Ophiothrix fragilis* in the Dutch Oosterschelde Estuary over the period 1979-90. These changes appeared to be driven by winter temperatures. Following the mild winters of 1979-80 and 1987-88, populations of brittlestars increased enormously, the animals occupying 60-90% of the available hard substrata in layers up to 5 cm deep. Populations were greatly reduced (to less than 10% spatial coverage) following cold winters in 1978-79, 1984-85 and 1985-86. The populations undergoing these changes were living in very shallow water (5-7 m depth) and were therefore vulnerable to spells of unusually cold weather.
Heavy metal contamination	Waste: industrial effluent discharge	Not sensitive	Gounin, Davoult & Richard (1995) studied the transfer of heavy metals (iron, manganese, lead, copper and cadmium) through *Ophiothrix* beds. They concluded that heavy metals ingested or absorbed by the animals transited rapidly through the body and were expelled in the faeces. The brittlestars did not appear to accumulate metals in the tissues and so would not act to decontaminate the near-bottom water mass.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Low	The water-accumulated fraction of diesel oil has been found to be acutely toxic to *Ophiothrix fragilis* and *Ophiocomina nigra* (Newton 1995). So far, however, there are no field observations of epifaunal brittlestar beds being damaged by any of these forms of pollution. It is logical to suppose that brittlestar beds would be adversely affected by major pollution incidents such as oil spills.
Changes in nutrient	Aquaculture: fin -fish	Low	The expansion of cage aquaculture of Atlantic salmon along the

levels			fiordic coastlines of western Scotland and Ireland over the past few decades has led to increased local inputs of organic material into many semi-enclosed water bodies (Black 1996). The effects of this on brittlestars have not been studied in detail, but some relevant observations have been made in Killary Harbour, western Ireland (Keegan & Mercer 1986). A dense aggregation of *Ophiothrix* and *Ophiocomina* was recorded in 1974 from a site at the mouth of the harbour, mainly on rocky outcrops but extending out onto adjacent sand silt areas. A salmon farm was established at the site in the late 1980s, within 100 m of the main beds. Despite the presence of this farm for ten years, the extent and density of the brittlestar beds appeared not to have changed (B. Ball pers. com.), although an increase in siltation had taken place.
Changes in oxygenation	Aquaculture: fin-fish	Intermediate	High levels of organic enrichment such as that expected from aquaculture waste would have deleterious effects on brittlestars and other suspension feeders by excessive sedimentation and hypoxia.
Displacement	Fishing: benthic trawling	Low	Brittlestars themselves are of no economic value, and their aggregations are not significant habitats for any commercially important fish or shellfish. Fishermen tend to avoid areas with dense brittlestar populations because the animals foul their nets (Aronson 1989). There is little likelihood of damage to brittlestar beds by fishing activities. In fact Aronson & Harms (1985) speculated that human overexploitation of fish resources could favour the spread of brittlestar aggregations by reducing predation pressure on the animals.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs* and also potentially within *Sandbanks covered by sea water at all times* and *Large shallow inlets and bays*
UK Biodiversity Action Plan	None

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Sheltered circalittoral rock

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Hartnoll 1998).

Classification

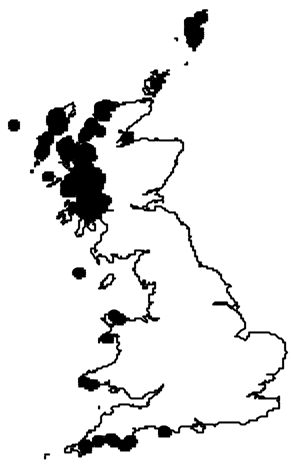
Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A3.7	Circalittoral rock sheltered from wave action & currents including tidal streams
Wadden Sea	-	-
Britain/Ireland (MNCR BioMar 97.06)	SCR	Sheltered circalittoral rock
France (ZNIEFF-MER)	IV.6	Part of Fonds durs : cailloutis, galets et roches.

Description

Circalittoral rock or mixed substrata, sheltered from wave action and from significant tidal currents. The still nature of the habitat is usually accompanied by silty conditions and the rock is often well grazed and dominated by encrusting algae (*Aglaozonia*, *Pseudolithoderma extensum*, coralline crusts). The larger solitary ascidians (*Ascidia* spp., *Ascidiella* spp., *Corella parallelogramma* and *Ciona intestinalis*) are prominent in many of the biotopes. The brachiopods *Neocrania anomala* and *Terebratulina retusa* are particularly characteristic of such sheltered rock.

GB Distribution

(from MNCR database March 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full , variable, reduced

	As a result of the depths at which they occur reduced salinity is rarely a significant factor. Nevertheless reduced salinities do occur in sealochs at depths in excess of 30m.
Wave exposure	Sheltered, Very sheltered
Tidal streams	Weak, Very weak
	Tidal streams flow to and fro with the tidal cycle, and they do not attenuate with depth as rapidly as does wave action. The presence or absence of water movement will alter the balance of competition between species which might be otherwise able to survive across a wide range of exposure. The end result is that there are very different circalittoral biotopes in different conditions of current exposure. The distribution of species will result from a balance between their ability to withstand vigorous water movement, and their need for water flow to assist their feeding processes. Sheltered areas tend to be dominated by ascidians and more delicate sponges.
Substratum	Bedrock; boulders and cobbles; mixed substrata
	Large boulders which are not regularly displaced will provide a variety of cryptic environments on their undersides.
Depth band	5-50 m +
Zone	Circalittoral
Temperature	Localised short-term fluctuations in seawater temperature, resulting from heat loss or gain to the air or the substratum, can occur in the shallow surface layer in inshore water. Circalittoral faunal turf communities are largely insulated from such transient influences by their depth. Seasonal shallow thermoclines may form, particularly in sheltered areas such as sealochs, and extend down to 15 m. Some animals such as the brachiopods *Neocrania* and *Terebratulina* seem restricted to below this thermocline (Hiscock 1985).
Light	Light is the environmental factor which basically determines the upper depth limit of the circalittoral – the decrease of light with depth defines the upper limit of the zone. In areas where enough incident light reaches the seabed the rock substratum community tends to be dominated by large macroalgae creating the infralittoral zone.
Water quality	Transparency and water clarity are affected by dissolved material and suspended particles in the water, and are important because they influence the penetration of light. Suspended material in the water can settle out of the water column, and can affect both the settlement and survival of circalittoral rock communities. This is usually only a problem in sheltered conditions where water movement is minimal.

Species composition and biodiversity

For SCR in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Bougainvillia ramosa	••	•••	Occasional
Protanthea simplex	••	•••	Frequent
Caryophyllia smithii	•••	•	Occasional
Pomatoceros triqueter	••••	•	Frequent
Protula tubularia	••	••	Occasional
Pagurus bernhardus	•••	•	Occasional
Munida rugosa	•••	••	Occasional
Neocrania anomala	•••	•••	Frequent
Terebratulina retusa	•	•••	Occasional
Asterias rubens	••••	•	Occasional
Ophiothrix fragilis	•••	•	Occasional
Echinus esculentus	••••	•	Occasional
Clavelina lepadiformis	•••	•	Occasional
Ciona intestinalis	••••	•	Occasional
Corella parallelogramma	•••	••	Occasional
Ascidiella aspersa	••	••	Frequent
Ascidia mentula	••••	•	Occasional

Ascidia virginea	•••	••	Occasional
Corallinaceae indet.	•••	•	Common
Pseudolithoderma extensum	•	•••	Common
Aglaozonia (asexual *Cutleria*)	•	••	Frequent

Ecological relationships

Environmental factors determine which circalittoral rock species can inhabit a given location and this will depend on the biological characteristics of each species – such as size, habit, feeding method and reproductive mode. However, not every species occurs throughout its potential range – its realised distribution is moderated by biological interactions such as competition, grazing and predation. Circalittoral communities have been poorly studied in respect to biological interactions because in order to determine the real role of species in a community experimental manipulation in the field is required. This has been carried out extensively in the intertidal and infralittoral but rarely in the circalittoral owing to the logistics of working at such depths.

Habitat complexity

A great majority of prominent circalittoral rock species are sessile. However, under conditions of shelter a number of the circalittoral faunal turf species may be mobile. Such species consist mainly of decapod crustaceans, gastropod molluscs and echinoderms, and as grazers or predators these must be able to move to locate further food supplies. Even so, many of them are very well attached to the rocks, such as starfish and sea urchins with their many sucker-like tube feet.

Recruitment processes

Whilst most of the circalittoral rock species spend their larval life in the plankton, there are a few planktonic species which spend their early stages within the circalittoral rock biotopes. This is true, in rather different degrees, of the hydroids and the jellyfish. Hydroids are common and conspicuous members of circalittoral faunal turf biotopes, but the attached hydroids are only the juvenile stages. The sexually reproducing mature stages are small medusae which are released into the plankton, where they reproduce to produce larvae which settle again. In contrast, for jellyfish the large adult medusae in the plankton are the prominent phase. The juvenile stages live attached to rocks as an inconspicuous scyphistoma stage in which the jellyfish overwinters. In spring this buds off a series of juvenile medusae, or ephyrae, which grow rapidly in the plankton to form the adult.

Productivity

Although not primary producers circalittoral communities are important secondary producers. They accumulate and concentrate the primary production from a large water mass, and make this readily available to higher trophic levels.

Keystone (structuring) species

Sheltered circalittoral rock biotopes typically are not dominated by single species, but support a mosaic of species.

Importance of habitat for other species

Circalittoral rock communities interact with others by the provision of food and /or temporary shelter to mobile species which are not permanent members of the community. Shelter is important to juvenile fish, which can find refuge (and food) amongst the dense turf of sessile species. A food source is provided to large mobile crustaceans and fish which are attracted by the rich and stationary food supply available on circalittoral rock.

Temporal changes

Sheltered circalittoral rock biotopes tend to be relatively stable in nature when compared with semi-exposed circalittoral communities.

Time for community to reach maturity

Information is restricted, but it is clear that a number of the more prominent members of the circalittoral rock communities are relatively long lived, and fairly slow growing, some with life spans ranging from 6-100 years. The soft coral *Alcyonium digitatum* is a prominent member of the circalittoral rock community and observations have shown that colonies of 10-15 cm in height are between five and ten years old (Hartnoll, unpubl.).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Fishing: benthic trawling	Low	Although towed gear may not directly cross circalittoral rock (see above), the activities of dredging and trawling on nearby level bottoms with sediments could have effects on neighbouring communities. Towed gear results in the suspension of fine sediment (Jones 1992), which can affect the efficiency of filter feeding (Sherk 1971; Morton 1977) and most of the faunal turf communities are filter feeders. Effects can include abrasion and clogging of gills, impaired respiration, clogging of filter mechanisms, and reduced feeding and pumping rates.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Low	Untreated oil is not a risk to circalittoral communites as it is concentrated mainly at the surface. If oil is treated by dispersant the resulting emulsion will penetrate the water column.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	The primary effect of eutrophication is to stimulate algal growth, both of benthic macroalgae and microscopic phytoplankton. Since by definition circalittoral faunal turf communities are essentially animal- dominated, the effects of eutrophication will be indirect. One effect of eutrophication will be the way it influences the growth of benthic macroalgae, which may influence the level of the boundary between the infralittoral and the circlittoral. Improved macroalgal growth might be expected to lower this boundary, but at the same time increased phytoplankton density will reduce light penetration. Changes in the phytoplankton are more likely to produce impacts. Increased phytoplankton densities will change the food supply for the predominantly filter-feeding faunal turf communities. Blooms of toxic algae may affect survival of circalittoral faunal turf communities, perhaps particularly in their planktonic larval stages. Algal blooms are often considered a near-surface phenomenon, and are more likely to pose a threat in sheltered conditions.
Abrasion	Fishing: benthic trawling	Low	Towed gear is potentially the most destructive impact, and has been the subject of intensive study (MacDonald *et al.* 1996). However, most circalittoral rock biotopes will not generally be threatened since the generally steep and rocky substrata are unsuitable for both trawls and dredges. However there are types of towed gear designed for rocky areas – the rockhopper otter trawl, and the Newhaven scallop dredge and these could pose a risk to circalittoral faunal turf communities on gently sloping or level rock.
	Fishing: potting/	Low	Static gear is deployed regularly on rocky grounds, either in the

	creeling	form of pots or creels, or as bottom set gill or trammel nets. Qualitative observations of pots and creels being dropped and hauled in Devon and Scotland showed that potting did not appear to have any immediate effect on several species that had previously been thought to be sensitive to impact (Eno *et al* 1996). Whilst the potential for damage is lower per unit deployment compared to towed gear, there is a risk of cumulative damage to sensitive species if use is intensive. Damage could be caused during the setting of pots or nets and their associated ground lines and anchors, and by their movement over the bottom during rough weather and during recovery.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in extent or quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Reefs*, *Submerged or partially submerged sea caves* and occurs within *Large Shallow Inlets and bays* and more rarely in deep *Lagoons*. Possibly also in *Estuaries*.
UK Biodiversity Action Plan	None

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Infralittoral gravels and sands

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al*. 1997b) and a review undertaken for the UK Marine SACs Project (Elliott *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A4.1	Sublittoral mobile cobbles, gravels and coarse sands
Wadden Sea	03.02.03	Benthic zone of the shallow coastal waters, coarse sand, gravel /shells bottoms, few macrophytes
Britain/Ireland (MNCR BioMar 97.06)	IGS	Infralittoral gravels and sands
France (ZNIEFF-MER)	III.5.2.1	Faciès des sables grossiers hétérogènes à *Lanice conchilega*
	III.5.3	Biocénose des sables grossiers et fins graviers brassés par les vagues (SGBV)

Description

Gravel and sand habitats in the infralittoral zone, extending from the extreme lower shore into the shallow sublittoral. This habitat may support seaweed communities or, more commonly, be characterised by animal communities, which are influenced by a high degree of disturbance from wave action or strong tidal currents. Although supporting a wide range of species, these habitats typically include fairly robust infaunal species of amphipods, bivalves and polychaetes.

Note: Maerl beds are considered as a separate habitat review

GB distribution

(from MNCR database in February 1999)

Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable, Reduced / low
Wave exposure	Very exposed, Exposed, Moderately exposed, Sheltered, Very sheltered
Substratum	Gravel, sand Infralittoral mobile sandbanks contain all grades of sand (63ìm-1mm) with a very low silt and clay content. One of the features of such a mixture of particle sizes is their low sorting coefficient. Small particles occupy the spaces between larger grains and thus reduce pore space. Another feature of subtidal sandbanks is they may have a highly dynamic nature and instability resulting from the inability of material to form cohesive clumps.
Depth band	0-20m
Zone	Infralittoral
Vertical elevation	Infralittoral gravels and sands occur within the photic zone and will therefore sustain many primary producers (Hiscock 1983). Any increase in depth or turbidity of the water will affect the light penetration and thus the primary producers; in the case of the biotope complexes covered here, the primary producers are benthic microalgae. The quality of light reaching such sandbanks will determine the type of microalgae colonising the sediment. In shallow or constricted areas the water above the banks may be very turbid (Carter 1988) thus limiting primary production. Any change in water depth would change the characteristics of the sandbank. If water depth were to decrease, the sandbank may become exposed on low spring tides, which would decrease survival of subtidal fauna that cannot withstand exposure. The depth of the sandbank would also affect predator populations of birds, which are restricted to certain diving depths.
Porosity	Particle size, its mixture and compaction influence the permeability or percolation rate (Pethick 1984) especially those with a mixture of particles. Infralittoral sandbanks tend to have a high porosity. The instability of infralittoral sandbanks and the inability of the material to form cohesive clumps prevents the colonisation of vegetation but allows the development of interstitial populations of organisms.
Organic content	Infralittoral sandbanks typically have low levels of organic matter and are well oxygenated in the surface layers (Eagle 1973), the organic matter derived from decaying seaweed, the faeces and remains of animals. The mobile nature of this substrate produces a deeper anaerobic layer (>15 cm) and any organic matter incorporated into the sediment is degraded rapidly. High-energy areas have a low carbon to nitrogen ratio due to the low organic content, reduced productivity and rapid degradation of labile organic material.
Oxygen content	Oxygen content is a function of the degree of oxygenation (aeration) and the inherent oxygen demand of organic matter. As infralittoral sand has a low organic content, they are usually sufficiently oxygenated by seawater which may percolate to several metres (Eagle 1983).
Microbial activity	Microbial activity is low in areas of higher energy as there is limited organic detritus available for bacterial degradation coupled with the particles' comparatively low surface area to volume ratio that provides a surface for microbial populations.

Species composition and biodiversity

For IGS in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Nemertea indet.	•	••	Present
Nephtys sp.	••	•	Common
Nephtys cirrosa	•	••	Common
Spiophanes bombyx	••	••	Frequent
Magelona mirabilis	••	••	Frequent
Chaetozone setosa	••	••	Common
Lanice conchilega	••	••	Occasional
Pagurus bernhardus	•	•	Occasional
Fabulina fabula	••	•••	Abundant
Chamelea gallina	•	•••	Frequent
Asterias rubens	•	•	Occasional

Ecological relationships

The species composition in shallow inshore areas may be similar to that of intertidal sand flats (Willems *et al.* 1982; Atkins 1983). The presence of any species in an area is dependent on its tolerance to those environmental variables such that considerable spatial and temporal variation occurs within estuarine and coastal sediment areas.

Habitat complexity

The physical environment of infralittoral sand with strong currents is often too harsh for vegetation to become established. However, more sheltered sand may support the sugar kelp *Laminaria saccharina* attached to stones and shallow conditions with adequate light will maintain a microphytobenthic (diatoms) community. Mobile sandbanks are colonised by infaunal/epifaunal small crustaceans, polychaetes and molluscs which are adapted to the changing hydrography and substratum; they are able to reburrow rapidly following being washed-out of the sediment during storms (Vanosmael *et al.* 1982). For example, the body form and mobility of magelonid polychaetes and species such as *Nephtys cirrosa* and *Micropthalmus similis* are well suited to burrowing in mobile sands. These features indicate that the communities are clearly shaped by physical rather than biological factors. The sediment in a mobile sandbank system may range from fine to coarse clean sands, and the density of individuals and species richness is often highest in the coarsest grade, mainly due to large numbers of interstitial polychaetes (Vanosmael *et al.* 1982). The mean macrobenthic diversity and species richness of clean mobile sandbanks is generally lower than the surrounding sea bed (reflecting the greater stresses inherent in these environments) although the fauna is essentially comparable with that of the open sea. Due to the continual sediment disturbance, the community may have a large opportunistic component, including species such as *Chaetozone setosa*, and may be prevented from reaching a climax community. The heart urchin *Echinocardium cordatum* may also be common but is replaced by another heart urchin *Brissopsis lyrifera* in more silty areas. Sand-eels e.g. *Ammodytes tobianus* and *A. marinus* are widespread. The meiofauna also form an important component of the sandbank fauna. Interstitial organisms occur in sediments with a median grain size above 200 åm and polychaetes are found abundantly in sediments with a particle size above 300 åm (Willems *et al.* 1982). The meiofauna may be characterised by low densities of nematodes and high densities of copepods, annelids and halacarid mites.

Recruitment processes

The population dynamics of the fauna in exposed habitats may be based on long-term breeding success, e.g. 6-7 years for tellinids with a cohort produced which may then dominate the population (Pearson & Barnett 1987). The opportunistic pollution-tolerant polychaete *Capitella capitata* has both benthic and planktonic larvae and breeds thoughout the year; this means it is able to colonise impacted or stressed areas very quickly. Subtidal mobile sandbanks are usually dependent on an input of colonising organisms and have few species with benthic reproduction, thus any disruption to the delivering currents will cause changes.

Productivity

No information available.

Keystone (structuring) species

No information available.

Importance of habitat for other species

Infralittoral sandbanks provide a source of prey for demersal fish, especially those mobile small crustaceans which migrate from the sediment and thus become available for predation (Costa & Elliott 1991). The habitat is often important as fish nursery areas e.g. for plaice *Pleuronectus* *platessa* (Gibson 1973), and may be characterized by low organic enrichment though there may be localised pockets of organic matter or areas which receive anthropogenic waste. The sandbanks are also important areas for crab populations and other epifauna, particularly echinoderms. The epifaunal component may represent a large proportion of the biomass of the sand bank fauna with large numbers of *Asterias rubens* and brittlestars such as *Ophiura albida*. Predatory fauna such as hermit crabs e.g. *Pagurus bernhardus*, the swimming crab *Liocarcinus depurator* and the edible crab *Cancer pagurus* may also be present. Birds such as the gullimot, razorbill, puffin and terns will feed on the fish such as sand-eels *Ammodytes* spp. which are found in mobile sands (Batten *et al.* 1990).

Temporal changes

No information available.

Time for community to reach maturity

No information available.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum loss	Extraction: navigational/ maintenance dredging	Intermediate	Dredging and aggregate extraction will affect the sediment and hydographic regimes. Dredging of sandbanks will occur where they interfere with navigation and also to deepen and widen channels for shipping. The activity can also cause loss and damage by the indirect effects of increased scour and erosion on artificially steepened slopes. Dredging will disturb the benthic community and possibly reduce the number and diversity of benthic species and affect larval recruitment (Rosenberg 1977). However, it is emphasised that subtidal sandbanks are the result of relatively high energy conditions and as such will be naturally disturbed by changes in hydrographic conditions. The ability of the community to recover from sediment disturbance is therefore high (Rees 1994; Kaiser & Spencer 1996).
Changes in turbidity	Waste: spoil dumping	Intermediate	Dredged material disposal over subtidal sandbanks may occur adjacent to dredged areas. However, in areas of strong tidal current dispersion of dredge plumes may be high and thus the effects minimal. Any increase in the amount of suspended particles will influence turbidity, light penetration and primary production of the water column and substrata (Iannuzzi *et al.* 1996). Suspension- feeding invertebrates may also be affected by suspended dredge spoil, as it will clog their respiratory or breathing apparatus. However, it is emphasised that subtidal sandbanks are the result of relatively high energy conditions and as such will be naturally disturbed by changes in hydrographic conditions and will accommodate man-induced conditions such as dredge spoil.
Changes in temperature	Climate change/global warming	Intermediate	Infralittoral sandbanks are not subjected to such extreme changes in temperature as intertidal areas although fluctuations will occur in stratified waters or on the boundaries of frontal systems. Variation in water temperature may affect the succession of macrobenthic species with the occurrence or survival of different groups of species related to periods of mild or cold winter temperatures.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	Infralittoral sediments will be less at risk from oil spills than intertidal sediments unless dispersants are used in clean-up operations or if wave action allows sediment mobility and thus oil to be incorporated into the sediments.
Changes in nutrient levels	Waste: sewage discharge	Low	In contrast to the low-energy areas, the higher-energy sediment biotopes are less likely to receive and/or retain such

levels	discharge		contamination. The coarse sediments and hydrodynamic characteristics, including high dispersion, of subtidal sandbanks dictates that there are few cases of severe pollution in this habitat.
Displacement	Fishing: benthic trawling	Intermediate	Commercial shell and fin-fisheries can potentially have a large effect on the integrity of infralittoral sand. The affects of fishing will depend on the type of gear used. Megafaunal species are in general more vulnerable to fishing affects than macrofaunal species because they are slow growing and thus slowly recover from disturbance. Removal of non-commercial-sized fish will affect the nursery function of the habitat.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not assessed
UK	Not significantly declined in extent. Significantly declined in quality.
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Can be protected as *Sandbanks which are slightly covered by sea water all the time*; also occurs within *Estuaries* and *Large shallow inlets and bays* and more rarely in *Lagoons*
UK Biodiversity Action Plan	None

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Maerl beds

Compiled by: Leigh Jones, Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 IJY, UK.

Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Birkett *et al.* 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A4.1/B-IGS.Mrl.Phy	*Phymatolithon calcareum* maerl beds in shallow-water clean gravel and coarse sand
	A4.4/B-IMX.MrlMx	Maerl beds on shallow-water muddy mixed sediments
Wadden Sea	-	Not present/listed
Britain/Ireland (MNCR BioMar 97.06)	IGS.Mrl	Maerl beds (open coasts/clean sediments)
	IMX.MrlMx	Maerl beds (muddy mixed sediments)
France (ZNIEFF-MER)	III.7.1	Fonds à *Lithothamnion* (= *Phymatolithon*) *calcareum, Lithothamnion corallioides*

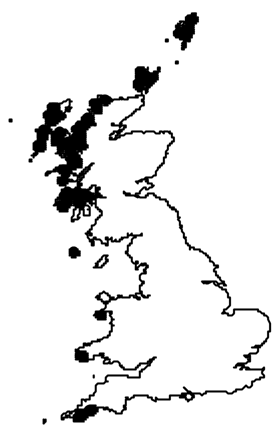
Description

IGS.Mrl. Beds of maerl in coarse clean sediments of gravels and clean sands, which occur either on the open coast or in tide-swept channels of marine inlets (latter often stony). In fully marine conditions the dominant maerl is typically *Phymatolithon calcareum* (IGS.Phy), whilst under variable salinity conditions in some Scottish sealochs beds of *Lithothamnion glaciale* (IGS.Lgla) may develop.

IMX.MrlMx. Maerl beds of the genus *Lithothamnion* or *Lithophyllum* which develop on shallow sublittoral muddy gravels. Such sediments are found in marine inlets, such as rias and sealochs, usually in fully marine or near marine conditions where significant tidal currents are lacking. Three species of maerl may dominate; *L. corallioides* (IMX.Lcor), which is relatively widespread, and *Lithophyllum dentatum* and *L. fasciculatum* (IMX.Lden and IMX.Lfas) which have restricted distributions in Ireland.

GB distribution

(from MNCR database March 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full, Variable (IGS.Mrl) The salinity tolerance of maerl is species specific with *Phymatolithon calcareum, Lithothamnion corallioides* and *Lithophyllum* sp. usually associated with full salinity areas and *Lithothamnion glaciale* with variable salinities such as in Scottish sealochs. Maerl beds in Galway Bay, Ireland are subject to fully saline water for most of the year, bottom salinity being measured as between 34.4 ‰ and 34.8 ‰. However, in February and April the salinity was reduced to about 30 ‰ (Birkett *et al* 1998)
Wave exposure	Exposed (IGS.Mrl), Moderately exposed (IGS.Mrl), Sheltered, Very sheltered (IMX.MrlMx)
Tidal streams	Strong (IGS.Mrl), Moderately strong (IGS.Mrl), Weak, Very weak
Substratum	Gravels (IGS.Mrl), Clean gravels (IGS.Mrl), Muddy gravels (IMX.MrlMx)
Zone	Infralittoral
Depth range	0-20 m (IGS.Mrl), 0-10 m (IMX.MrlMx)
Temperature	Maerl biotopes occur in a wide range of temperature regimes, from the tropics to northern Norway, but the species composition and distribution of the maerl beds is greatly influenced by temperature. The most obvious temperature-related phenomenon in the UK is the absence of *Lithothamnion corallioides* from Scotland, either because winter temperatures occasionally drop below the minimum survival temperature of this species (between 2-5°C) or because temperatures do not remain high enough for long enough to support sufficient annual growth. Laboratory studies on Spanish maerl (Adey & Mckibben 1970) showed that *Phymatolithon calcareum* survived down to 2°C, dying at 0.4°C, and that the optimum growth was at 15°C. *Lithothamnion corallioides* had a higher minimum survival temperature, dying at 2°C, and surviving without growth at 5°C.
Water quality	The light levels under which maerl can grow are suggested by the depth ranges in which it grows. Maerl found in tropical waters is usually found at depths below the range of the reef - binding coralline algae associated with coral reefs. At the other extreme of the habitat range, at a few sites in western Ireland (e.g. Mannin Bay, part of Killary Harbour and Muckinish) and Brittany, France maerl occurs intertidally, generally only near the extreme low-water mark.
Nutrients	Cabioch (1969) has suggested tolerance of elevated nutrient levels on the basis of field observations of maerl distribution in Brittany, France; however experimental studies are lacking.
Calcium	King & Scramm (1982) reported that the salient factor affecting growth of maerl in culture experiments using various salinity growth media was the calcium ionic concentration, rather than salinity *per se*. They found an optimum uptake of calcium carbonate at 30 ‰.

Species composition and biodiversity

Characterising species

For IGS.Mrl in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Cerianthus lloydii	•••	•	Frequent
Pagurus bernhardus	•••	•	Occasional
Liocarcinus depurator	•••	•	Occasional
Gibbula magus	••	••	Occasional
Asterias rubens	••••	•	Occasional
Echinus esculentus	•••	•	Occasional
Lithothamnion glaciale	••	•	Frequent
Phymatolithon calcareum	••••	••	Common
Polyides rotundus	••	••	Occasional
Halarachnion ligulatum	••	••	Occasional
Nitophyllum punctatum	••	••	Occasional
Brongniartella byssoides	••	••	Occasional

Dictyota dichotoma	•••	•	Occasional
Laminaria saccharina	•••	•	Frequent

For IMX.MrlMx in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Suberites ficus	••	••	Rare
Cerianthus lloydii	•••	•	Frequent
Anemonia viridis	•••	••	Occasional
Anthopleura ballii	•••	••	Occasional
Sagartiogeton undatus	•	••	Frequent
Terebellidae indet.	•••	•	Occasional
Myxicola infundibulum	•••	••	Common
Liocarcinus depurator	•••	•	Occasional
Gibbula magus	••	••	Occasional
Asterias rubens	••••	•	Occasional
Marthasterias glacialis	•••	••	Occasional
Dudresnaya verticillata	••	••	Frequent
Lithophyllum dentatum	•	•••	Common
Lithophyllum fasciculatum	•	•••	Common
Lithothamnion corallioides	•••••	••	Common
Phymatolithon calcareum	••	••	Frequent
Phymatolithon purpureum	•	•••	Occasional
Gracilaria gracilis	••	••	Frequent
Halarachnion ligulatum	••••	••	Frequent
Rhodophyllis divaricata	•	••	Frequent
Dictyota dichotoma	•••	•	Frequent

The maerl beds of Brittany and of the Mediterranean have long been recognised as communities with a particularly high diversity of plant and animal species. In the British Isles, there may be somewhere in the range of 150-200 or more macroalgal species found on maerl, and perhaps over 500 benthic faunal species. Amongst the associated organisms are many rare species which are unusual, rare or poorly known: a recent report on maerl beds in the sound of Arisaig, Scotland by Davies & Hall-Spencer (1996) revealed four species of polychaete and an isopod species likely to be new to science, in addition to large numbers of the isopod *Paramunna bilobata*, previously described as a rare gravel-dwelling species.

Ecological relationships

There are numerous features of maerl that contribute to its value as a habitat for other marine species (Nunn 1992). It provides a surface to which other seaweeds can attach (Cabioch 1969; Adey & Adey 1973; Adey & McIntyre 1973). Other species then feed on these e.g. *Aplysia punctata* and rissoids molluscs. The maerl may also be directly grazed by species such as *Tectura virginea*. Maerl also provides attachment sites for animals such as *Antedon bifida*, hydroids and bryozoans. The loose structure of maerl provides shelter for small gastropods with infauna including many bivalves such as *Mya truncata* and *Dosinia exoleta*. Epifauna include small Crustacea (Farnham & Bishop 1985). The integrity of the maerl bed in turn requires at least some elements of the rich epiflora associated with it as a stabilizing feature. Jacquotte

(1962) and Cabioch (1969) discussed the importance of various creeping species in stabilizing the maerl deposits by the formation of stolons and secondary attachments. The interactions with invertebrate grazers are also very important in keeping open substratum clear for settlement by algal and animal species.

Habitat complexity

Many coralline algae produce chemicals, which promote the settlement of the larvae of certain herbivorous invertebrates. The herbivores then graze off the epiphytic and often fast-growing algae, which might otherwise overgrow the coralline algae, competing for light and nutrients. The presence of herbivores associated with corallines can generate patchiness in the survival of dominant seaweeds.

Recruitment processes

Maerl has not been studied as a habitat for the juvenile stages of demersal and pelagic species. Divers visiting maerl beds have commented on the numbers of small individuals that can be seen. The open structure of a maerl bed would certainly provide a secure habitat for juveniles. In the west of Ireland, maerl deposits are known to act as nursery grounds for the black sea urchin *Paracentrotus lividus.*

Keystone (structuring) species

Lithothamnion corallioides, *Lithothamnion glaciale, Phymatolithon calcareum*, *Lithophyllum denudatum* and *L. fasciculatum*

Importance of habitat for other species

No information available.

Temporal changes

Juvenile maerl plants grow as crusts on pebble or shell substrata. The erect branches formed by these crusts break off and give rise to free-living maerl thalli growing as nodules. Jacquotte (1962) found *Halopithys incurvus* to be more frequent in the winter and attributed seasonal changes in maerl bed epiflora in the Mediterranean to seasonal changes in illumination. Cabioch (1969) found a few crustose species to be more abundant in the winter. In Ireland, the species diversity of maerl beds has been shown to increase in the summer (Maggs 1983) and it was suggested that this was as a result of the greater stability of the biotope owing to the calmer weather normally experienced at this time of year. Long- and short-term changes in biodiversity have both been noted. As an illustration of the difficulties that may be encountered in monitoring the epiflora component of maerl beds, Maggs (1983) reported that during a 2-year-long sampling programme, nine conspicuous species disappeared from the maerl beds under investigation while a further three species appeared in the biotope.

Time for community to reach maturity

Species composition of the maerl in a bed is known to cycle over a period of time (3-30 years). Maerl thalli are long lived; thalli of *Lithophyllum dentatum* have been estimated to be between 20-100 years old (Fazakerley, unpubl.).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum loss	Extraction: maerl	High	Dead maerl extraction is liable to lead to muddy plumes and excessive sediment load in the water column. Heavy siltation also clogs up the maerl matrix, which serves as a habitat for infauna, and once clogged, the passage of oxygenated seawater between the maerl fragments is restricted and the number of infaunal species is reduced.
Changes in temperature	Climate change/global warming	Intermediate	Even in the relatively short term, global warming of the anticipated 1-3°C within the next century could have an effect on the composition of maerl beds in the UK, in that the cold-intolerant species *Lithothamnion corallioides* might be able to extend its distribution northwards.
Changes in turbidity	Extraction: navigational/ maintenance dredging	Intermediate	Dredging results in the suspension of the fine silt and clay fractions of the sediment, which is deposited by inshore currents. This will increase turbidity and decrease the amount of penetrating light as well as smothering other algae. If the underlying substratum is altered, it is unlikely that maerl will be able to re-establish itself at the site, given the probable method of reproduction of the species involved.
Changes in nutrient levels	Waste: sewage discharge	Intermediate	The increase in levels of macronutrients (particularly nitrogen and phosphorus) in European coastal waters results in the excessive growth of ephemeral macroalgal species which may smother the maerl. Increased turbidity in coastal waters may also occur as a result of prolific phytoplankton growth, thus reducing available penetrating light.
Changes in oxygenation	Aquaculture: fin -fish	Intermediate	Positioning cages over a maerl biotope would lead to fish faeces and partly -consumed food pellets contaminating the bed and may result in anaerobiosis due to the oxygen demand of the decomposing material. Detrital rain from the cages would act in a similar way to terrigenous silt, reducing light penetration through the water column and smothering the maerl surface so that the stabilising epiphytic algae could no longer establish themselves.
Abrasion	Fishing: benthic trawling	Intermediate	The removal of living maerl thalli from the biotope surface, the loss of the stabilising algae and the disruption of the structure the community structure occur. These major changes have been reported in Rade de Brest, France where the maerl beds support populations of the scallop *Chlamys varia* , which are locally abundant and are intensively fished during the winter months. The dredging activity has been reported as resulting in severe disruption to the maerl bed and associated flora and fauna (Hily & Le Foll 1990).
Removal of target species	Extraction: maerl	High	Maerl is extracted in large amounts for use in animal food additives, water filtration systems, but mostly to replace lime as an agricultural soil conditioner. Live maerl extraction is very problematic as the growth rates for replacement are so slow. Hall-Spencer (1995) expressed the view that "commercial dredging of maerl deposits is particularly destructive since this removes the productive surface layer and dumps sediment on any plants which escape dredging, inhibiting habitat recovery".

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadded Sea	Not present
UK	Probability of significant decline in extent (depending on future level of maerl extraction)
	Not significantly declined in quality (but some decline in quality)
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	*Phymatolithon calcareum* and *Lithothamnion corallioides* are listed on the EC Habitats Directive Annex Vb. Sites for maerl beds can be designated as the Annex I habitat *Sandbanks slightly covered by seawater all of the time*, occur within *Large shallow inlets and bays* and may be present in some (Scottish) *Lagoons*.
UK Biodiversity Action Plan	Maerl beds (Habitat Action Plan)

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Eelgrass *Zostera marina* beds

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Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Davison 1998).

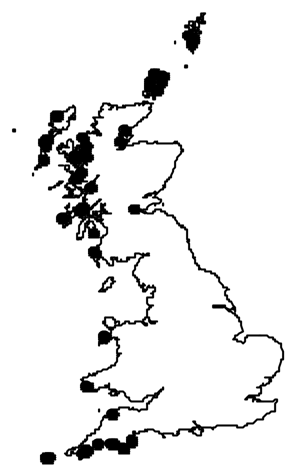
Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov. 1999)	A4.5/B-IMS.Sgr.Zmar	*Zostera* beds in lower shore or infralittoral clean or muddy sand.
Wadden Sea	03.02.05	Benthic zone of the shallow coastal waters with muddy and sandy bottom, rich in macrophytes
Britain/Ireland (MNCR BioMar 97.06)	IMS.Zmar	*Zostera marina*/*angustifolia* beds in lower shore or infralittoral clean or muddy sand
France (ZNIEFF-MER)	II.3.3	Herbiers de *Zostera marina*, *Zostera noltii* (= *Z. nana pro parte*) du médiolittoral inférieur
	III.3.4	Herbiers de *Zostera marina*

Description

IMS.Zmar. Expanses of clean or muddy fine sand in shallow water and on the lower shore (typically to about 5 m depth) can have dense stands of *Zostera marina/angustifolia* [Note: the taxonomic status of *Z. angustifolia* is currently under consideration but is most likely a dwarf form of *Zostera marina*]. In IMS.Zmar the community composition may be dominated by these *Zostera* species and therefore characterised by the associated biota. Other biota present can be closely related to that of areas of sediment not containing *Zostera marina*, for example, *Laminaria saccharina*, *Chorda filum* and infaunal species such as *Ensis* spp. and *Echinocardium cordatum* (e.g. Bamber 1993) and other bivalves listed below. It should be noted that sparse beds of *Zostera marina* might be more readily characterised by their infaunal community. Beds of this biotope in south-west Britain may contain conspicuous and distinctive assemblages of Lusitanian fauna such as *Laomedea angulata*, *Hippocampus* spp. and Stauromedusae. Some examples of *Zostera marina* beds have markedly anoxic sediments associated with them.

GB distribution (from MNCR database March 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full; Variable; Reduced; Low. McRoy (1966) suggests optimum salinities of 10 to 39‰; den Hartog (1970) reports tolerances as low as 5‰ in the Baltic. Laboratory studies indicate that maximum germination occurs at 30°C and 1‰ salinity (Hootsmans *et al.* 1987). Field studies indicate that germination occurs over a wide range of temperatures and salinities (Churchill 1983, Hootsmans *et al*. 1987). In brackish waters along the Atlantic coast, *Zostera marina* behaves as an annual plant, shedding its leaves in winter (Jacobs 1982). Low salinities may encourage production of reproductive shoots and stimulate leaf production. *Zostera marina* beds survived disease especially in low salinity conditions in the eastern United States (Muehlstein, Porter & Short 1991).
Wave exposure	Sheltered, Very sheltered, Extremely sheltered, Ultra sheltered
Tidal streams	Weak, very weak
Substratum	Clean sand, muddy fine sand, mud
Zone	Lower shore, Upper infralittoral
Depth range	Lower shore 0-5 m
Temperature	Optimum temperature range for *Zostera marina* appears to be between 5 and 30 °C (Marsh *et al*. 1986; Bulthius 1987). Seasonal growth is closely associated with temperature. Yonge (1949) suggested that growth ceases below 10 °C and that flowers could only open and seeds form when the temperature exceeded 15 °C. *Zostera marina* beds, which occur intertidally, may be damaged by frost although the rhizomes most likely survive (Covey & Hocking 1987).
Water quality	*Zostera marina* requires high light levels. It most commonly occurs shallower than 2 m below chart datum, exceptionally to 5 m and the deepest recorded depth it has been found in Britain and Ireland is 13 m below chart datum off south-west Ireland (Cullinane *et al*. 1985). Harrison (1987) describes how the extent of a *Zostera marina* bed expanded after construction of a causeway blocked the flow of silty water.
Nutrients	It seems most likely that nitrogen is the limiting nutrient. In carbonate-based sediments, phosphates may be limiting due to adsorption onto sediment particles (Short 1987). Mild nutrient enrichment of sediments may stimulate growth of *Zostera marina* shoots (Roberts *et al*. 1984).

Species composition and biodiversity

Characterising species

For IMS.Zmar in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Anemonia viridis	●●	●●	Frequent
Arenicola marina	●●	●	Occasional
Lanice conchilega	●●	●	Occasional
Pagurus bernhardus	●●	●	Occasional
Carcinus maenas	●●●	●	Occasional
Gibbula cineraria	●●	●	Occasional
Hinia reticulata	●●	●●	Occasional
Chorda filum	●●	●●	Frequent
Laminaria saccharina	●●	●	Occasional
Ulva sp.	●●	●	Frequent
Zostera marina	●●●●●	●●●	Abundant

Ecological relationships

Zostera marina provides a habitat for a wide range of species to find shelter or a suitable substratum on which to live. Fish occur amongst the eelgrass and include the wrasse and goby species also found in kelp. The green wrasse *Labrus turdus* is normally associated with eelgrass beds in the Mediterranean and may be present in Isles of Scilly *Zostera marina* beds (Fowler 1992). Especially found in eelgrass beds are pipefish *Syngnathus typhle* and *Entelurus aequoreus* and, rarely, seahorses *Hippocampus ramulosus*. Cuttlefish *Sepia officinalis* are also found and lay their eggs amongst eelgrass. Small prosobranchs, especially *Rissoa* sp(p) and *Lacuna vincta* graze on the leaves. The mud snail *Hydrobia ulvae* is found on leaves in brackish conditions. At open coast sites, stauromedusae stalked jellyfish *Haliclystus auricula* and *Lucernariopsis campanulata* may be present on leaves. The hydroid *Laomedea angulata* and the algae *Rhodophysema georgii*, *Halothrix lumbricalis*, *Leblondiella densa*, *Myrionema magnusii*, *Cladosiphon zosterae* and *Punctaria crispata* have only been recorded attached to eelgrass leaves. The endophytic green alga *Entocladia perforans* is also host-specific to *Zostera marina*. Eelgrass rhizomes help to stabilise sediments and may thereby increase species diversity. Sea anemones *Cereus pedunculatus*, *Cerianthus lloydii* and the prosobranch *Nassarius reticulatus* are often common in the sediment. In the Isles of Scilly, the sea anemone *Anthopleura ballii* is unusually present.

Habitat complexity

Eelgrasses provide shelter and hiding places. The leaves and rhizomes provide substrata for the settlement of epibenthic species which in-turn may be grazed upon by other species.

Recruitment processes

Zostera marina provides refuges for many species of fish and nursery areas for some.

Sediment stabilisation

The slowing of water movement by leaves encourages accumulation of sediments whilst the dense rhizome and root system stabilizes the sediment preventing or reducing sediment loss. The consolidation of the sediments enables the development of richer infaunal communities with higher densities of individuals than those in adjacent bare sediments (reviewed most recently in Boström & Bonsdorff (1997).

Productivity

Eelgrasses have high rates of primary production and are an important source of organic matter whose decomposition provides a starting-point for detritus-based food chains. They also provide a substratum for other plant species.

Keystone (structuring) species

Zostera marina, *Labrynthula macrocystis*

Importance of habitat for other species

Intertidal and probably shallow subtidal *Zostera marina* beds provide a source of food for a variety of wildfowl, although not to the extent that intertidal *Zostera noltii* do. Studies of feeding on *Zostera* rarely differentiate which species is being referred to. Tubbs & Tubbs (1983) reported that brent geese-grazing contributed to the cover of *Zostera marina* and *Zostera noltii* being reduced from between 60-100% cover in September to between 5-10% cover between mid-October and mid-January. The observation that the decline in *Zostera marina* during the wasting disease of the 1930s was followed by very heavy losses of the Brent goose and the Canada goose (den Hartog 1977) suggests that they rely on *Zostera marina* for a large proportion of their food. However, it remains unclear and seems unlikely that wildfowl grazing affects subtidal *Zostera marina* beds.

Temporal changes

Zostera marina beds are naturally dynamic, at least in open coastal areas. In the Isles of Scilly, beds have 'advancing' and 'receding' edges. The fungus *Labrynthula macrocystis* caused the loss of over 90% of *Zostera marina* beds in the 1920s and 1930s and a full recovery has not yet occurred (see Vergeer *et al.* 1995 for a recent review). *Zostera marina* beds may show marked annual changes. In brackish conditions, there is die-back of the leaves in the autumn and regrowth in the spring and early summer (Jacobs 1982; Dyrynda 1997). This die-back has been observed to be almost complete in The Fleet in Dorset, UK (Dyrynda 1997) and resulted in sediment destabilization as well as loss of cover for fish and substratum for invertebrates.

Time for community to reach maturity

Zostera marina beds most likely do not seed and establish rapidly. There has been little recovery of *Zostera marina* beds following the wasting disease in the 1930s. Olesen & Sand-Jensen (1994) reported that, in Danish waters, new *Zostera marina* beds could take at least five years to become established and stable with small patches (<32 shoots) showing high mortalities. However, these observations are near to established beds and seeding over a distance particularly between isolated water bodies is likely to be slow. An extensive series of experiments has been undertaken to try to re-establish beds (see, for instance, Fonesca *et al.* 1994).

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Substratum change	Waste: sewage discharge	Intermediate	Smothering by algae may be linked to eutrophication. *Zostera marina / angustifolia* plants were overwhelmed by *Enteromorpha* spp.in Langstone Harbour, but their final demise may have been due to grazing by Brent geese (den Hartog 1994).
Changes in temperature	Climate change/global warming	Low	Den Hartog (1970) suggested that *Zostera marina* generally tolerates temperatures up to 20^{o}C without showing signs of stress. There is likely to be damage through frost to beds exposed at low water (den Hartog 1987).
Changes in turbidity	Waste: spoil dumping	High	Prolonged increases in turbidity would reduce light penetration and prevent adequate photosynthesis by deeper populations of *Zostera marina*. Geisen *et al.* (1990) suggest that turbidity caused by eutrophication, deposit extraction and dredging activities were major factors in the decline of *Zostera* in the Wadden Sea.
Synthetic compound contamination	Uses: coastal farming Uses: boats/shipping (anti-fouling)	Intermediate	Terrestrial herbicides have been found to inhibit growth and cause decline in *Zostera marina* (Delistraty & Hershner 1984). Some effects may be indirect. For instance *Zostera marina* readily uptakes heavy metals and TBT (Williams *et al.* 1994). Whilst plants appeared unaffected, any loss of grazing prosobranchs due to TBT contamination in the leaves or externally would result in excessive algal fouling of leaves, poor productivity and possible smothering.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Intermediate	Apparently healthy *Zostera marina* beds are known to exist in areas subject to low-level chronic hydrocarbon contamination (see, for instance, Howard, Baker & Hiscock 1989). Smothering by stranded oil is likely to occur on lower shore populations but little is known of its effects.

Changes in nutrient levels	Waste: sewage discharge	Intermediate	High nitrate concentrations have been implicated in the decline of *Zostera marina* by Burkholder *et al.* (1993). Such eutrophication may increase the cover of epiphytic algae and prevent photosynthesis of sea grass plants. Eutrophication may increase abundance of *Labrynthula macrocystis* (see below). However, nutrient enrichment may stimulate growth of *Zostera marina* (Fonesca *et al*. 1994)
Changes in oxygenation	Aquaculture: fin -fish	High	No evidence of effects found in the literature but the de-oxygenation of water would be likely to adversely affect plants.
Abrasion	Uses: Boats/shipping (anchoring, mooring, beaching & launching) Fishing: benthic trawling	Intermediate	Eelgrass is generally not physically robust. Their root systems are typically located within the top 20 c, of the sediment and so can be dislodged easily by a range of activities. including trampling, anchoring, digging , dredging and powerboat wash (Fonseca 1992).

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Threatened by complete destruction
UK	Significantly declined in extent (subject to review)
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	A named component of *Lagoons* (a priority habitat *)* and *Shallow sandbanks slightly covered by seawater all of the time*. Also a characteristic feature *of Large shallow inlets and bays* and *Estuaries* and occurs on the lower shore in *Mudflats and sandflats not covered by sea water at low water.*
UK Biodiversity Action Plan	Seagrass beds (Habitat Action Plan)

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Seapen and burrowing megafauna communities

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Derived, in part, from: the UK marine biotope classification (Connor *et al.* 1997b) and a review undertaken for the UK Marine SACs Project (Hughes 1998).

Classification

Classification	*Code*	*Biotope(s)*
Europe (EUNIS Nov.1999)	A4.3/B-CMU.SpMeg	Sepens and burrowing megafauna in circalittoral muds
Wadden Sea	-	Not listed/present
Britain/Ireland (MNCR BioMar 97.06)	CMU.SpMeg	Seapens and burrowing megafauna in circlittoral soft mud
	CMU.SpMeg.Fun	Seapens, including *Funiculina quadrangularis* and burrowing megafauna in undisturbed circalittoral soft mud
France (ZNIEFF-MER)	IV.1.1	Vases molles à *Virgularia mirabilis-Virgularia tuberculata*

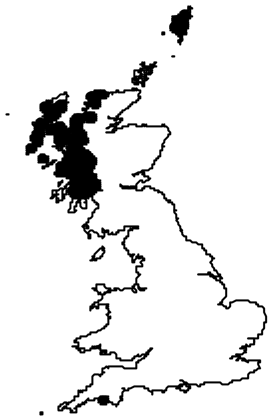
Description

CMU.SpMeg. Plains of fine mud at depths greater than about 15 m may be heavily bioturbated by burrowing megafauna; burrows and mounds may form a prominent feature of the sediment surface with conspicuous populations of seapens, typically *Virgularia mirabilis* and *Pennatula phosphorea*. These soft mud habitats occur extensively throughout the more sheltered basins of sealochs and voes and are present in quite shallow depths (as little as 15 m) in these areas probably because they are very sheltered from wave action. This biotope also seems to occur in deep offshore waters in the North Sea, where densities of *Nephrops norvegicus* may reach 68 per 10 m^{-2} (see Dyer *et al.* 1982, 1983), and the Irish Sea. The burrowing crustaceans present may include *Nephrops norvegicus*, *Calocaris macandreae* or *Callianassa subterranea*. The former of these species is the only one frequently recorded from surface observations, whilst grab sampling may fail to sample any of these species. Indeed, some forms of sampling may fail to indicate seapens as characterising. The crab *Goneplax rhomboides* may sometimes be recorded, again rarely, in this habitat. Large mounds formed by the echiuran *Maxmuelleria lankesteri* are also present in some sealoch sites. It is unclear from the data examined whether differences in the balance of species composition from site to site represent additional biotopes within this assemblage. *Pachycerianthus multiplicatus* is quite specific to this habitat and is scarce in Great Britain (Plaza & Sanderson 1997). The ubiquitous epibenthic scavengers *Asterias rubens*, *Pagurus bernhardus* and *Liocarcinus depurator* are present in low numbers. The brittlestars *Ophiura albida* and *Ophiura ophiura* are sometimes present, but are much more common in slightly coarser sediments. In the deeper fjordic lochs which are protected by an entrance sill, the tall seapen *Funiculina quadrangularis* may also be present (CMU.SpMeg.Fun). The brittlestars *Amphiura chiajei* and *Amphiura filiformis* may be present in large numbers, although there may be some sites where these species are absent. The infauna may contain significant populations of the polychaetes *Pholoe* spp., *Glycera* spp., *Nephtys* spp., spionids, *Pectinaria belgica* and *Terebellides stroemi*, the bivalves *Nucula sulcata*, *Corbula gibba* and *Thyasira flexuosa* and the echinoderm *Brissopsis lyrifera*, although the latter may not be frequently found in remote samples. Overall, CMU.SpMeg is closely allied to CMU.BriAchi and COS.ForThy and shows strong similarities in infaunal species composition. It may differ from these biotopes as a result of a lack of disturbance or linkage to productive overlying waters (?). IMU.PhiVir is superficially similar to CMU.SpMeg but is found in shallower, less thermally stable waters and lacks the large burrowing species.

CMU.SpMeg.Fun. Deep muds, especially in sealochs, which support populations of seapens such as *Virgularia mirabilis* and *Pennatula phosphorea*, but sometimes also with forests of the nationally scarce *Funiculina quadrangularis*. The sediment is usually extensively burrowed by crustaceans, the most common of which is *Nephrops norvegicus*, but *Callianassa subterranea* may also be present (the latter is likely to be under-recorded by grab sampling because it is deep burrowing). *Lesueurigobius friesii* is present at many sites. *Amphiura* spp. are usually present in high densities.

GB distribution

(from MNCR database March 1999)



Habitat requirements

Habitat factor	*Range of conditions*
Salinity	Full The seapens *Pennatula phosphora* and *Funiculina quadrangularis*, appear to require full or close-to full salinity. Where they occur in enclosed waters, it is most likely that fresh-water influence is restricted to shallow surface waters. *Virgularia mirabilis* however appears to be somewhat more tolerant of occasional lowing of salinity.
Wave exposure	Sheltered, Very sheltered, Extremely sheltered (CMU.SpMeg)
Tidal streams	Weak, Very weak
Substratum	Mud, Mud with some shell gravel (CMU.SpMeg)
Zone	Circalittoral
Depth range	10-200 m
Temperature	Biotopes, which include the seapens *Pennatula phosphora and Funiculina quadrangularis* appear to require thermally, stable conditions and may thrive especially deeper than thermoclines. They most likely occur where annual temperature variability is between 5 and 15 °C. Biotopes with *Virgularia mirabilis* only may be subject to higher temperatures as they occur in shallower waters.
Water quality	The seapen biotopes considered here typically occur in depths below 15 m in wave-sheltered sealochs and much deeper in the open sea suggesting that water movement is more important to their existence than light. However, species within the biotopes are most likely very sensitive to light. The Norway lobster *Nephrops norvegicus* is most active at night in shallow depths and during the day in deep water, suggesting that a particular level of light is of critical importance. The red band fish *Cepola rubescens* feeds at dawn and dusk (Atkinson & Pullin 1996).
Nutrients	Seapen biotopes seem able to tolerate natural and enhanced levels of nutrients. Both *Virgularia mirabilis* and *Pennatula phosphora* were found to be abundant and the sediment macrofauna apparently little affected, near to a distillery outfall enriched with organic compounds and where sediment organic carbon content was <5% (Nickell & Anderson 1997). Along an organic enrichment gradient associated with sewage sludge

dumping, the burrowing decapods associated with seapen communities were found to be abundant in areas of <4% organic carbon, and absent where this exceeded 6% Smith (1988). However, where organic enrichment causes or contributes to hypoxia, effects can be severe with burrowing species abandoning their burrows and exposing themselves to predation (for instance, Stachowitsch 1984).

Species composition and biodiversity

Characterising species

For CMU.SpMeg in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Virgularia mirabilis	••••	••	Frequent
Pennatula phosphorea	••	•••	Occasional
Cerianthus lloydii	•••	•	Occasional
Pachycerianthus multiplicatus	•	•••	Rare
Maxmuelleria lankesteri	•	•••	Present/Not known
Nephtys incisa	••	••	Present/Not known
Nephrops norvegicus	•••	•••	Frequent
Calocaris macandreae	•	•••	Frequent
Callianassa subterranea	•	•••	Occasional
Goneplax rhomboides	•	•••	Occasional
Turritella communis	••	••	Frequent
Amphiura chiajei	••	••	Common
Amphiura filiformis	••	••	Common
Brissopsis lyrifera	•	•••	Present/Not known

For CMU.SpMeg.Fun in the UK	*% Frequency*	*Faithfulness*	*Typical abundance*
Funiculina quadrangularis	•••••	•••	Occasional
Virgularia mirabilis	••••	••	Occasional
Pennatula phosphorea	••••	•••	Frequent
Cerianthus lloydii	••••	•	Occasional
Pachycerianthus multiplicatus	••	•••	Occasional
Terebellidae indet.	••	•	Occasional
Astacilla longicornis	••	•••	Rare
Nephrops norvegicus	••••	•••	Frequent
Calocaris macandreae	•	•••	Occasional
Callianassa subterranea	•	•••	Occasional
Pagurus bernhardus	••••	•	Occasional
Turritella communis	••	••	Frequent
Aequipecten opercularis	••	••	Occasional
Aequipecten opercularis	••	••	Occasional
Asterias rubens	••••	•	Occasional
Amphiura chiajei	••	••	Common
Amphiura filiformis	••	••	Abundant
Lesueurigobius friesii	••	•••	Occasional

Ecological relationships

There are few interdependent features within deep faunal-burrowing mud communities and no single species can be considered a keystone species whose activity is essential to community structure. The burrowing species create tunnels in the sediment which themselves provide a habitat for other burrowing or inquilinistic species. Echiuran worms produce long-lasting burrows that provide a habitat for a variety of small polychaetes and bivalves but no obligate species. There are interrelationships. For instance, the shrimp *Jaxea nocturna*, which often lives in association with the echiuran worm *Maximulleria lankesteri* (Nickell *et al*. 1995a) may benefit from the oxygen-rich mud pulled into its burrows by the worm. The Norway lobster *Nephrops norvegicus* is known to prey on the burrowing shrimp *Calocaris macandreae* (Smith 1988). However, occurrence together including sharing burrows is mainly by chance. The large sea anemone *Pachycerianthus multiplicatus*, which occurs solely in these biotopes, creates a habitat for attached species (O'Connor *et al.* 1977). Some unusual sessile species can be found growing on the mouthparts of burrowing crustaceans and *Symbion pandora*, which was only recently discovered, appears to belong to a hitherto undescribed phylum (Conway Morris 1995). The rarely recorded deep-water brittlestar *Asteronyx loveni* occurs in association with *Funiculina quadrangularis*. The species living in deep mud biotopes are cryptic in nature and not generally subject to predation. Indeed, there is little evidence of predation although tissue from *Virgularia mirabilis* (most likely the top of the colony) has been found in the stomach of haddock (Marshall & Marshall 1882). The sea slug *Armina loveni* feeds on *Virgularia mirabilis* and is known to occur from Norway to western France (Thompson 1988). Birkeland (1974) found that the starfish *Crossaster papposus* was a common predator on the seapens in Puget Sound and this species also occurs widely in the north-east Atlantic although not commonly in the biotopes included here.

Habitat complexity

Burrowing activity creates a much more architecturally complex habitat that would be the case for un-exacavated mud. However, the most important feature of excavation is the working of the sediment and the ventilation of the burrows which ensures that sediment is oxygenated to a much greater depth than would be the case in un-burrowed sediment. Such oxygenation should enable the development of a much richer and/or higher biomass community of species living within the sediment and not in contact with the surface.

Recruitment processes

The major component species in seapen biotopes appear to have plankton stages at some phase in their life cycle so that colonization may be from distant sources.

Keystone (structuring) species

The presence of burrowing species is essential in providing structure to the biotope. However, this importance is mainly for the burrowing species themselves.

Importance of habitat for other species

Only a small number of predatory species are likely to utilize this biotope. *Nephrops norvegicus* is known to be eaten by a variety of bottom-feeding fish including haddock, cod, skate and dogfish. In some areas, up to 80% of cod stomachs are found to contain *Nephrops* (Howard 1982). Burrowing shrimps and echiuran worms are also found in the stomachs of bottom feeding fish.

Temporal changes

Seapen faunal communities appear to persist over long periods at the same location. However, whilst the population density of some species is very stable (for instance, *Calocaris macandreae* off the Northumberland coast – Buchanan 1974), others vary greatly (for instance *Echiurus echiurus* in the German Bight – Rachor & Bartel 1981). Virgularia mirablis populations are known to completely withdraw into the sediment, but little is known of the periodicity of this behaviour.

Time for community to reach maturity

Almost nothing is known about the population dynamics and longevity of seapens in the north-east Atlantic, but data from other species suggest that they are likely to be long-lived and slow growing with patchy and intermittent recruitment. The burrowing decapods which also characterise the biotopes vary in longevity and reproductive strategies with, for instance, the thalassinoid mud-shrimp *Calocaris macandreae* known to reproduce slowly and live for up to ten years.

Sensitivity to human activities

Activities listed are those which influence, or are likely to influence this habitat and which are assessed in the UK marine SAC project review. The sensitivity rank may require amendment in the light of new information becoming available.

Sensitivity to:	*Human activity*	*Rank*	*Comments*
Siltation	Waste: spoil dumping	Intermediate	Small and temporary increases in silt deposition will be dealt with by the ability of species to self-clean. However, deposition of thick silt through dumping is likely to both smother the species present to an extent where they are unable to self-clean or dig-out and may produce a substratum which is unsuitable for re-colonisation.
Changes in turbidity	Coastal defence: dredging Extraction: navigational/ maintenance dredging	Low	Dredging results in the suspension of the fine silt and clay fractions of the sediment, which is deposited by inshore currents. Effects are uncertain but may clog feeding structures.
Hydrocarbon contamination	Uses: boats/shipping (oil spills)	Low	Oil would have to be dispersed deep into the water column to affect these biotopes and, because they occur in sheltered locations, it is unlikely that storms would do this. Effluents disposed into enclosed areas such as sealochs and fjords could be retained and have an effect. *Callianassa subterranea* appears to be highly sensitive to sediment contamination by oil-based drilling muds
Changes in oxygenation	Aquaculture: fin -fish Waste: sewage discharge	High	The burrowing species in particular require well-oxygenated water. Whilst able to tolerate quite high levels of organic material (which may result in hypoxia), seapen faunal communities are absent from areas which are de-oxygenated and characterised by a distinctiv e Nutrient enrichment would have an impact most likely through resultant hypoxia.bacterial community.
Displacement/ Abrasion	Fishing: benthic trawling	High	The seapens *Funiculina quadrangularis* and *Pennatula phosphora* are most likely to be affected, as they do not retract into the sediment. The score applies to removal. Displaced individuals, which are not damaged, will re-burrow. Burrowing species probably occur too deep to be displaced and can most likely dig-out after a trawling event.
Removal of non-target species	Fishing: potting/creeling	Low	Qualitative observations of pots and creels being dropped and hauled in Devon and Scotland showed that potting did not appear to have any immediate effect on sea pens (Eno *et al.* 1996). It was found that seapens began to bend away from pots dropping on top of them even before the pot had made contact with the animal. This was a passive response of the animals to the pressure wave travelling ahead of the dropping pot, which effectively removed their tips from direct impact. The sea pens consistently righted themselves following the removal of the pots. However, the long term effects of such impacts are not known and it would

	require further study to determine whether the apparent immediate recovery was consistent in the long term or whether there is a gradual but cumulative deterioration of condition in impacted animals.

Conservation and protection status

Conservation status

Region	*Status*
OSPAR area	Not assessed
Wadden Sea	Not present
UK	Not significantly declined in extent
	Significantly declined in quality
Other sub-regions	Not assessed

Protected status

Protection mechanism	*Habitat*
EC Habitats Directive	Seapen faunal communities can be found in some very sheltered examples of Annex I type *Large shallow inlets and bays*, and in *Scandinavian fjords*. However, the deep sediment habitats in which they mostly occur (other than in Scandinavia) are not adequately represented in Annex I.
UK Biodiversity Action Plan	Mud in deep water (Habitat Action Plan)

Refere nces

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