The Marine Life Information Network® for Britain and Ireland (*MarLIN*)

Description, temporal variation, sensitivity and monitoring of important marine biotopes in Wales.

Volume 3. Infralittoral biotopes.

Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales

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Contents

Sponge crusts and anemones on wave-surged vertical infralittoral rock (EIR.SCAn)

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Last updated 29/05/2002

This information is not refereed.

Dense growths of *Corynactis* with sponge crusts. Image width ca XX cm.
Image: Kate Northen / Joint Nature Conservation Committee

Recorded and expected EIR.SCAn distribution for Britain and Ireland

Description of biotope

Vertical very exposed and exposed bedrock gullies, tunnels and cave entrances subject to wave-surge dominated by sponge crusts (such as *Clathrina coriacea*, *Leucosolenia botryoides* and *Halichondria panicea*) and anemones (such as *Sagartia elegans* and dwarf *Metridium senile*) generally dominate the area, the anemones often appearing to protrude through the sponge layer. This biotope is generally unaffected by sand scour (compare with those dominated by sponge crusts and ascidians (EIR.SCAs). A variant of this biotope has been identified from the very wave-surged sublittoral fringe with dense aggregations of the hydroid *Tubularia* (EIR.SCAn.Tub). Both of these biotopes may contain colonial ascidians, but never at high densities (compare with EIR.SCAs). Encrusting coralline algae and tufts of foliose red seaweeds may also occur on well-illuminated rock faces. Due to the wave-surged nature and vertical orientation of these biotopes, kelps are rare and certainly never dominate (compare with EIR.LhypFa and EIR.Ala.Myt). This biotope may also include a turf of *Crisia* or *Scrupocellaria* spp. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

None

Biotope classification

UK and Ireland Classification

Major habitat	IR	Infralittoral rock (and other hard substrata)
Habitat complex	EIR	Exposed infralittoral rock
Biotope complex	EIR.SG	Robust faunal cushions and crusts (surge gullies and caves)

Biotope EIR.SCAn Sponge crusts and anemones on wave-surged vertical infralittoral rock

Similar biotopes: EIR.SCAs; EIR.SCAn.Tub.

Other similar biotopes that occur in wave surged situations include EIR.SCAs dominated by sponges and ascidians in conditions affected by scour, and EIR.SCAn.Tub that has dense aggregations of the hydroid *Tubularia indivisa*.

Biotopes represented by this Key Information review:

EIR.SCAn.Tub	Sponge crusts, anemones and *Tubularia indivisa* in shallow infralittoral surge gullies
EIR.SCAs	Sponge crusts and colonial ascidians on wave-surged vertical infralittoral rock
EIR.SCAs.DenCla	*Dendrodoa grossularia* and *Clathrina coriacea* on wave-surged vertical infralittoral rock
EIR.SCAs.ByH	Sponge crusts, colonial (polyclinid) ascidians and a bryozoan/hydroid turf on wave-surged vertical or overhanging infralittoral rock
EIR.SC	Sponge crusts on extremely wave-surged infralittoral cave or gully walls

Other biotope classification schemes

European Union Nature Information System (EUNIS) Habitat classification code: A3.412 - Sponge crusts and anemones on wave-surged vertical infralittoral rock (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

Species in this biotope most likely compete aggressively for space. For instance, the sea anemone *Metridium senile* has 'catch tentacles' that are used to sting other species in the assemblage causing necrotic patches. Others may overgrow encrusting fauna and flora. Sebens (1985), studying similar communities on rock walls in the Gulf of Maine, ranked *Metridium senile* and *Alcyonium siderium* together with *Aplidium pallidum* as the encrusting species of highest competitive ability there. Parallels between the rock wall communities in Maine can be drawn with the species in EIR.SCAn in general terms. It is less clear how competitive *Sagartia elegans* anemones are but they are obviously successful at establishing and reproducing in this biotope. There will be significant competition for food. Many inhabitants of the biotope are suspension feeders and are doubtless in competition for food although the strong water movement is likely to bring a plentiful supply. Many of the species in the biotope are subject to predation although not necessarily that causes mortality. *Metridium senile* is attacked by *Aeolidia papillosa* and by *Pycnogonum litorale* whilst *Halichondria panicea* is consumed by *Henricia sanguinolenta* at least. *Alcyonium digitatum* is attacked by *Tritonia hombergii* and *Simnia patula*. (See *MarLIN* Web sites for separate species).

Seasonal and longer term change

None have been recorded but the biotope is found in very wave exposed conditions where surveys are only likely in summer. Sebens (1985) found that, for similar rock wall communities in Gulf of Maine, there was year-to-year variability in percentage cover of component species but composition never drastically changed.

Habitat structure and complexity

The habitat includes few features that might create microhabitats or localized shelter. Fissures in the rock do, however, provide shelter and a habitat for crabs and other crustaceans to colonize.

Dominant trophic groups Suspension feeders
Predators

Productivity

The biotope is highly productive in terms of animal tissue (secondary production).

Major sources of organic carbon	Detritus Dissolved organic matter

Recruitment processes

Predominantly from the plankton. The majority of the species in the biotope have long-lived planktonic larvae.

Time for community to reach maturity

Probably two or three years but competitive interactions and the arrival of slower colonizing species will mean that dynamic stability is unlikely for several years.

Additional information

None.

Habitat preference and distribution

Distribution in Britain and Ireland

Recorded from St Kilda where it is found extensively, sites in north-west Scotland and a location in north-east England.

Habitat preferences

Temperature range preferences	None
Water clarity preferences	Very high clarity / Very low turbidity High clarity / Low turbidity Medium clarity / Medium turbidity
Limiting nutrients	No information found
Other preferences	Wave surge.

Additional information

Few animal species survive extremely wave surged situations but, for those that can, food supply is high and the species that benefit thrive.

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Key structural	*Alcyonium digitatum*	Dead man's fingers
Important functional	*Asterias rubens*	Common starfish
Important other	*Botryllus schlosseri*	Star ascidian
Key functional	*Echinus esculentus*	Edible sea urchin
Important other	*Halichondria panicea*	Breadcrumb sponge
Key structural	*Laminaria hyperborea*	Tangle or cuvie

Key structural	*Metridium senile*	Plumose anemone

Explanation

The species identified to represent sensitivity are representative of major groups occurring in the biotope. Most provide structuring and functional aspects to the community. The representative species include major space occupiers that compete with each other and that are therefore key to the structure and composition of the biotope. The sea urchin *Echinus esculentus* is included as, through its grazing activity, it is important for creating space for encrusting species to settle ('structuring' the community) and may therefore prevent one or a small number of species becoming dominant.

Species found especially in biotope

No text entered

Additional information

Clathrina coriacea, *Sagartia elegans* and *Corynactis viridis* are other species commonly associated with this biotope and which might help to identify sensitivity and recoverability. At the time of writing, they had not been researched and only generally known information about them is taken account of. There are no species listed as especially found in this biotope although several (*Clathrina coriacea*, *Leucosolenia botryoides*, *Tubularia indivisa*, *Sagartia elegans*) are especially found in conditions of severe wave action. Some of the encrusting sponge species present in the biotope may be nationally rare or scarce but information on their distribution is not readily available and may anyway be subject to under-recording.

Biotope sensitivity

Physical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	High	Moderate	Major Decline	High
Smothering	Intermediate	High	Low	Decline	Low
Increase in suspended sediment	Low	Very high	Very Low	No Change	High
Decrease in suspended sediment	Tolerant	Not Relevant	Tolerant	No Change	High
Desiccation	Intermediate	High	Low	Minor Decline	Moderate
Increase in emergence regime	High	High	Moderate	Decline	Moderate
Decrease in emergence regime	Tolerant*	Not Relevant	Not sensitive*	Rise	High
Increase in water flow rate	Not Relevant	Not Relevant	Not relevant	Not Relevant	High
Decrease in water flow rate	Not Relevant	Not Relevant	Not relevant	Not Relevant	High
Increase in temperature	Tolerant	Not Relevant	Tolerant	Not Relevant	Moderate
Decrease in temperature	Tolerant	Not Relevant	Tolerant	Not Relevant	High
Increase in turbidity	Tolerant	Not Relevant	Tolerant	Not Relevant	High
Decrease in turbidity	Low	Very high	Very Low	No Change	Moderate
Increase in wave exposure	Tolerant*	Not Relevant	Not sensitive*	Minor Decline	Moderate

Decrease in wave exposure	High	High	Moderate	Rise	Moderate
Noise	Tolerant	None	Tolerant	Not Relevant	Not Relevant
Visual Presence	Tolerant	Not Relevant	Tolerant	Not Relevant	Not Relevant
Abrasion & physical disturbance	High	High	Moderate	Major Decline	High
Displacement	High	High	Moderate	Major Decline	High
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	Intermediate	High	Low	Minor Decline	Low
Heavy metal contamination	Insufficient information	Not Relevant	Insufficient information	Not Relevant	Not Relevant
Hydrocarbon contamination	Intermediate	Very high	Low	Minor Decline	Low
Radionuclide contamination	Insufficient information	Not Relevant	Insufficient information	Not Relevant	Not Relevant
Changes in nutrient levels	Tolerant*	Not Relevant	Not sensitive*	No Change	Moderate
Increase in salinity	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Decrease in salinity	High	High	Moderate	Decline	Low
Changes in oxygenation	High	High	Moderate	Decline	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	Low	Very high	Very Low	No Change	Low
Introduction of non-native species	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Extraction of key or important characterizing species	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Extraction of important species	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant

Explanation of sensitivity and recoverability

Physical Factors	
Substratum Loss (see benchmark)	The majority of characterizing and dominant species in this biotope are fixed to the substratum and, therefore, will be removed with the substratum. Intolerance is therefore high. For recoverability, see additional information below.
Smothering (see benchmark)	The most likely smothering event in this habitat is by other species, for instance, a dense settlement of a colonial ascidian over other species. Some existing species such as sponges are likely to be killed as access to food and oxygen will be denied. Others, such as *Alcyonium digitatum* and sea anemones will protrude through and above the smothering. Since parts of the community may be partially destroyed and

	the diversity reduced, intolerance is considered intermediate. For recoverability, see additional information below.
Increase in suspended sediment (see benchmark)	The species present in the biotope are mainly passive and active suspension feeders perhaps benefiting from suspended organic matter with the suspended sediment but also possibly adversely affected by clogging of feeding organs by increase in siltation. Overall, it is likely that minor adverse effects will occur due to clogging of feeding organs. Species are unlikely to be killed during high suspended sediment of one month and intolerance has been recorded as low. Recovery will be of condition only and so will be very high.
Decrease in suspended sediment (see benchmark)	The species present in the biotope are mainly passive and active suspension feeders feeding on planktonic organisms, perhaps benefiting from suspended organic matter with the suspended sediment. There might therefore be slightly less food but the adverse effects of silt clogging feeding organs would be removed so, on balance, no adverse effect is likely.
Desiccation (see benchmark)	This biotope may be exposed to air during low water of spring tides but occurs in shaded situations often kept wet by wave action and so is susceptible to minor desiccation. Increased desiccation due to very hot sunny and still weather occurring during those low spring tides may cause some damage to some species in the exposed part of the community. For recoverability, see additional information below.
Increase in emergence regime (see benchmark)	Although this biotope may be exposed to air during low water of spring tides, it is composed of species that are normally fully immersed. If emergence increased by the equivalent of a change in one zone in already lower shore examples of the biotope, several species would be likely to be killed. For recoverability, see additional information below.
Decrease in emergence regime (see benchmark)	This biotope is predominantly fully submerged and may extend its occurrence into previously emergent substrata.
Increase in water flow rate (see benchmark)	The biotope is established as a result of wave surge conditions which are overwhelmingly the most important type of water movement. However, whilst increase in water flow rate is not considered important to this biotope, note that similar biotopes occur in areas exposed to extremely strong tidal streams.
Decrease in water flow rate (see benchmark)	The biotope is established as a result of wave surge conditions which are overwhelmingly the most important type of water movement. Therefore Not relevant is indicated. Nevertheless, the biotope has similarities to ones found in extremely strong tidal flows where decrease in water flow would be important.
Increase in temperature (see benchmark)	Some of the species that dominate this biotope (for instance, *Alcyonium digitatum* and *Metridium senile*) appear to be most abundant in colder waters of the north-east Atlantic. However, their distribution extends well south of the British Isles and short-term increases in temperatures are unlikely to affect their abundance. The sea urchin *Echinus esculentus* may be intolerant of an increase in temperature. Bishop (1985) suggested that this species cannot tolerate high temperatures for prolonged periods due to increased respiration rate and resultant metabolic stress. Longer term increase in temperature may allow species such as *Corynactis viridis*, a southern species, to increase in dominance. Overall, the short-term increase in temperature that this factor includes is unlikely to adversely affect the biotope.
Decrease in temperature (see benchmark)	Species that dominate this biotope are mainly widespread further north in the north-east Atlantic and the biotope is not expected to change as a result of decrease in temperature whether short term or for one year. If temperature decrease was for a longer period, some species might switch to functionally similar ones with a more northern distribution, for instance, *Strongylocentrotus droebachiensis* for *Echinus*

	esculentus.
Increase in turbidity (see benchmark)	The community is animal dominated and characterized so that reduction in light levels as a result of increased turbidity is not relevant.
Decrease in turbidity (see benchmark)	Decrease in turbidity may lead to colonization of the biotope by some algal species. However, since the biotope is in shaded situations, the algae are likely to occupy little space and not displace animal species. Therefore intolerance is assessed as low. The habitat is highly amenable to domination by animals that spread rapidly and, on return to previous conditions, algae are likely to be overwhelmed.
Increase in wave exposure (see benchmark)	The biotope occurs in very wave exposed situations and appears to thrive in the most severe conditions. Therefore, an increase in wave exposure is likely to develop this biotope from, perhaps, a different biotope or a less well-developed example of EIR.SCAn. However, species richness may fall as the biotope becomes dominated by only the most wave tolerant species.
Decrease in wave exposure (see benchmark)	The biotope is found only in wave surge habitats on very exposed coasts and the species in it are some of the small number that are able to survive such severe conditions. Decrease in wave exposure would allow other species to colonize the biotope and it is likely that a different biotope, for instance MIR.AlcByH (*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock), would develop. Therefore, intolerance is high even though species richness is likely to increase as the biotope will be lost.
Noise (see benchmark)	Species in the biotope are not sensitive to noise except that some fish might leave or avoid the area of the biotope.
Visual Presence (see benchmark)	Species in the biotope are not sensitive to visual presence. Fish and crustaceans will probably react to shading, although not to the extent that change will occur.
Abrasion & physical disturbance (see benchmark)	Organisms living in the biotope are likely to be damaged or removed by physical disturbance. A few will escape as they are present in crevices or fissures. Overall, a high intolerance is expected. For recoverability, see additional information below.
Displacement (see benchmark)	The majority of organisms that characterize this biotope are sessile and would not reattach once displaced. Some, such as sea anemones are capable of reattachment but are more likely to be swept away in the exposed conditions that this biotope occurs. Therefore an intolerance of high is recorded. For recoverability, see additional information below.
Chemical Factors	
Synthetic compound contamination (see benchmark)	Little evidence has been found. However, Smith (1968) reported dead colonies of *Alcyonium digitatum* at a depth of 16m in the locality of Sennen Cove (Pedu-men-du, Cornwall) resulting from the offshore spread and toxic effect of detergents during the *Torrey Canyon* oil spill. Also, *Echinus esculentus* may be intolerant. Large numbers of dead *Echinus esculentus* were found between 5.5 and 14.5 m in the vicinity of Sennen Cove, presumably due to a combination of wave exposure and heavy spraying of dispersants in that area (Smith, 1968). Hoare & Hiscock (1974) observed that *Urticina felina* survived near to an acidified halogenated effluent discharge in a 'transition' zone where many other species were unable to survive, suggesting a tolerance to chemical contamination. The biotope is shallow and therefore susceptible to chemicals near to the surface. Overall, an intolerance of intermediate is given but with a low confidence.
Heavy metal contamination (see benchmark)	Insufficient information.

Hydrocarbon contamination (see benchmark)	This is a sublittoral biotope and oil spills that are not dispersed into the water column are unlikely to have an effect on the majority of species because concentrations in the water column are likely to be low. However, the biotope occurs in wave exposed situations where oil may be distributed into the water column. Rostron & Bunker (1997) found that, on the whole, sublittoral epibenthic rock communities were in "good condition" following the Sea Empress oil spill. However, small crustaceans, which are known to be particularly intolerant of oil pollution, might have been affected. For one species that is considered characteristic of the biotope and important within it, *Echinus esculentus*, there may be a significant impact. Large numbers of dead *Echinus esculentus* were found between 5.5 and 14.5 m in the vicinity of Sennen Cove during the *Torrey Canyon* oil spill, presumably due to a combination of wave exposure and heavy spraying of dispersants in that area (Smith, 1968). Because of the likely susceptibility of some species in the biotope, intolerance is identified as intermediate but with low confidence. For recoverability, see additional information below.
Radionuclide contamination (see benchmark)	Insufficient information.
Changes in nutrient levels (see benchmark)	A slight increase in nutrient levels could be beneficial for suspension feeding species in the biotope by promoting growth of phytoplankton and therefore increasing food supplies. Indeed, *Balanus crenatus*, a species frequently found in the biotope, was the dominant species on pier pilings, which were subject to urban pollution (Jakola & Gulliksen, 1987). Although increased nutrients may cause algae to thrive and smother species, this biotope is shaded and algal increase is not likely to be relevant.
Increase in salinity (see benchmark)	The biotope and similar biotopes are found in full salinity, therefore a further increase in salinity is unlikely.
Decrease in salinity (see benchmark)	Only a minority of the species in the biotope are believed to tolerate decreased salinity (for instance, *Metridium senile* - see *MarLIN* Web site). The distribution of others such as *Alcyonium digitatum* and *Echinus esculentus* only or mainly on the open coast suggests that they are likely to be intolerant of decrease in salinity. An intolerance of high is suggested but with low confidence due to lack of specific information.
Changes in oxygenation (see benchmark)	The habitat that this biotope occurs in is one where oxygenation is going to be very high. For some of the major structural or functional species (for instance *Alcyonium digitatum*, *Echinus esculentus*, intolerance has been established to be high (see species reviews). Recoverability is expected to be high (see additional information below).
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	*Echinus esculentus*, which may be important in this biotope in clearing space for settlement, is susceptible to 'bald-sea-urchin disease', which causes lesions, loss of spines, tube feet, pedicellaria, destruction of the upper layer of skeletal tissue and death. It is thought to be caused by the bacteria *Vibrio anguillarum* and *Aeromonas salmonicida*. However, no evidence of mass mortalities of *Echinus esculentus* associated with disease has been recorded in Britain and Ireland. Galls on the blade of *Laminaria hyperborea* and spot disease are associated with the endophyte *Streblonema* sp. although the causal agent is unknown (bacteria, virus or endophyte). Resultant damage to the blade and stipe may increase losses in storms. The endophyte inhibits spore production and therefore recruitment and recoverability. Larger predators such as *Simnia patula* which feeds on *Alcyonium digitatum* and *Aeolidia papillosa* which feeds on *Metridium senile* may be more important than microbial pathogens in causing mortality to key species in the biotope.

Introduction of non-native species (see benchmark)	There are no current non-native species that are known to occur in this biotope. However, future arrivals may include species that could dominate the habitat and displace native species.
Extraction of key or important characterizing species (see benchmark)	No key or important characterizing species are known to be extracted. *Laminaria hyperborea* is extracted but not from such wave exposed situations.
Extraction of important species (see benchmark)	No important structural or functional species are known to be extracted. *Laminaria hyperborea* is extracted but not from such wave exposed situations.

Additional information

Recoverability

Many of the species in this and similar biotopes are fast colonizing and almost all of the sessile species have planktonic larvae or propagules. For instance, for *Metridium senile*, Sebens (1985) suggests that the larva is lecithotrophic but has a 'pre-metamorphosis' period of months, a dispersal potential of >10,000m and a colonization rate of 5-10 years. Growth of *Metridium senile* is rapid. Bucklin (1985) working in Britain found that for *Metridium senile* f. *dianthus* fragments and for *Metridium senile* f. *pallidum* newly settled individuals, a growth rate of up to 0.6 mm and 0.8 mm in pedal diameter per day occurred respectively. Another dominant species, *Alcyonium digitatum*, spawns during December and January. Gametes are released into the water and fertilization occurs externally. The embryos are neutrally buoyant and float freely for 7 days. The embryos give rise to actively swimming lecithotrophic planulae which may have an extended pelagic life (see below) before they eventually settle (usually within one or two further days) and metamorphose to polyps (Hartnoll, 1975; 1998). Some species might be slower to colonize and grow but it is expected that close to a full complement of species will have re-settled within five years. Sebens (1985) manipulated similar communities including by scraping rocks clear of existing fauna, and concluded that scraped areas returned to an approximation of the previous state within two years.

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors							
	Alcyonium digitatum	***Asterias rubens***	***Botryllus schlosseri***	***Echinus esculentus***	***Halichondria panicea***	***Laminaria hyperborea***	***Metridium senile***
Community Importance	Key structural	Important functional	Important other	Key functional	Important other	Key structural	Key structural
Substratum Loss	High	High	High	High	High	High	High
Smothering	Intermediate	Low	High	Intermediate	High	Low	Low
Increase in suspended sediment	Low	Low	High	Low	Low	Low	Low
Decrease in suspended sediment	See explanation	See explanation	See explanation	See explanation	Not Sensitive	See explanation	Not Sensitive*
Desiccation	Not Relevant	High	Intermediate	Intermediate	Intermediate	High	Intermediate
Increase in emergence regime	Not Relevant	Not Sensitive	Intermediate	Low	Intermediate	High	High
Decrease in emergence regime	See explanation	See explanation	See explanation	See explanation	Not Sensitive	See explanation	Not Sensitive*
Increase in water flow rate	Not Sensitive*	Intermediate	Intermediate	Low	Intermediate	High	Intermediate

Decrease in water flow rate	Intermediate	See explanation	See explanation	See explanation	Low	See explanation	Low
Increase in temperature	Low	High	Low	Intermediate	Low	High	Not Sensitive
Decrease in temperature	Low	Low	See explanation	See explanation	Low	See explanation	Not Sensitive
Increase in turbidity	Low	Low	Low	Low	Not Sensitive	Intermediate	Not Sensitive*
Decrease in turbidity	See explanation	See explanation	See explanation	See explanation	Not Sensitive	See explanation	Intermediate
Increase in wave exposure	Not Sensitive	Intermediate	Intermediate	Low	Intermediate	High	Low
Decrease in wave exposure	Intermediate	Low	See explanation	See explanation	Low	See explanation	Not Sensitive*
Noise	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive
Visual Presence	Not Sensitive	Not Sensitive	Not Sensitive	Low	Not Sensitive	Not Sensitive	Not Sensitive
Abrasion & physical disturbance	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Displacement	High	Low	High	Low	High	High	Low
Chemical factors							
	Alcyonium digitatum	***Asterias rubens***	***Botryllus schlosseri***	***Echinus esculentus***	***Halichondria panicea***	***Laminaria hyperborea***	***Metridium senile***
Community Importance	Key structural	Important functional	Important other	Key functional	Important other	Key structural	Key structural
Synthetic compound contamination	Intermediate	Intermediate	Insufficient information	High	Insufficient information	Low	Low
Heavy metal contamination	Insufficient information	Intermediate	Insufficient information	High	Insufficient information	Intermediate	Insufficient information
Hydrocarbon contamination	Low	High	Insufficient information	High	Low	Low	Low
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	Low	Low	Low	Not Sensitive*	Insufficient information	Intermediate	Not Sensitive*
Increase in salinity	Intermediate	High	Intermediate	Intermediate	Low	Intermediate	Low
Decrease in salinity	See explanation	See explanation	See explanation	See explanation	Low	See explanation	Low
Changes in oxygenation	High	High	Intermediate	Intermediate	Intermediate	Insufficient information	Not Sensitive
Biological factors							
	Alcyonium digitatum	***Asterias rubens***	***Botryllus schlosseri***	***Echinus esculentus***	***Halichondria panicea***	***Laminaria hyperborea***	***Metridium senile***
Community Importance	Key structural	Important functional	Important other	Key functional	Important other	Key structural	Key structural
Introduction of microbial pathogens/ parasites	Insufficient information	Intermediate	Insufficient information	Intermediate	Insufficient information	Low	Insufficient information
Introduction of non-native species	Insufficient information	Insufficient information	Not Sensitive*	Not Relevant	Insufficient information	Insufficient information	Not Sensitive

Extraction of this species	Not Relevant	Not Relevant	Not Relevant	Intermediate	Not Relevant	Intermediate	High
Extraction of other species	Intermediate	Low	High	Low	High	Intermediate	High

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors							
	Alcyonium digitatum	***Asterias rubens***	***Botryllus schlosseri***	***Echinus esculentus***	***Halichondria panicea***	***Laminaria hyperborea***	***Metridium senile***
Community Importance	Key structural	Important functional	Important other	Key functional	Important other	Key structural	Key structural
Substratum Loss	High	High	High	High	High	Moderate	High
Smothering	High	Very high	High	High	High	Immediate	Immediate
Increase in suspended sediment	Very high	High	High	Very high	Immediate	Immediate	Immediate
Decrease in suspended sediment	See explanation	See explanation	See explanation	See explanation	Not Relevant	See explanation	Not Relevant
Desiccation	Not Relevant	High	High	High	Very high	Moderate	High
Increase in emergence regime	Not Relevant	Not Relevant	High	Very high	Very high	Moderate	High
Decrease in emergence regime	See explanation	See explanation	See explanation	See explanation	Not Relevant	See explanation	Not Relevant
Increase in water flow rate	Not Relevant	High	High	Very high	Very high	Moderate	Very high
Decrease in water flow rate	High	See explanation	See explanation	See explanation	Immediate	See explanation	Very high
Increase in temperature	High	High	Very high	High	Very high	Moderate	Not Relevant
Decrease in temperature	High	High	See explanation	See explanation	Very high	See explanation	Not Relevant
Increase in turbidity	Very high	Very high	Immediate	Very high	Not Relevant	Moderate	Not Relevant
Decrease in turbidity	See explanation	See explanation	See explanation	See explanation	Not Relevant	See explanation	High
Increase in wave exposure	Not Relevant	High	Moderate	Very high	Very high	Moderate	Immediate
Decrease in wave exposure	High	High	See explanation	See explanation	Very high	See explanation	Not Relevant
Noise	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Not Relevant	Not Relevant	Immediate	Not Relevant	Not Relevant	Not Relevant
Abrasion & physical disturbance	High	High	High	High	High	Moderate	Very high
Displacement	High	Immediate	Moderate	Very high	High	Moderate	Very high
Chemical factors							
	Alcyonium digitatum	***Asterias rubens***	***Botryllus schlosseri***	***Echinus esculentus***	***Halichondria panicea***	***Laminaria hyperborea***	***Metridium senile***
Community Importance	Key structural	Important functional	Important other	Key functional	Important other	Key structural	Key structural
Synthetic	High	High	Not Relevant	High	Not Relevant	Immediate	Very high

compound contamination							
Heavy metal contamination	Insufficient information	High	Not Relevant	High	Not Relevant	Immediate	Not Relevant
Hydrocarbon contamination	High	High	Not Relevant	High	High	Immediate	Immediate
Radionuclide contamination	Insufficient information	Insufficient information	Not Relevant	Insufficient information	Not Relevant	Insufficient information	Not Relevant
Changes in nutrient levels	High	High	High	Not Relevant	Not Relevant	Moderate	Not Relevant
Increase in salinity	High	High	High	High	High	Moderate	Immediate
Decrease in salinity	See explanation	See explanation	See explanation	See explanation	High	See explanation	Very high
Changes in oxygenation	High	High	High	High	High	Not Relevant	Not Relevant
Biological factors							
	Alcyonium digitatum	***Asterias rubens***	***Botryllus schlosseri***	***Echinus esculentus***	***Halichondria panicea***	***Laminaria hyperborea***	***Metridium senile***
Community Importance	Key structural	Important functional	Important other	Key functional	Important other	Key structural	Key structural
Introduction of microbial pathogens/ parasites	Insufficient information	High	High	High	Not Relevant	Immediate	Not Relevant
Introduction of non-native species	Insufficient information	Insufficient information	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Extraction of this species	Not Relevant	Not Relevant	Not Relevant	High	Not Relevant	Moderate	High
Extraction of other species	High	High	Moderate	Very high	High	Moderate	High

Importance

Marine natural heritage importance

Listed under:	**UK Biodiversity Action Plan** **EC Habitats Directive**
National importance	Scarce
Habitat Directive feature (Annex 1)	Reefs Submerged or partly submerged sea caves Large shallow inlets and bays
UK Biodiversity Action Plan habitat	Inshore sublittoral rock (broad habitat statement)

Biotope importance

Important for predators on component species (see 'Ecological relationships').

Exploitation

None

Additional information

The biotope includes a very dynamic community of species including fast-growing colonizers. The habitat could be a component of Marine Nature Reserves established under the Wildlife and Countryside Act 1981.

This Biology and Sensitivity Key Information review can be cited as follows:
Hiscock, K., 2002. Sponge crusts and anemones on wave-surged vertical infralittoral rock. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 25/01/2005]. Available from: <http://www.marlin.ac.uk>

Laminaria digitata and piddocks on sublittoral fringe soft rock (MIR.Ldig.Pid)

Key information authored by: Jacqueline Hill

Last updated 30/09/2000

This information is not refereed.

View across shore showing extensive kelp beds on chalk. Image width ca 4 m.
Image: David George / Joint Nature Conservation Committee

Recorded and expected MIR.Ldig.Pid distribution for Britain and Ireland

Description of biotope

Soft rock, such as chalk, in the sublittoral fringe characterized by *Laminaria digitata* and rock-boring animals such as piddocks (*Barnea candida*, *Pholas dactylus* and *Petricola pholadiformis*), the bivalve *Hiatella arctica* and worms *Polydora* spp. Beneath the kelp forest, a wide variety of red seaweeds, including *Corallina officinalis*, *Palmaria palmata*, *Chondrus crispus*, *Membranoptera alata* and *Halurus flosculosus*, may occur. Empty piddock burrows are often colonized by the anemones *Sagartia elegans* or by the sand-tube building worm *Sabellaria spinulosa*. The undersides of small chalk boulders are colonized by encrusting bryozoans, colonial ascidians and the keel worm *Pomatoceros lamarcki*. The boulders and any crevices within the chalk provide a refuge for small crustaceans such as *Carcinus maenas*, young *Cancer pagurus*, *Pagurus bernhardus* and *Porcellana platycheles* . [Further data and analysis still required]. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

No text entered

Biotope classification		
UK and Ireland Classification		
Major habitat	IR	Infralittoral rock (and other hard substrata)
Habitat complex	MIR	Moderately exposed infralittoral rock
Biotope complex	MIR.KR	Kelp with red seaweeds (moderately exposed rock)
Biotope	MIR.Ldig.Pid	*Laminaria digitata* and piddocks on sublittoral fringe soft rock

Similar biotopes: MIR.Ldig.Ldig

Other biotope classification schemes

European Union Nature Information System (EUNIS) classification: A3.2/BMIR.KR Kelp and red seaweeds on moderately exposed infralittoral rock (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

Kelp habitats are dynamic ecosystems where competition for space, light and food result in patchy distribution patterns of flora and fauna. Kelp biotopes are diverse species rich habitats and over 1,200 species have been recorded in UK moderately exposed kelp biotopes (MIR.KR) (Birkett *et al.*, 1998). Kelps are major primary producers; up to 90% of kelp production enters the detrital food web and is probably a major contributor of organic carbon to surrounding communities (Birkett *et al*., 1998). Major interactions are thought to be the effects of competition for space, shading, herbivory and predation.

- In most kelp biotopes there is evidence of strong competition for space, especially for space on a favourable substratum. Competition may between individual plants of the same species, between kelps and substratum-colonizing species of animals and other algae and between colonial animals and encrusting algae. Competition for space between individuals and species is dynamic, resulting in a constantly changing patchwork of species covering any suitable substrata within the biotope.
- The blades of *Laminaria digitata* plants form a canopy layer which may cut off much of the incident irradiance. This restricts the development of species with high light demands so that the understorey of plants becomes dominated by shade tolerant red algae. It also allows species normally restricted to the lower infralittoral in kelp-free areas to compete more effectively in the reduced light levels of the kelp bed and so are found at shallower depths.
- Within kelp beds there are relatively few species that are directly grazing either the kelp or the understorey algae as the enzymes required to directly utilize algae as food are not common. Those species able to graze directly on the kelp include the gastropods: *Gibbula* spp., *Littorina* spp., *Haliotis tuberculata* (in the Channel Islands only), *Helcion pellucidum*, *Lacuna* spp. and the Rissoidae, together with some amphipods and isopods. *Helcion pellucidum* grazes epiphytes and the kelp tissue directly, forming pits similar to the home scars of intertidal limpets. The larger, laevis form excavates large cavities in the holdfast of *Laminaria* spp. which creates tissue damage weakening the adult plant and possibly contributes to its loss due to wave action and storms (Kain, 1979). Infestation with *Helcion pellucidum* varies between sites and decreases with depth.
- Burrowing species such as the piddocks, including the common piddock *Pholas dactylus*, and the tube worm *Polydora ciliata* are characteristic of this biotope and contribute to the creation of a relatively high silt environment through burrowing activities. The abundance of filter feeding organisms such as sponges, bryozoans and tunicates within kelp biotopes indicates the importance of planktonic input to the benthic community. Although very little information is available about planktonic communities in kelp beds it can be assumed that there will be larger inputs of larval stages from species with bentho-pelagic life cycles than in the general plankton (Birkett *et al.*, 1998).
- Predation within kelp beds has not been well studied in the UK. Although some species are known to prey on others, such as starfish on mussels, very little is known of the predator-prey relationships for the many species occurring in kelp beds.
- Kelp plants are exploited as a habitat; the holdfast, stipe and frond each support a different type of community consisting of possibly thousands of individuals from hundreds of species; holdfasts shelter a particularly rich diversity of animals from a wide range of taxa (see Habitat complexity).

Seasonal and longer term change

Most species in the biotope are perennial and seasonal changes are likely to be in condition of individuals rather than presence or absence.

- Growth rate of *Laminaria digitata* is seasonally controlled with a period of rapid growth from February to July and one of slower growth from August to January. Increased wave exposure and storms in winter months are likely to erode *Laminaria digitata* blades so that they appear tattered in winter months and overall standing biomass is reduced. Periodic storms are also likely to remove older and weaker plants creating patches cleared of kelp and increasing the local turbidity. Cleared patches may encourage growth of sporelings or gametophyte maturation. Growth of understorey algae is also reduced in the winter months.

- Some species of algae have seasonally heteromorphic life histories spending a part of the year as a cryptic or encrusting growth form and only becoming recognizable in the foliose phase of their life cycles. The occurrence of such algae is often seen as the occurrence of 'ephemeral' algae. Some hydrozoans may be present in the kelp bed in their attached, colonial form only for a part of the year, spending the rest of the year as medusae.
- With a life span of less than a year and a reproductive period of 3-4 months in the spring or summer numbers of *Polydora ciliata* are likely to be fairly seasonal with highest abundance of individuals after recruitment in the summer and autumn.
- Very little information is available regarding longevity and recruitment of *Pholas dactylus*. Spawning takes place in summer months so recruitment probably occurs in the period during late summer and autumn. However, the species grows up to 150 mm long and so probably has a lifespan of several years. It is likely that populations of *Pholas dactylus* will not be subject to significant seasonal changes in abundance.

It should be emphasized that present understanding of the natural fluctuations in the species assemblages, populations, distribution and diversity of species in kelp habitats is very limited.

Habitat structure and complexity

The structure of the biotope is complex with many different microhabitats. They include bedrock, crevices, sediment pockets, the holdfast, stipe and blade of *Laminaria digitata* plants themselves, undersides of boulders and empty piddock burrows.

- Holdfasts provide refuge to a wide variety of animals supporting a diverse fauna that represents a sample of the surrounding mobile fauna and crevice dwelling organisms, e.g. polychaetes, small crabs, gastropods, bivalves, and amphipods.
- Kelp fronds are grazed by molluscs such as the blue-rayed limpet *Helcion pellucidum*.
- Older *Laminaria digitata* stipes provide a substratum for a large number of epiphytic flora and fauna and it has been estimated that rugose stipes provide one and a half times that surface area provided by the bedrock (Jones *et al*., 2000).
- Empty burrows of piddocks, such as the common piddock *Pholas dactylus*, create additional refugia which are recorded as being colonized by anemones and sand-tube building polychaetes. Other species seeking refuges, such as small crabs and worms doubtless use empty piddock holes.
- The understorey of red algae and crevices in the bedrock provide space for many cryptic fauna.
- In areas of mud tubes built by *Polydora ciliata* can agglomerate and form layers of mud up to an average of 20 cm thick, occasionally to 50 cm. These layers can eliminate the original fauna and flora, or at least can be considered as a threat to the ecological balance achieved by some biotopes (Daro & Polk, 1973).

Dominant trophic groups	Photoautotrophs Suspension feeders Deposit feeders (detritivores)

Productivity

Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone kelps produce nearly 75% of the net carbon fixed and large kelps often produce annually well in excess of a kilogram of carbon per square metre of shore. However, only about 10% of this productivity is directly grazed. Kelps contribute 2-3 times their standing biomass each year as particulate detritus and dissolved organic matter that provides the energy supply for filter feeders and detritivores, such as piddocks and polychaetes like *Polydora ciliata*, in and around the kelp bed. 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 make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains.

Major sources of organic carbon	Photosynthesis (macroalgae and/or halophytic plants) Detritus Dissolved organic matter

Recruitment processes

Most species in this biotope produce planktonic propagules annually and so recruitment is often from distant sources and is frequent.

- Benthic species, plant and animal, that possess a planktonic stage: gamete, spore or larvae, are likely to be influenced by kelp mediated alteration of fluid and particulate, and consequently larval fluxes. Kelp canopies also affect the physical environment, such as the substratum, experienced by actively settling planktonic larvae. The substrata beneath kelp plants for example, are often dark and sediment laden, conditions likely to affect larval settlement and post settlement survival. Both the demographic structure of populations and the composition of assemblages may be profoundly affected by variation in recruitment rates driven by such factors.
- *Laminaria digitata* plants are fertile all year round with maximum production of spores in July - August and November - December. Young sporophytes (germlings) appear all year with maxima in spring and autumn. Chapman (1981) demonstrated that substantial recruitment of *Laminaria digitata* plants to areas barren of kelp plants was possible up to 600m away from reproductive plants.
- *Pholas dactylus* spawns in the summer and larvae are pelagic.
- The spawning period for *Polydora ciliata* varies, from February until June in northern England for example, and from April - September in the Black Sea. Larvae are substrate specific selecting rocks or sediment according to their physical properties settling preferentially on substrates covered with mud
- Among sessile organisms, patterns fixed at settlement, though potentially altered by post settlement mortality, obviously cannot be influenced by dispersal of juveniles or adults.
- Some of the species living in kelp beds do not have pelagic larvae, but instead have direct development producing their offspring as 'miniature adults'.

Time for community to reach maturity

Kain (1975) examined the recolonization of cleared concrete blocks by kelp plants and other algae and found that *Laminaria digitata* plants were re-established within 2 years and that red algae returned with a year. Although there is no information available on colonization times or growth rates for the common piddock the other main rock borer, *Polydora ciliata* is able to rapidly (within months of reproductive period) colonize a suitable area. Recruitment of other species to the kelp bed may take longer. However, maturity is likely to be reached within five years.

Additional information

No text entered

Habitat preference and distribution

Distribution in Britain and Ireland

Recorded from a few sites on the south Kent coast and north Wales.

Habitat preferences

Temperature range preferences	
Water clarity preferences	No text entered
Limiting nutrients	Nitrogen (nitrates)
Other preferences	

Additional information

No text entered

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Key structural	*Laminaria digitata*	Oarweed
Key structural	*Pholas dactylus*	Common piddock
Key functional	*Polydora ciliata*	A bristleworm
Important characterizing	*Palmaria palmata*	Dulse

Explanation

Laminaria digitata and *Pholas dactylus* are the key structuring species and also give the name to the biotope. The fronds, stipe and holdfast of the kelp plants create structural complexity within the biotope. The piddock *Pholas dactylus* is a key structuring species because of the holes it makes and the refugia provided by the holes. The burrowing polychaete *Polydora ciliata* is functionally important because tube building can modify the substratum and in areas of mud tubes can agglomerate, forming layers of mud that can sometimes be thick enough to eliminate the original fauna and flora, or at least can be considered as a threat to the ecological balance achieved by some biotopes (Daro & Polk, 1973). The understorey of red algae in the biotope is represented by *Palmaria palmata* which is frequently found both on rocks and sometimes on older *Laminaria digitata* stipes.

Species found especially in biotope

Pholas dactylus Common piddock
Barnea candida White piddock

Additional information

No text entered

Biotope sensitivity

Physical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	High	Moderate	Major Decline	Moderate
Smothering	Intermediate	High	Low	Major Decline	Very low
Change in suspended sediment	Intermediate	High	Low	Decline	Very low
Desiccation	Intermediate	High	Low	Minor Decline	Low
Change in emergence regime	Intermediate	High	Low	Decline	Low
Change in water flow rate	Low	High	Low	Minor Decline	Low
Change in temperature	Intermediate	High	Low	Decline	Moderate
Change in turbidity	Intermediate	High	Low	Major	Moderate

				Decline	
Change in wave exposure	Intermediate	High	Low	Major Decline	Low
Noise	Tolerant	Not Relevant	Tolerant	NR	Not Relevant
Visual Presence	Tolerant	Not Relevant	Tolerant	NR	Not Relevant
Abrasion & physical disturbance	Intermediate	High	Low	Minor Decline	Low
Displacement	High	High	Moderate	Major Decline	Low
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	High	High	Moderate	Major Decline	Moderate
Heavy metal contamination	Intermediate	High	Low	Minor Decline	Low
Hydrocarbon contamination	Intermediate	High	Low	Major Decline	Moderate
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	NR	Not Relevant
Changes in nutrient levels	Low	High	Low	Decline	Very low
Change in salinity	Intermediate	High	Low	Decline	Very low
Changes in oxygenation	Low	High	Low	Decline	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	Low	High	Low	No Change	Moderate
Introduction of non-native species	Low	High	Low	No Change	Moderate
Extraction of key or important characterizing species	Low	High	Low	Major Decline	Low
Extraction of important species	Low	Low	Moderate	No Change	Low

Explanation of sensitivity and recoverability

Physical Factors	
Substratum Loss (see benchmark)	Most of the species characteristic of this biotope are permanently attached to the substratum so would be removed upon substratum loss. These species are unable to re-attach and will be swept away so intolerance is assessed as high. The total population of *Polydora ciliata* is unlikely to be lost because it can reburrow into any remaining suitable substratum. Species diversity will be significantly reduced because many of the microhabitats provided by the characterizing species will be lost. Recovery of the main characterizing species *Laminaria digitata* is rapid with cleared rocks fully recolonized within two years (Kain, 1979). Most other characterizing species have a planktonic larva and/or are mobile and so can migrate into the affected area. Colonization of most species of fauna inhabiting kelp holdfast fauna in Norway were found as early as one year after kelp trawling

	(Christie *et al*., 1998) and on rocks the more diverse community of coralline algae joined by species of cnidarians, bryozoans and sponges seen on undredged plots was absent three years after kelp trawling (Birkett *et al*., 1998). However, although full species richness and abundance may be reduced the appearance of the biotope will be much as before substratum loss and so recovery is high.
Smothering (see benchmark)	Some species, especially adult *Laminaria digitata* plants, are likely to protrude above any smothering material. The burrowing species such as *Pholas dactylus* and *Polydora ciliata* are able to tolerate high levels of smothering and sedimentation. However, others species such as the active suspension feeders and foliose algae are likely to be killed by smothering. Smothering can also be highly detrimental to kelp plants, in particular spores, gametophytes and young plants (Dayton, 1985) which will reduce the kelp population within the biotope and so intolerance has been assessed as intermediate. Species diversity within the biotope is likely to experience a major decline. Recovery is high because most characterizing species have a planktonic larva and/or are mobile and so can migrate into the affected area.
Change in suspended sediment (see benchmark)	*Laminaria digitata* can be found in areas of siltation although in very high silt environments the species may be out-competed by *Laminaria saccharina*. Since many of the species, *Pholas dactylus* and *Polydora ciliata* in particular, in this biotope live in areas of high silt content (turbid water) it is expected that they would survive increased levels of silt in the water. However, very high levels of silt may clog respiratory and feeding organs of some suspension feeders such as sea squirts and may result in a decline in faunal species diversity. Increased siltation is unlikely to have a significant effect in terms of smothering by settlement in the regime of strong water flow typical of this biotope. A significant decrease in siltation levels may reduce food input to the biotope resulting in reduced growth and fecundity.
Desiccation (see benchmark)	The biotope is predominantly sublittoral but does extend onto the shore and therefore has some ability to resist desiccation. *Laminaria digitata* in particular can return to original photosynthetic rate on reimmersion after 40-50% water loss. Species living below the kelp, such as foliose red algae, sponges and ascidians are likely to be protected from the worst effects of desiccation by the kelp canopy. However, increased desiccation equivalent to moving one biological zone up the shore is likely to result in the death of some intolerant sessile species so intolerance of the biotope is assessed as intermediate.
Change in emergence regime (see benchmark)	The biotope is predominantly sublittoral and so a change in the emergence regime at the benchmark level (one hour in the time covered or not covered by the sea for a period of 1 year) is likely to result in a depression of the upper limit of the biotope. Some sessile species, such as sea squirts, are unlikely to survive a long term increase in emergence. Many of the subordinate species, especially solitary sea squirts, are unlikely to survive an increased emergence regime and mobile species are likely to move away so that species diversity will decline. However, in the presence of a suitable substratum the biotope is likely to re-establish further down the shore. Kain (1975) recorded that *Laminaria digitata* had recolonized cleared rocks within 2 years so recovery should be high. Most other characterizing species have planktonic larvae and/or are mobile and so can migrate into the affected area. Growth rates of sessile species in the biotope are generally rapid. For instance, *Halichondria panicea* increases by about 5% per week (Barthel, 1988).
Change in water flow rate (see benchmark)	The biotope occurs in a wide range of water flow environments, from very weak to moderately strong and so will be relatively tolerant of changes. In areas of very strong water flow it is often out-competed by *Alaria esculenta* and in much slower water by *Laminaria saccharina*. *Laminaria digitata* is not found in areas subject to sand scouring. Water motion affects light by moving canopies and influences

	the impact of sedimentation and scour and importantly water motion determines the availability of nutrients. It is unlikely that species in the biotope will be killed by an increase or decrease in flow rate. Existing organisms are likely to persist although conditions will not be ideal. Decreased water flow will lead to a reduced competitive advantage for suspension feeding animals especially sponges which will decline in growth rate.
Change in temperature (see benchmark)	*Laminaria digitata* is a eurythermal species with sporophytes growing over a wide temperature range. Lüning (1984) detected a seasonal shift in heat tolerance of *Laminaria digitata* plants in Helgoland of 2 °C between spring and summer so the species is likely to be relatively tolerant of a long term, chronic change in temperature. However, the biotope may be intolerant of rapid changes in temperature outside its tolerance range. During an exceptionally warm summer in Norway, Sundene (1964) reported the destruction of *Laminaria digitata* plants exposed to temperatures of 22-23 °C. In Scotland, when spring low tides coincided with night time extreme air frosts on several consecutive days, mortality of all but the lowest shore adult *Laminaria digitata* plants occurred (Todd & Lewis, 1984). Therefore, the biotope is likely to be of intermediate intolerance to short term acute temperature change. Loss of plants will result in reduces species diversity.
Change in turbidity (see benchmark)	Changes in turbidity may affect the distribution or growth rates of *Laminaria digitata* and other algae. Reduced turbidity may increase productivity of kelps and other algae but is not expected to increase the depth range to which the biotope extends because limiting conditions for the depth to which *Laminaria digitata* can grow are not usually to do with light, but due to competition with the truly sublittoral kelp *Laminaria hyperborea*. Increases in turbidity around a sewage treatment plant was thought to be responsible for the absence of *Laminaria digitata* plants in the Firth of Forth (Read *et al.*, 1983) and has been reported to result in a reduced depth range and the fewer new plants under the kelp canopy. An increase in turbidity will reduce photosynthesis and growth of plants. On return to normal turbidity levels the growth rate would be quickly return to normal. In almost all cases not involving canopy competition, irradiance is most severely reduced by suspended particles in the water column (Dayton, 1985). There may be some clogging of suspension feeding apparatus in sea squirts, brittle stars and feather stars although those groups survive in occasionally very turbid conditions. Species richness may decline in the long-term.
Change in wave exposure (see benchmark)	The biotope occurs in areas of moderate wave exposure. Although the kelp *Laminaria digitata* can tolerate a wide range of wave exposures a significant increase in wave exposure will have a detrimental effect on the biotope because of the friable nature of the substratum resulting in a loss of sessile species. Changes in wave exposure may also interfere with feeding for the piddocks, *Polydora ciliata* and other suspension feeding organisms.
Noise (see benchmark)	The macroalgae characterizing the biotope have no known sound or vibration sensors. The response of macroinvertebrates is not known.
Visual Presence (see benchmark)	Macrophytes have no known visual sensors. Most macroinvertebrates have poor or short range perception and although some are likely to respond to shading caused by predators the biotope as a whole is unlikely to be sensitive to visual disturbance.
Abrasion & physical disturbance (see benchmark)	The fronds of *Laminaria digitata* are leathery and the whole plant is very flexible so physical disturbance by a scallop dredge or an anchor landing on or being dragged across the seabed, is unlikely to cause significant damage to the kelp bed as a whole. However, some plants may be fatally damaged or ripped off the substratum. Other algae and sessile species such as sponges and large solitary tunicates are likely to be sensitive to abrasion and so the biotope as a whole has

	been assessed as having intermediate intolerance.
Displacement (see benchmark)	Displacement of *Laminaria digitata*, the key species, will result in loss of the biotope because plants are unable to re-attach. Species abundance and diversity will be significantly reduced because the additional habitats and refugia provided by kelp fronds, stipes and particularly the holdfast will be lost. However, recovery is good because recolonization of kelp plants to previous densities takes place within about 2 years (Kain, 1975). Similarly, displaced piddocks will be lost but empty burrows may provide additional refugia for small invertebrates.
Chemical Factors	
Synthetic compound contamination (see benchmark)	Several of the species characteristic of the biotope are reported as having high intolerance to synthetic chemicals. For instance, Cole *et al*. (1999) suggests that herbicides such as Simazina and Atrazine are very toxic to macrophytic algae. Hiscock and Hoare (1974) noted that almost all red algal species were absent from areas adjacent to an acidified halogenated effluent in Amlwch Bay, North Wales. Red algae have also been found to be sensitive to oil spill dispersants (O'Brien & Dixon, 1976). Bivalve molluscs, such as piddocks are reported to be very intolerant of TBT contamination (see *Pholas dactylus* review) with reduced abundance and growth reported in the field and laboratory. Other species in the biotope, in particular polychaete worms, are much more tolerant of chemical pollutants. The tube dwelling polychaetes *Polydora ciliata* and *Pomatoceros triqueter*, for example, flourished close to the Amlwch Bay bromide extraction plant effluent (Hoare & Hiscock, 1974). Therefore, the result of an increase in synthetic chemicals within the biotope is likely to be the death of several of the more intolerant species, including key species such as *Pholas dactylus*. Abundance of other more pollution tolerant species, especially polychaete worms, is likely to increase. The overall impact is one of the probable loss of key species and a major decline in species diversity and the intolerance of the biotope is therefore reported as high. Recovery is good because recolonization of algae takes place within 2 years and most fauna have pelagic larvae and so can recolonize rapidly.
Heavy metal contamination (see benchmark)	No information is available on the effect of heavy metals on the biotope. Intolerance of the key species is reported as intermediate, with likely effects on growth and fecundity, so biotope intolerance is assessed as intermediate. There may be a decline in overall species diversity with long term heavy metal pollution.
Hydrocarbon contamination (see benchmark)	No significant effects of the *Amoco Cadiz* spill were observed for *Laminaria* populations and the *World Prodigy* spill of 922 tons of oil in Narragansett Bay had no discernible effects on *Laminaria digitata* (Peckol *et al.*, 1990). However, analysis of kelp holdfast fauna after the *Sea Empress* oil spill in Milford Haven illustrated decreases in number of species, diversity and abundance at sites nearest the spill (SEEEC, 1998). It is also expected that other species in the biotope will be intolerant of hydrocarbons. A proliferation of polychaete worms often follows oil spills. A major decline in species diversity within the biotope is likely and so intolerance is reported as intermediate.
Radionuclide contamination (see benchmark)	Insufficient information.
Changes in nutrient levels (see benchmark)	The growth of macroalgae in temperate coastal waters is generally expected to be limited by nitrogen in the summer period. In Helgoland, where ambient nutrient concentrations are double those of the Scotland site *Laminaria digitata* grows in the summer months. Higher growth rates have also been associated with plants situated close to sewage outfalls. However, after removal of sewage pollution in the Firth of Forth, *Laminaria digitata* became abundant on rocky shores from which they had previously been absent. Therefore, although nutrient enrichment

	may benefit *Laminaria digitata*, the indirect effects of eutrophication, such as increased light attenuation from suspended solids in the water column and interference with the settlement and growth of germlings, may be detrimental. Increased nutrients may increase the abundance of ephemeral algae and result in smothering or changing the character of the biotope.
Change in salinity (see benchmark)	Kelps are stenohaline seaweeds, in that they do not tolerate wide fluctuations in salinity (Birkett *et al*., 1998) although *Laminaria digitata* has been reported to grow in salinities of 25psu. The biotope occurs in situations that are naturally subject to fluctuating salinity because of precipitation but kelp growth rates may be adversely affected if subjected to periodic salinity stress. Localized, long term reductions in salinity, to below 20 psu, may result in the loss of kelp beds in affected areas and thus loss of the biotope (Birkett *et al*., 1998). Other species within the biotope may be intolerant of large salinity changes resulting in reduced species diversity.
Changes in oxygenation (see benchmark)	The biotope occurs in areas where still water conditions do not occur and so some species may be intolerant of hypoxia. Cole *et al*. (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2mg/l. For instance, death of a bloom of the phytoplankton *Gyrodinium aureolum* in Mounts Bay, Penzance in 1978 produced a layer of brown slime on the sea bottom. This resulted in the death of fish and invertebrates presumably due to anoxia caused by the decay of the dead dinoflagellates (Griffiths *et al*., 1979). Kinne (1972) reports that reduced oxygen concentrations inhibit both algal photosynthesis and respiration. However, on return to oxygenated conditions, rapid recovery is likely. The main characterizing species, *Laminaria digitata*, colonizes cleared areas of the substratum within two years (Kain, 1975) and most other characterizing species have a planktonic larva and/or are mobile and so can migrate into the affected area.
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	There is very little information available on microbial pathogens infecting the characterizing species of the biotope. However the occurrence of hyperplasia or gall growths, seen as dark spots, on *Laminaria digitata* is well known and may be associated with the presence of endophytic brown filamentous algae. Fronds of *Palmaria palmata* frequently bear algal epiphytes and endophytes, a number of marine fungi and galls produced by nematodes, copepods and bacteria. Growth rates of algae may be impaired by such infections. However, no evidence of losses of this biotope due to disease was found and it is likely that microbial pathogens will have only a minor possible impact on this biotope.
Introduction of non-native species (see benchmark)	The non-native species currently (October 2000) most likely to colonize this biotope are the Northwest Pacific kelp *Undaria pinnatifida* and the Japanese brown algae *Sargassum muticum*. *Undaria pinnatifida*, which has been introduced into south-west Britain in recent years, may cause displacement of native kelps including *Laminaria digitata* although in Brittany only areas inhabited by *Saccorhiza polyschides* have been affected. *Sargassum muticum* which is generally considered to be a 'gap-filler' has not been documented to directly displace *Laminaria digitata* but in France it has replaced *Laminaria saccharina* through over-growing and shading of underlying species (Eno *et al*., 1997). The American piddock *Petricola pholadiformis* has become established along south and east coasts of England from Lyme Regis in Dorset to the Humber although there is no documentary evidence that the species has displaced any native piddocks (Eno *et al*., 1997).
Extraction of key or important characterizing species	Extraction of *Laminaria digitata* does occur although there is no evidence available on the effects of *Laminaria digitata* harvesting on the biodiversity of kelp bed species. However, since the whole plant, including the holdfast is removed it is likely that faunal diversity will show a major decline. Recovery

(see benchmark)	should be high because recolonization by *Laminaria digitata* on cleared rocks takes place within 2 years (Kain, 1979) and most other characterizing species have planktonic larvae and/or are mobile and so can migrate into the affected area.
Extraction of important species (see benchmark)	*Palmaria palmata* is used as a vegetable substitute or animal fodder although harvesting on a commercial scale only takes place in France. Other species in the biotope are unlikely to be significantly affected by the extraction of *Palmaria palmata*.

Additional information

No text entered

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors				
	Laminaria digitata	***Pholas dactylus***	***Polydora ciliata***	***Palmaria palmata***
Community Importance	Key structural	Key structural	Key functional	Important characterizing
Substratum Loss	High	High	High	High
Smothering	Intermediate	Low	Not Sensitive	Intermediate
Increase in suspended sediment	Intermediate	Low	Not Sensitive	Low
Decrease in suspended sediment	See explanation	See explanation	See explanation	See explanation
Desiccation	Intermediate	Intermediate	Intermediate	Intermediate
Increase in emergence regime	Intermediate	Intermediate	Intermediate	Intermediate
Decrease in emergence regime	See explanation	See explanation	See explanation	See explanation
Increase in water flow rate	Low	Low	Intermediate	Intermediate
Decrease in water flow rate	See explanation	See explanation	See explanation	See explanation
Increase in temperature	Intermediate	Intermediate	Low	Intermediate
Decrease in temperature	See explanation	See explanation	See explanation	See explanation
Increase in turbidity	Intermediate	Low	Not Sensitive	Low
Decrease in turbidity	See explanation	See explanation	See explanation	See explanation
Increase in wave exposure	Low	Low	Low	Intermediate
Decrease in wave exposure	See explanation	See explanation	See explanation	See explanation
Noise	Not Sensitive	Low	Not Sensitive	Not Relevant
Visual Presence	Not Sensitive	Low	Low	Not Relevant
Abrasion & physical disturbance	Intermediate	Intermediate	Intermediate	Intermediate
Displacement	High	High	Low	High
Chemical factors				
	Laminaria digitata	***Pholas dactylus***	***Polydora ciliata***	***Palmaria palmata***
Community Importance	Key structural	Key structural	Key functional	Important characterizing
Synthetic compound contamination	Intermediate	High	Low	High
Heavy metal contamination	Intermediate	Intermediate	Intermediate	Intermediate
Hydrocarbon contamination	Low	Insufficient information	Intermediate	High
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient information

Changes in nutrient levels	Low	Insufficient information	Low	Intermediate
Increase in salinity	Intermediate	Intermediate	Low	Intermediate
Decrease in salinity	See explanation	See explanation	See explanation	See explanation
Changes in oxygenation	Insufficient information	Low	Low	Low
Biological factors				
	Laminaria digitata	***Pholas dactylus***	***Polydora ciliata***	***Palmaria palmata***
Community Importance	Key structural	Key structural	Key functional	Important characterizing
Introduction of microbial pathogens/parasites	Low	Insufficient information	Insufficient information	Insufficient information
Introduction of non-native species	Low	Not Sensitive	Insufficient information	Not Relevant
Extraction of this species	Intermediate	Intermediate	Low	Intermediate
Extraction of other species	Intermediate	Not Sensitive	Not Relevant	Intermediate

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors				
	Laminaria digitata	***Pholas dactylus***	***Polydora ciliata***	***Palmaria palmata***
Community Importance	Key structural	Key structural	Key functional	Important characterizing
Substratum Loss	High	High	High	High
Smothering	High	High	Not Relevant	High
Increase in suspended sediment	High	High	Not Relevant	High
Decrease in suspended sediment	See explanation	See explanation	See explanation	See explanation
Desiccation	High	High	High	High
Increase in emergence regime	High	High	High	High
Decrease in emergence regime	See explanation	See explanation	See explanation	See explanation
Increase in water flow rate	High	Very high	High	High
Decrease in water flow rate	See explanation	See explanation	See explanation	See explanation
Increase in temperature	High	High	High	High
Decrease in temperature	See explanation	See explanation	See explanation	See explanation
Increase in turbidity	High	Immediate	Not Relevant	Very high
Decrease in turbidity	See explanation	See explanation	See explanation	See explanation
Increase in wave exposure	High	High	High	High
Decrease in wave exposure	See explanation	See explanation	See explanation	See explanation
Noise	Not Relevant	Immediate	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Immediate	High	Not Relevant
Abrasion & physical disturbance	High	High	High	High
Displacement	High	High	High	High
Chemical factors				
	Laminaria digitata	***Pholas dactylus***	***Polydora ciliata***	***Palmaria palmata***
Community Importance	Key structural	Key structural	Key functional	Important characterizing
Synthetic compound contamination	High	High	High	High
Heavy metal contamination	High	High	High	High
Hydrocarbon contamination	High	Insufficient information	High	High

Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	High	Insufficient information	High	High
Increase in salinity	High	High	High	High
Decrease in salinity	See explanation	See explanation	See explanation	See explanation
Changes in oxygenation	Insufficient information	High	High	Immediate
Biological factors				
	Laminaria digitata	***Pholas dactylus***	***Polydora ciliata***	***Palmaria palmata***
Community Importance	Key structural	Key structural	Key functional	Important characterizing
Introduction of microbial pathogens/parasites	High	Not Relevant	Not Relevant	Not Relevant
Introduction of non-native species	Insufficient information	Not Relevant	Insufficient information	Not Relevant
Extraction of this species	High	High	High	High
Extraction of other species	High	Insufficient information	Not Relevant	High

Importance

Marine natural heritage importance

Listed under:	**UK Biodiversity Action Plan** **EC Habitats Directive**
National importance	Scarce
Habitat Directive feature (Annex 1)	Reefs Large shallow inlets and bays Estuaries
UK Biodiversity Action Plan habitat	Littoral and sublittoral chalk Inshore sublittoral rock (broad habitat statement)

Biotope importance

Kelp beds provide refuge for nursery areas for a wide range of species and 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 habitat during parts of their lifecycles.

- *Laminaria digitata* plants can reduce current flow and ameliorate wave exposure, allowing more delicate organisms to survive in the shallow sublittoral. Shading by the canopy allows shade tolerant algae, especially Rhodophyceae to extend into the upper infralittoral.
- Kelp plants themselves usually become the habitat for other marine species providing attachment sites for a wide range of other seaweeds and sessile animals. Kelp beds also contain a series of stratified habitats supporting an extremely diverse fauna (see ‘Habitat complexity’).
- Kelp beds are important primary producers of organic carbon for surrounding communities (see ‘Productivity’) (Birkett et al. 1998).
- Empty piddock burrows provide refugia for species especially anemones, small crabs and worms.

Exploitation

Kelp species around the world have been exploited over the years as a source of chemicals for industry. Kelp cast up on the shore has long been collected for use as an agricultural fertilizer. More recently *Laminaria digitata* is commercially harvested in Brittany for alginate production and in Ireland and France for sea-vegetable production.

Additional information

No text entered

This Biology and Sensitivity Key Information review can be cited as follows:
Hill, J.M., 2000. *Laminaria digitata* and piddocks on sublittoral fringe soft rock. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/01/2005]. Available from: <http://www.marlin.ac.uk>

Laminaria digitata, ascidians and bryozoans on tide-swept sublittoral fringe rock (MIR.Ldig.T)

Key information authored by: Charlotte Marshall

Last updated 11/01/2005

This information is not refereed.

If you would be willing to supply *MarLIN* with an image of this species/habitat please contact marlin@mba.ac.uk

Recorded and expected MIR.Ldig.T distribution for Britain and Ireland

Description of biotope

Very sheltered bedrock, boulders and cobbles that are subject to moderate to strong tidal water movement characterized by dense *Laminaria digitata*, ascidians and bryozoans. Species richness is generally greater than in the non tide-swept *Laminaria digitata* biotope (MIR.Ldig.Ldig), with a greater abundance and wider range of foliose red seaweeds. The increased water movement encourages several filter-feeding faunal groups to occur. The sponges *Leucosolenia* spp., *Halichondria panicea* and *Hymeniacidon perleve* frequently occur on steep and overhanging faces. In addition, the ascidians *Ascidia conchilega*, *Dendrodoa grossularia* and colonial ascidians are also found. Areas where increased tidal movement influences such a community are in the narrows and/or intertidal sills of sealochs. This biotope may be found immediately below the tide-swept *Fucus serratus* biotope (SLR.Fserr.T). The sublittoral fringe of similarly sheltered shores that are not tide-swept are generally characterized by mixed *Laminaria saccharina* and *Laminaria digitata* (SIR.Lsac.Ldig) or *Laminaria saccharina* (SIR.Lsac). (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

No text entered

Biotope classification

UK and Ireland Classification

Major habitat	IR	Infralittoral rock (and other hard substrata)
Habitat complex	MIR	Moderately exposed infralittoral rock
Biotope complex	MIR.KR	Kelp with red seaweeds (moderately exposed rock)
Biotope	MIR.Ldig.T	*Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock

Other biotope classification schemes

European Union Nature Information System (EUNIS) habitat classification: A3. 2113/MIR.KR.Ldig.T *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

Kelp habitats are dynamic ecosystems where competition for space, light and food result in patchy distribution patterns of flora and fauna. Kelp beds are diverse species rich habitats and over 1,200 species have been recorded in United Kingdom (UK) moderately exposed kelp biotopes (MIR.KR) (Birkett *et al.*, 1998). Kelps are major primary producers; up to 90% of kelp production enters the detrital food web and is probably a major contributor of organic carbon to surrounding communities (Birkett *et al.*, 1998). Major interactions are thought to be the effects of competition for space, shading, herbivory and predation.

- In most kelp biotopes there is evidence of strong competition for space, especially for space on a favourable substratum. Competition may occur between individual plants of the same species, between kelps and substratum-colonizing species of animals and other algae and between colonial animals and encrusting algae. Competition for space between individuals and species is dynamic, resulting in a constantly changing patchwork of species covering any suitable substrata within the biotope, including the surface of the kelp plants themselves. This is especially true of the components of tide-swept biotopes such as MIR.Ldig.T. Tide swept biotopes offer luxuriant conditions for suspension feeders by providing a continual supply of food and removing finer sediment that may otherwise interfere with their delicate feeding apparatus. As a result, strong competition between the suspension feeders that thrive in this biotope will mean that any available substratum is likely to be colonized. Much of the rock surface will be covered by a 'foundation' of encrusting calcareous algae on top of which other species will grow.
- The blades of *Laminaria digitata* plants form a canopy layer, which may cut off much of the incident irradiance. This restricts the development of species with high light demands so that the understorey of plants becomes dominated by shade tolerant red algae including Corallinaceae, *Palmaria palmata*, *Chondrus crispus* and *Ceramium nodulosum*. It also allows species normally restricted to the lower infralittoral in kelp-free areas to compete more effectively in the reduced light levels of the kelp bed and so are found at shallower depths.
- Within kelp beds there are relatively few species that graze either the kelp or the understorey algae directly, as the enzymes required to directly utilize algae as food are not common. However, the gastropod *Gibbula cineraria* is frequently found in this biotope and may graze the kelp, foliose red seaweeds and the rock below. The blue-rayed limpet *Helcion pellucidum* also grazes on kelp and, when younger, red seaweeds such as *Mastocarpus stellatus*, which is commonly found in the understory of this biotope. The edible sea urchin *Echinus* and green sea urchin *Psammechinus milaris* also graze on kelp species in addition to prey species such as bryozoans, tunicates and hydroids.
- Predation within kelp beds has not been well studied in the UK and very little is known of the predator-prey relationships for the many species occurring in kelp beds. The common shore crab *Carcinus maenas* is probably the largest mobile predator associated with this biotope and preys upon *Gibbula cineraria*.
- As mentioned previously, tide swept biotopes offer a continual supply of suspended particulate matter that support a thriving suspension feeding community. Suspension feeders in MIR.Ldig.T

represent several different phyla.

- **Sponges** Of the sponges, the breadcrumb sponge *Halichondria panicea* is most commonly associated with this biotope. This species is usually found as an encrusting mat on rock and algae. *Hymeniacidon perleve* is also likely to be present.
- **Ascidians** Both solitary and colonial ascidians are found in this biotope. The colonial ascidians *Botryllus schlosseri* (the star ascidian) and *Botrylloides leachi*, and the solitary baked bean sea squirt *Dendrodoa grossularia* are all frequent.
- **Cnidaria** Several hydroid species are commonly found on rock below the kelp in this biotope, especially *Dynamena pumila* and *Sertularia argentea*.
- **Crustacea** Crustacean suspension feeders associated with this biotope are not the most important group, in terms of frequency and abundance, but include the barnacles *Balanus crenatus* and *Semibalanus balanoides*.
- **Annelida** The tube worm *Pomatoceros triqueter* is the most common suspension feeing annelid associated within this biotope. It was found in two thirds of the records of this biotope and can rapidly colonize patches of bare rock. Spirorbid worms may be found.
- **Bryozoa** *Alcyonidium gelatinosum*, *Alcyonidium hirsutum*, *Electra pilosa, Membranipora membranacea* and *Scrupocellaria* spp. are all likely to compete for space on the fronds and stipes of the kelp plants.

The dominance of suspension feeding fauna indicates the importance of planktonic input to the benthic community of the biotope. Although very little information is available about planktonic communities in kelp beds it can be assumed that there will be larger inputs of larval stages from species with bentho-pelagic life cycles than in the general plankton (Birkett *et al*., 1998).

- Kelp plants are also exploited as a habitat; the holdfast, stipe and frond each support a different type of community, although only the oldest *Laminaria digitata* plants will have epiphytic flora and fauna on the stipe (which is smooth in all but the oldest individuals). However, holdfasts shelter a particularly rich diversity of animals from a wide range of taxa (see Habitat Complexity). Epiphytes on the stipe may include the sponge *Halichondria panicea* and red algae *Palmaria palmata* and *Phycodrys rubens* whereas the frond is more likely to be colonized by the bryozoan *Membranipora membranacea*.

Seasonal and longer term change

Present understanding of the natural fluctuations in the species assemblages, populations, distribution and diversity of species in kelp beds is limited. The plants in this biotope are likely to experience some seasonal change in abundance, the general pattern being a lower percentage cover over the winter months. However, this biotope is limited to extremely sheltered habitats and therefore, the occurrence of winter storms is unlikely to affect it to the same extent that more wave exposed habitats would be affected.

- Growth rate of *Laminaria digitata* is seasonally controlled with a period of rapid growth from February to July and one of slower growth from August to January. Increased wave exposure and storms experienced during winter months may erode *Laminaria digitata* blades and reduce the overall standing biomass. Periodic storms may remove older and weaker plants creating patches cleared of kelp. Cleared patches may encourage growth of sporelings or gametophyte maturation. Growth of understorey algae may also be reduced in the winter months.
- Concomitant with the reduction in available surface area of *Laminaria digitata* blades, a proportion of epiphytic bryozoans, ascidians and sponges will also be lost. However, epilithic representatives of these species will remain on the bedrock and boulders.
- Increased wave exposure and storm frequency over the winter months may also increase the frequency of impacts from wave driven debris, such as pebbles and boulders. These impacts may create 'bare' patches on the surface of the bedrock, and the boulders themselves, which may be colonized by fast growing species including the tube worm *Pomatoceros triqueter*.

Habitat structure and complexity

Owing to the tide-swept habitat with which this biotope is associated, a diverse marine life is supported. The fast currents provide a continual supply of suspended material sustaining a profusion of both active and passive suspension feeders that dominate the fauna. Fine sediment is removed by the current and the settlement of material, that could otherwise be detrimental to the suspension feeders, is prevented. It is the complex structure of this habitat and its many different niches that allow such a diverse range of suspension feeders to coexist. Almost every possible substratum including the bedrock, boulders and cobbles, and the holdfast, stipe and blade of the *Laminaria digitata* itself, is covered with various flora and fauna. In addition to the luxuriant conditions for suspension feeders, Hiscock (1983) lists some the benefits of strong water movement to include the potential for a greater photosynthetic efficiency, thereby possibly increasing the depth penetration of the algae. Increased water movement has been associated with an increase in photosynthesis in several algal species including *Fucus serratus* and *Ascophyllum nodosum* (Robbins, 1968, cited in Hiscock, 1983).

- Holdfasts provide refuge to a wide variety of animals supporting a diverse fauna that may include polychaetes, small crabs, gastropods, bivalves, and amphipods.
- Kelp fronds are likely to be colonized by encrusting bryozoans (e.g. *Membranipora membranacea*), ascidians (e.g. *Botryllus schlosseri*), hydroids (e.g. *Dynamena pumila*) and sponges (e.g. *Halichondria panicea*).
- Stipes of *Laminaria digitata* can support a considerable epiphytic flora, mainly of smaller species (Gayral & Cosson, 1973; Jones *et al.*, 2000).
- The bedrock and boulders offer surfaces for settlement and shelter of species and are colonized by encrusting and foliose red algae but dominated by animals including ascidians, bryozoans, sponges and tubicolous worms.

Dominant trophic groups	Photoautotrophs Suspension feeders

Productivity

- Kelp plants are major primary producers in shallow rocky marine habitats in Britain and Ireland. Within the euphotic zone, kelps produce nearly 75% of the net carbon fixed and large kelps often produce annually well in excess of a kilogram of carbon per square metre of shore. However, only about 10% of this productivity is directly grazed. Kelps contribute 2-3 times their standing biomass each year as particulate detritus and dissolved organic matter that provides the energy supply for filter feeders and detritivores in and around the kelp bed. Dissolved organic carbon, algal fragments and microbial film organisms are continually removed by the sea, which may enter the food chain of local subtidal ecosystems, or be exported further offshore. The Corallinaceae and foliose red algae, although not as significant as the kelp, also contribute to primary production within this biotope.
- The fast currents associated with this biotope provide a continual supply of suspended material that sustains a diverse suspension feeding community. Suspension feeders including sponges, bryozoans, ascidians and hydroids, represent the dominant fauna in this biotope highlighting the importance of secondary production.
- Rocky shores make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains.

Major sources of organic carbon	Photosynthesis (macroalgae and/or halophytic plants) Photosynthesis (microalgae) Plankton

Recruitment processes

- *Laminaria digitata* plants are fertile all year round with maximum production of spores in July - August and November - December. Young sporophytes (germlings) appear all year with maxima in spring and autumn. Chapman (1981) demonstrated that substantial recruitment of *Laminaria digitata* plants to areas barren of kelp plants was possible up to 600 m away from reproductive plants.
- Kelp plants themselves can affect recruitment in other species through their influence on the underlying substrata. Shading and mechanical sweeping, for example, will adversely affect settling larvae and post settlement survival.
- With respect to the underlying red algae, tetrasporangia from *Corallina officinalis* have been recorded throughout the year although settlement occurs after a couple of days which has the potential to limit dispersal. Recruitment in dulse, *Palmaria palmata,* is most certainly limited in terms of dispersal. Females do not release carpospores so male gametophytes produce spermatia which sink rapidly to enable the male and females gametes to come into contact for fertilization. *Lithophyllum incrustans* reproduce annually and it has been calculated that 1 mm^2 of reproductive

thallus produces 17.5 million bispores per year with an average settlement of only 55 sporelings/year (Edyvean & Ford, 1984).

- The majority of characteristic fauna associated with this biotope produce planktonic larvae and therefore, depending on respective plankton durations, recruitment is possible from both local sources and populations further away. Breeding in the bryozoan *Membranipora membranacea* continues through early summer with planktonic cyphonautes settling proceeding into early autumn (Ryland & Hayward, 1977). *Pomatoceros triqueter*, a tubeworm, produces planktonic all year around, although settlement appears to be limited in winter months.

Time for community to reach maturity

Kain (1975) examined the recolonization of cleared concrete blocks by kelp plants and other algae and found that *Laminaria digitata* plants were re-established within 2 years and that red algae returned with a year. Many other characterizing species have planktonic larvae and/or are mobile and so can migrate into the affected area. Colonization of most species of fauna inhabiting kelp holdfast, for example, were found as early as one year after kelp trawling of *Laminaria hyperborea* plants in Norway, although numbers of both individuals and species, especially isopods and amphipods, increase with a corresponding increase in holdfast size (Christie *et al.*, 1998). However, although these species colonize the biotope quite rapidly maturity of the overall community is likely to be longer (see 'Recoverability'). For example, encrusting coralline algae such as *Lithophyllum incrustans* are slow growing (2-7 mm per annum - see Irvine & Chamberlain, 1994) and recruitment of other species to the kelp bed may take longer. In dredged kelp beds in Norway for example, although the rock between *Laminaria hyperborea* plants was uniformly covered with coralline algae after 3 years, the more diverse community of cnidarians, bryozoans and sponges associated with coralline algae seen on undredged plots was absent (Rinde *et al.*, 1992, cited in Birkett *et al.*, 1998). Although it was suggested that the kelp forest recovered to an almost 'normal' state within 3 to 4 years, full biological restoration after harvesting may take at least ten years (Birkett *et al*., 1998).

Additional information

No text entered

Habitat preference and distribution

Distribution in Britain and Ireland

MIR.Ldig.T has been recorded on the west coasts of Britain in the Isles of Scilly, Milford Haven, Holy Island off the Pembrokeshire coast, the Menai Strait, west Scotland and the Inner and Outer Hebrides. It has not been recorded from the east coast of Britain. In Ireland, it has been recorded in one site on the east coast (Wicklow Head), and from several sites on the west coast. Irish survey data has not been analyzed to identify biotopes although it seems likely that the biotope will occur in tidal sounds and rapids such as occur in Strangfrod Lough.

Habitat preferences

Temperature range preferences	Data deficient.
Water clarity preferences	Data deficient
Limiting nutrients	Data deficient
Other preferences	Extremely sheltered from wave exposure.

Additional information

This biotope is associated with areas of moderate to strong water flow rates. It is typically found in narrow channels, shallow lagoons/rapids or the entrances to fjordic sea lochs and to obs. In the Menai Strait and Loch Roag the biotope experiences tidal flow rates of up to 8 knots (Brazier *et al.*, 1999).

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Important functional	*Halichondria panicea*	Breadcrumb sponge
Important characterizing	*Botryllus schlosseri*	Star ascidian
Important characterizing	*Membranipora membranacea*	A bryozoan
Important characterizing	*Corallina officinalis*	Coral weed
Important characterizing	*Palmaria palmata*	Dulse
Key Structuring	*Laminaria digitata*	Oarweed
Important Structural	*Gibbula cineraria*	Grey top shell
Important other	*Lithophyllum incrustans*	An encrusting coralline algae

Explanation

Laminaria digitata is the major characterizing species within this biotope and is the most significant component in terms of size and dominance. It provides a substratum for important characterizing species and a habitat and refuge for many others. The breadcrumb sponge *Halichondria panicea* is likely to compete with and exclude bryozoans and ascidians for space and is therefore considered to be an important functional species. Coral weed *Corallina officinalis* and dulse *Palmaria palmata* are frequently found in this biotope where they can be abundant. They are included as they are representative of the associated range of foliose red seaweeds. *Membranipora membranacea* is the most frequently occurring bryozoan in this biotope and has been used to represent other less commonly occurring bryozoans. The encrusting coralline algae *Lithophyllum incrustans* has been included as an important 'other' species because, although it is not a characterizing species within this biotope, it represents the encrusting coralline algae that are likely to cover much of the rock in many of the records of MIR.Ldig.T.

Species found especially in biotope

No text entered

Additional information

The MNCR recorded 425 species in 45 records of this biotope although not all the species occurred in all records of the biotope (JNCC, 1999).

Biotope sensitivity

Physical Factors

	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	High	Moderate	Major Decline	High
Smothering	Tolerant	Not Relevant	Not sensitive	Not Relevant	Low
Increase in suspended sediment	Low	Very high	Very Low	Decline	Low

Decrease in suspended sediment	Tolerant	Not Relevant	Not sensitive	Not Relevant	Moderate
Desiccation	High	High	Moderate	Not Relevant	Low
Increase in emergence regime	Intermediate	High	Low	Major Decline	Low
Decrease in emergence regime	Tolerant	Not Relevant	Not sensitive	Not Relevant	Not Relevant
Increase in water flow rate	Tolerant*	Not Relevant	Not sensitive*	Rise	Moderate
Decrease in water flow rate	High	High	Moderate	Major Decline	Moderate
Increase in temperature	Intermediate	High	Low	Minor Decline	Low
Decrease in temperature	Intermediate	High	Low	Minor Decline	Low
Increase in turbidity	Intermediate	High	Low	Minor Decline	Low
Decrease in turbidity	Tolerant*	Not Relevant	Not sensitive*	Rise	Low
Increase in wave exposure	High	High	Moderate	No Change	Very low
Decrease in wave exposure	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Noise	Tolerant	Not Relevant	Not sensitive	Not Relevant	High
Visual Presence	Tolerant	Not Relevant	Not sensitive	Not Relevant	High
Abrasion & physical disturbance	High	High	Moderate	Minor Decline	Low
Displacement	High	High	Moderate	Major Decline	Low
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	High	High	Moderate	Decline	Moderate
Heavy metal contamination	Low	Very high	Very Low	Minor Decline	Moderate
Hydrocarbon contamination	Intermediate	High	Low	Minor Decline	Moderate
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	Intermediate	High	Low	Minor Decline	Moderate
Increase in salinity	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Decrease in salinity	Intermediate	High	Low	Minor Decline	Low
Changes in oxygenation	Intermediate	High	Low	Minor Decline	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Introduction of non-native species	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Extraction of key or important characterizing species	Intermediate	High	Low	No Change	Low
Extraction of important species	Intermediate	High	Low	Decline	Low

Explanation of sensitivity and recoverability	
Physical Factors	
Substratum Loss (see benchmark)	Loss of the substratum will result in loss of the entire biotope and therefore intolerance has been assessed as high. Some species may survive as epiphytes on the *Laminaria digitata* but the kelp will be washed away from the area very quickly due to the strong currents. Recoverability is likely to be high (see additional information).
Smothering (see benchmark)	Smothering by a 5 cm layer of sediment is unlikely to adversely affect this biotope given that it is associated with areas of moderately strong to very strong tidal flow rates. The sediment will soon be washed away and 'normal' conditions will resume almost immediately. The abundance of filter feeders may experience some short lived interference with their feeding apparatus and respiratory flows. Furthermore, the holdfasts and lower end of the stipes of *Laminaria digitata* may experience some mild sand scour. However, at the benchmark level this is unlikely to adversely affect the species and therefore tolerant has been recorded.
Increase in suspended sediment (see benchmark)	Given the strong currents with which this biotope is usually associated, an increase in the amount of suspended sediment could lead to a scouring affect which could damage both the fronds of *Laminaria digitata* and their resident epiphytes. *Corallina officinalis* and *Lithophyllum incrustans* are likely to be afforded protection from scouring from the calcium carbonate within the plants and both are found on wave exposed shores. The current will prevent the sediment from settling and there are, therefore, unlikely to be any effects associated with siltation. However, increased suspended sediment, combined with the strong water flow, may interfere with the respiratory currents and feeding apparatus of the suspension feeders. Over the course of one month this interference and reduced total ingestion is likely to result in a reduced scope for growth and reproductive success for resident invertebrates. For short-lived species such as the bryozoans and sea squirts, this may prove fatal. In contrast, an increase in suspended sediment could also lead to an increase in the availability of food for the suspension feeders, especially if the organic fraction of the suspended sediment were to increase. This biotope supports a highly diverse suspension feeding community including sponges, annelida, bryozoans, ascidians and hydroids. There may be a small decline in faunal species diversity but on balance, intolerance has been assessed as low. Recovery is likely to be very high due to the fact that most of the intolerant species produce planktonic larvae and are therefore likely to be able to recolonize the area quickly from surrounding areas.
Decrease in suspended sediment (see benchmark)	A decrease in the amount of suspended sediment could reduce the scour effect these particles may have on the flora and fauna. Furthermore, the suspension feeding community may become more efficient as there would be fewer inorganic particles to clog and interfere with feeding apparatus. An increase in light availability may occur as a result of a decrease in suspended sediment (see turbidity). Assuming that the decrease in suspended sediment refers to inorganic particles, a reduction in total ingestion in the suspension feeding community is not expected. Therefore, tolerant has been assessed.
Desiccation (see benchmark)	Due to the fact that MIR.Ldig.T is in the sublittoral fringe, the benchmark level for desiccation would involve the biotope moving up the shore into the lower eulittoral for one year. This change is likely to have an adverse affect on the biotope, especially if the change in position coincided with hot or windy weather. At the upper extent of the biotope, *Laminaria digitata* plants may perish and the death of the understory species below would most likely follow. Hawkins & Harkin (1985) found that the removal of the *Laminaria digitata* canopy lower on the shore resulted in the bleaching of encrusting corallines. Furthermore, they found that

	during the hot summer of 1983, extensive damage was observed to encrusting corallines in several sites in Britain. Most of the associated fauna within this biotope are fixed to the substratum and therefore unable to escape an increase in desiccation. In addition, the fauna are dominated by suspension feeders and immersion is therefore a prerequisite to feeding. Over the course of the year, the reduction in available feeding time could prove fatal for short-lived species such as the bryozoans, sponges and ascidians. *Laminaria digitata* at the upper shore extent of the biotope are likely to be replaced by *Fucus serratus* that is more tolerant to desiccation. It is likely that the extent of the biotope would be reduced over the course of the year and, accordingly, intolerance has been assessed as high. Recoverability is expected to be high (see additional information).
Increase in emergence regime (see benchmark)	*Laminaria digitata* biotopes are predominantly sublittoral but extend into the lower eulittoral and therefore have some ability to resist desiccation. At the sublittoral fringe *Laminaria digitata* regularly becomes exposed to air at low water. Dring & Brown (1982) found that plants that lost up 40-50% of their initial water content were still able to return to their original photosynthetic rate on re-immersion. Many species living beneath the kelp canopy, such as *Halichondria panicea* and *Botryllus schlosseri* are also found further up the shore and are therefore likely to be tolerant to a certain degree of desiccation. Furthermore, the kelp canopy is likely to protect the algal understory and benthic fauna from the worst effects of desiccation by the kelp canopy. However, at the benchmark level, some *Laminaria digitata* plants at the upper extent of the biotope may perish from the effects of desiccation. In turn, flora and fauna in the understory may die since the canopy offers protection from desiccation, wind and insolation. The upper extent of the biotope may be reduced although this may be counteracted by an extension of the biotope at the lower limit. On balance, an intolerance of intermediate has been assessed with a high recovery (see additional information).
Decrease in emergence regime (see benchmark)	MIR.Ldig.T is found in the sublittoral fringe with depths on the lower shore ranging from 0 to 0.5 m above ELWS (chart datum). A decrease in emergence would reduce any emersion experienced by this biotope thus increasing feeding opportunities for all filter feeders, the dominant fauna within this biotope. At the lower shore extent of the biotope the *Laminaria digitata* may be replaced by *Laminaria hyperborea* and consequently the biotope *per se* could be reduced. However, this loss is likely to be counteracted by an increase in this upper shore extent of the biotope. Therefore this biotope is likely to be tolerant to a decrease in emergence.
Increase in water flow rate (see benchmark)	The high species richness associated with this biotope is, in part, due to strong flow rates which enable a wide variety of filter feeders to flourish. Strong flow rates prevent siltation in this otherwise very sheltered environment, bring suspended food, and are also likely to reduce the abundance of grazers. Where water flow rate increases, the biotope will be enhanced in character.
Decrease in water flow rate (see benchmark)	The high species richness associated with this biotope is, in part, due to strong flow rates which prevent siltation in wave sheltered habitats and enable a wide variety of filter feeders to flourish. A decrease in water flow rate, similar to that in the benchmark, would mean the biotope could experience negligible water flow rates for one year. This would be catastrophic for the faunal component of the biotope and would probably result in a major decline in species diversity and richness. The fauna in this biotope is dominated by low lying and encrusting filter feeders, the majority of which are highly intolerant to sedimentation. Under normal conditions, sedimentation would not be a problem, due to the high flow rates, but with reduced rates, sedimentation could smother the animals. Some filter feeders have the ability to cope with siltation and excess suspended material. For example, the breadcrumb sponge *Halichondria panicea* has a mechanism for sloughing off their complete outer tissue layer together with any debris (Barthel & Wolfrath, 1989). However, there is an energetic cost of cleaning their tissues, and this species, together with

	other filter feeders, would probably experience reduced growth over the benchmark. For annual species, including the star ascidian *Botryllus schlosseri*, this could prove fatal. The keel worm *Pomatoceros triqueter* and the bryozoans *Electra pilosa* and *Membranipora membranacea* are also highly intolerant to siltation and smothering (see *MarLIN* Web site) and probably represent but a few suspension feeders commonly associated with this biotope that are highly intolerant of siltation. The hydroid *Dynamena pumila* experienced marked decline in areas with increased silt content in Strangford Lough, Northern Ireland (Seed *et al.*, 1983). Round *et al.* (1961, cited in Hiscock, 1983) transferred colonies of the hydroid *Sertularia operculata* (studied as *Amphisbetia operculata*, from rocks in the tidal rapids at Lough Ine, Ireland, to a nearby sheltered bay. The colonies quickly became clogged with silt and most had died within 9 weeks of the transfer. The encrusting algae *Lithophyllum incrustans* is also likely to be highly intolerant at the benchmark level. The *Laminaria digitata*, with its flexible stipes, is likely to 'collapse' onto the underlying flora and fauna. This kelp blanket could completely overshadow the underlying seaweeds which would ultimately reduce their photosynthetic capabilities. Furthermore, the feeding efficiency of the underlying filter feeders may be reduced. With respect to predation, reduced flow rates may increase the abundance of the grazer *Gibbula cineraria* as strong water flow rates are likely to dislodge these animals from the blades of the kelp and other plants. Not only will this increase potential damage to the kelp plants and red seaweeds, the grazing activities of this species have also been shown to have a deleterious affect on the post-settlement establishment of larvae of ctenostome and cheilostome bryozoans, hydroids and ascidians (Turner & Todd, 1991). The *Laminaria digitata* will be outside their preferred tidal flow range (strong to very strong). Furthermore, Duggins *et al.* (2001) found that the mortality of the kelp *Nereocystis leutkeana* in the San Juan archipelago, Washington, was higher in populations that experienced periods of calm flow punctuated by intermediate to strong flow episodes. This was thought to be due to increased grazing efficiency in calmer periods. The grazers would attack the blades and stipes of the kelp so that when water flow rate increased again, they would more likely be torn off. In the case of this biotope, the resumption of 'normal' flow rates will have the same effect. All the key and important species associated with this biotope would be adversely affected by a reduction in tidal flow rate at the benchmark level and accordingly, intolerance has bee assessed as high. Recoverability is likely to be high (see additional information). The sublittoral fringe of similarly sheltered shores that are not tide-swept are generally characterized by mixed *Laminaria saccharina* and *Laminaria digitata* (MIR.Lsac.Ldig) or *Laminaria saccharina* (JNCC, 1999) and it is possible that one of these two biotopes will prevail should decreased flow rates persist.
Increase in temperature (see benchmark)	*Laminaria digitata* is a eurythermal species with sporophytes growing over a wide temperature range. Lüning (1984) detected a seasonal shift in heat tolerance of *Laminaria digitata* plants in Helgoland of 2 °C between spring and summer so the species is likely to be tolerant of a long term, chronic change in temperature at the benchmark level. *Corallina officinalis* from Helgoland survived temperatures between 0 °C and 28 °C when exposed for 1 week (Lüning, 1990). However, severe damage was noted in *Corallina officinalis* as a result of desiccation during unusually hot and sunny weather in summer 1983 (an increase of between 4.8 and 8.5 °C) (Hawkins & Hartnoll, 1985). In tank cultures of *Palmaria palmata*, all the plants were dead within a week at 20 °C and above, (Morgan *et al.*, 1980). Such high temperatures,

	however, are unlikely in the subtidal fringes of Britain and Ireland. Increased temperatures are also likely to increase the risk of desiccation in the encrusting coralline algae *Lithophyllum incrustans*. With regard to associated fauna, both the star ascidian *Botryllus schlosseri* and the breadcrumb sponge *Halichondria panicea* have large geographical ranges in which the UK is almost central. At the benchmark level these species are therefore likely to be tolerant of chronic temperature changes. On balance, the biotope may be tolerant to long term chronic change in temperature but is likely to be of intermediate intolerance to short term acute temperature change. During an exceptionally warm summer in Norway, Sundene (1964) reported the destruction of *Laminaria digitata* plants exposed to temperatures of 22-23 °C. Littler & Kauker (1984) suggested that in *Corallina officinalis*, the crustose base was more resistant of desiccation or heating than fronds and that this species is probably intolerant of abrupt short term temperature increases. Therefore, an intolerance of intermediate has been recorded. Recovery is expected to be high (see additional information).
Decrease in temperature (see benchmark)	The flora within this biotope have a varying tolerance with regard to low temperatures. In Scotland, Todd & Lewis (1984) reported mortality of all but the lowest shore *Laminaria digitata* plants when low spring tides coincided with extreme air frosts on several consecutive days. This was probably due to damage to the exposed meristems. In contrast, New Zealand specimens of *Corallina officinalis* were found to tolerate -4 °C (Frazier *et al*. 1988, cited in Lüning, 1990). *Palmaria palmata* does well in low temperatures, with an optimum between 6 and 15 °C, consistent with its distribution in northern temperate and arctic waters. Furthermore, in the laboratory, plants only became fertile if left at temperatures between 5-7 ° C with a short light period (Meer van der, 1979). However, Kain & Norton (1990) suggest that a widely distributed species like *Palmaria palmata* reacts less strongly to temperature differences than some other red algae. With regard to associated fauna, the star ascidian and breadcrumb sponge both have large geographical ranges in which the UK is almost central. At the benchmark level these species are therefore likely to be tolerant of chronic temperature changes. Acute temperature changes, however, are likely to be met with a higher intolerance, as illustrated by the work of Crisp (1964) following the severe winter of 1962-63. He noted damage to *Halichondria panicea* colonies during the severe winter but rapid recovery due to planktonic larvae. He reported the sponge *Hymeniacidon perleve* as unusually rare in abundance after the severe winter in North Wales. In South Wales, approximately half the population of *Pomatoceros triqueter* were reported to have died at Mumbles. Below a temperature of 7 °C, *Pomatoceros triqueter* is unable to build calcareous tubes (Thomas, 1940). This means that, even if the adults survived a decrease in temperature, larvae would not be able to attach to the substratum. In contrast, the hydroid *Dynamena pumila* was reported to have remained common in the habitats in which it was usually found in North Wales. On balance, the biotope may be tolerant to long term chronic change in temperature but is likely to be of intermediate intolerance to short term acute temperature change. Recovery is expected to be high (see additional information).
Increase in turbidity (see benchmark)	The extent of the lower limit of kelp distribution on rocky shores is determined by the amount of light penetration. Increased turbidity around a sewage treatment plant was thought to be responsible for the absence of *Laminaria digitata* plants in the Firth of Forth (Read *et al*., 1983) and has been reported to result in reduced the depth range and the fewer new plants under the kelp canopy. In Narragansett Bay, Rhode Island growth rates of *Laminaria digitata* fell during a summer bloom of microalgae that dramatically reduced downward irradiance. An increase in turbidity will reduce photosynthetic capability and therefore growth of both the

	kelp and understory plants. The majority fauna are unlikely to be directly affected by an increase in turbidity although the symbiotic algae living within the breadcrumb sponge *Halichondria panicea* may decline in abundance. However this will not affect the survival of the sponge. On balance an intolerance of intermediate has been recorded. Recovery is expected to be high (see additional information).
Decrease in turbidity (see benchmark)	Reduced turbidity is likely to favour kelp growth and the growth of other micro and macroalgae. Although the majority of associated fauna are unlikely to be directly benefited by this change, there may be more food available for grazers such as *Gibbula cineraria*. Furthermore, increased water clarity may lead to an increase in the amount of green algae in the biotope. Overall, the biotope is likely to benefit from reduced turbidity and may experience a small rise in species diversity.
Increase in wave exposure (see benchmark)	Although, individually, the species in this biotope are generally tolerant of varying wave exposures, the species assemblage itself, in terms of the abundance of different species, is likely to change. Therefore this biotope is likely to be lost but is likely to be replaced by *Laminaria digitata* on moderately exposed sublittoral fringe rock (MIR.Ldig.Ldig) which is highly similar in terms of species composition but associated with more exposed locations. The MNCR recorded more than 700 species in records of this biotope (JNCC, 1999). However, nearly 350 records of the biotope were studied to produce that figure and it is, therefore, possible that MIR.Ldig.Ldig is less diverse than MIR.Ldig.T where 425 species were recorded in only 45 records of the biotope (JNCC, 1999).
Decrease in wave exposure (see benchmark)	This biotope occurs in extremely sheltered conditions and therefore a decrease in wave exposure is not relevant.
Noise (see benchmark)	The dominant flora (*Laminaria digitata*) and encrusting fauna (bryozoans, sponges and ascidians) are unlikely to have mechanisms for detecting noise and will therefore be tolerant to this factor.
Visual Presence (see benchmark)	The dominant flora (*Laminaria digitata*) and encrusting fauna (bryozoans, sponges and ascidians) are unlikely to have mechanisms for detecting visual presence and will therefore be tolerant to this factor.
Abrasion & physical disturbance (see benchmark)	The fronds of *Laminaria digitata* are soft and are likely to be damaged by abrasion at the benchmark level. Similarly, the encrusting sponges, encrusting algae bryozoans and colonial ascidians may be scraped off the surface of the bedrock, boulders or kelp fronds and small clumps of foliose red seaweeds and coral weed may also be lost. In general, however, a proportion of each species is likely to remain and therefore, intolerance has been assessed as intermediate. Recoverability is likely to be high (see additional information below).
Displacement (see benchmark)	The key structural species *Laminaria digitata* cannot reattach itself after having been removed from the substratum and it is unlikely that other important flora (*Palmaria palmata* and *Corallina officinalis*) can either. Kelp canopy removal experiments in the Isle of Man revealed that, after *Laminaria digitata* was removed, the underlying community changed dramatically (Hawkins & Harkin, 1985). For example, encrusting corallines became bleached and colonized by successive algal phases, including filamentous brown and green algae. *Gibbula cineraria* are mobile and will be tolerant of displacement but all other important characterizing fauna are encrusting and fixed to the substrata and will be highly intolerant to displacement. This factor is likely to have a similar affect as substratum loss and accordingly, intolerance has been assessed as high. Recovery is likely to be high (see additional information).

Chemical Factors	
Synthetic compound contamination (see benchmark)	• *Laminaria digitata* along with almost all red algal species and many animal species were found to be absent from sites close to acidified, halogenated effluent from a bromide extraction plant (Hoare & Hiscock, 1974). • Axelsson & Axelsson (1987) investigated the effect on *Laminaria digitata* of exposure to various chemicals for 24 hours by measuring ion leakage as an indication of plasma membrane damage. However, only limited ion loss was seen on exposure to two detergents, nonylphenol ethoxylate (NP-10) and linear alkylbenzene sulfonate (LAS). • Cole *et al.* (1999) suggested that herbicides such as Simazina and Atrazine were very toxic to macrophytic algae. • Laboratory studies of the effects of oil and dispersants on several red algae species, including *Palmaria palmata* (Grandy, 1984, cited in Holt *et al.*, 1995) concluded that they were all intolerant of oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. • Smith (1968) reported that, in areas of heavy spraying of oil and detergent dispersants, *Corallina officinalis* was killed, and was affected down to a depth of 6 m in one site, presumably due to wave action and mixing. However, regrowth of fronds had begun within 2 months after spraying ceased. No information was found concerning the specific effects of synthetic chemicals on the important characterizing or important functional fauna. Given the evidence for the algal species however, an intolerance of high has been recorded. Assuming that the plants were able to reproduce and that the settlement of sporelings was not prohibited by residual chemicals, recovery is expected to be high. However, if the chemicals were bioaccumulated or resided in the biotope for a long time, this recovery may take significantly longer.
Heavy metal contamination (see benchmark)	The tolerance of *Laminaria digitata* to heavy metals is highly variable depending the on the metal concerned. Zinc was found to inhibit growth in *Laminaria digitata* at a concentration of 100 µg/L and at 515 µg/L, growth had almost completely ceased (Bryan, 1969). Axelsson & Axelsson (1987) investigated the effect of exposure to mercury (Hg), lead (Pb) and nickel (Ni) for 24 hours by measuring ion leakage to indicate plasma membrane damage. Inorganic and organic Hg concentrations of 1 mg/l resulted in the loss of ions equivalent to ion loss in seaweed that had been boiled for 5 minutes. *Laminaria digitata* was unaffected when subjected to Pb and Ni at concentrations up to 10 mg/l. The results also indicated that the species was intolerant of the tin compounds butyl-Sn and phenyl-Sn. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes and Boney (1971) reported that the red algae *Plumaria elegans* experienced 100% growth inhibition at 1 ppm Hg. However, no information was found concerning the specific effects of heavy metals on either *Palmaria palmata* or *Corallina officinalis* or any of the important faunal components of this biotope. Given the evidence for the algal species, however, intolerance has been assessed as low. Heavy metals have the potential to accumulate in plant tissue and therefore it may take some time for tissue levels to fall before recovery can begin. Assuming that the plants were able to reproduce and that the settlement of sporelings was not prohibited by residual metals, recovery is expected to be very high although this may take significantly longer depending on depuration of the metals from the biotope.
Hydrocarbon contamination (see benchmark)	The brown algae are thought to be largely protected from oil penetration damage by the presence of a mucilaginous coating (O'Brian & Dixon, 1976). In addition, effects of oil accumulation on the thalli are mitigated by the perennial growth of

	kelps. *Laminaria digitata* is less susceptible to coating than some other seaweeds because of its preference for exposed locations where wave action will rapidly dissipate oil. The strong tidal flow in this biotope may provide some protection to all seaweeds within this community. No significant effects of the *Amoco Cadiz* spill were observed for *Laminaria* populations and the *World Prodigy* spill of 922 tons of oil in Narragansett Bay had no discernible effects on *Laminaria digitata* (Peckol *et al.*, 1990). Furthermore, the upper limit of distribution for *Laminaria digitata* moved up wave exposed shores by as much as 2 m during the first few years after the *Torrey Canyon* oil spill due to the death of animals that graze the plants (Southward & Southward, 1978). Mesocosm studies in Norwegian waters showed that chronic low level oil pollution (25 µg/L) reduced growth rates in *Laminaria digitata* but only in the second and third years of growth (Bokn, 1985). O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil contamination. Where exposed to direct contact with fresh hydrocarbons, encrusting calcareous algae have a high intolerance. Crump *et al.* (1999) noted a dramatic bleaching on encrusting corallines and signs of bleaching in *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus* at West Angle Bay, Pembrokeshire after the *Sea Empress* oil spill. However, encrusting corallines recovered quickly and *Corallina officinalis* was not killed. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Palmaria palmata* (Grandy 1984, cited in Holt *et al.*, 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. It is possible that *Corallina officinalis* and other algae are more intolerant of the dispersants used during oil spills than the oil itself. Where exposed to direct contact with fresh hydrocarbons, encrusting coralline algae appear to have a high intolerance. Crump *et al.* (1999) describe "dramatic and extensive bleaching" of 'Lithothamnia' following the *Sea Empress* oil spill. Observations following the *Don Marika* oil spill (K. Hiscock, own observations) were of rockpools with completely bleached coralline algae. However, Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the Sea Empress spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. No information was found concerning the specific effects of hydrocarbon contamination on the important faunal component of this biotope. However, the intolerance of the sponges, ascidians and bryozoans is likely to be related to depth of the oil / tar deposition and the strong tidal flow associated with this biotope is likely to reduce this. Nevertheless, analysis of kelp holdfast fauna after the *Sea Empress* oil spill in Milford Haven illustrated decreases in number of species, diversity and abundance at sites nearest the spill (SEEEC, 1998). On balance, it is likely that some species within the biotope may be killed and accordingly, an intolerance of intermediate has been recorded. Recovery, assuming the environment was free from hydrocarbon pollution or at least back to 'normal' levels, should be high, especially since most of the intolerant species produce planktonic larvae and are therefore likely to be able to recolonize the area quickly from surrounding areas.
Radionuclide contamination (see benchmark)	No information was found regarding the actual effects of radionuclide contamination on this biotope.
Changes in nutrient levels (see benchmark)	The growth of macroalgae in temperate coastal waters is generally expected to be limited by nitrogen in the summer period. In the Bay of Fundy, for example, where there is a tidal flux of nutrients from the marshes there is luxurious growth of *Palmaria palmata*. A comparison of *Laminaria digitata* growth rates in Arbroath, Scotland with a more oligotrophic and a more eutrophic site appears to support this

	hypothesis (Davison *et al.*, 1984) (see *MarLIN* Web site). Corallines seem to be tolerant and successful in polluted waters. Kindig & Littler (1980) demonstrated that *Corallina officinalis* var. *chilensis* in South California showed equivalent or enhanced health indices, highest productivity and lowest mortalities (amongst the species examined) when exposed to primary or secondary sewage effluent. Specimens from unpolluted areas were less tolerant, suggesting physiological adaptation to sewage pollution (Kindig & Littler 1980). However, although nutrient enrichment may benefit *Laminaria digitata*, the indirect effects of eutrophication, such as increased light attenuation from suspended solids in the water column and interference with the settlement and growth of germlings, may be detrimental. After removal of sewage pollution in the Firth of Forth, *Laminaria digitata* became abundant on rocky shores from which they had previously been absent (Read *et al.*, 1983). Eutrophication often results in the loss of perennial algae, reduction of the depth range of algae (due to turbidity), and increases in opportunistic species such as ephemeral algae. High levels of ephemeral algae can cause smothering of species changing the character of the biotope. In addition, very high levels of nutrients can be toxic to macroalgae. *Palmaria palmata* placed in tanks with continuous immersion in high nutrients over several weeks stopped growing (Morgan *et al.*, 1980). and so intolerance is assessed as intermediate. Any recovery is likely to be high as species are unlikely to be completely lost and have planktonic larvae and high growth rates.
Increase in salinity (see benchmark)	This biotope occurs in the sublittoral fringe of full salinity environments. Consequently, an increase in salinity at the benchmark level is not relevant.
Decrease in salinity (see benchmark)	Birkett *et al.* (1998b) suggested that kelps are stenohaline, in that they do not tolerate wide fluctuations in salinity. Growth rate may be adversely affected if the kelp plant is subjected to periodic salinity stress. The lower salinity limit for *Laminaria digitata* lies between 10 and 15 psu. On the Norwegian coast, Sundene (1964) found healthy *Laminaria digitata* plants growing between 15 and 25 psu. Axelsson & Axelsson (1987) investigations indicated damage of plants plasma membranes occurs when salinity is below 20 or above 50 psu. Localized, long term reductions in salinity, to below 20 psu, may result in the loss of kelp beds in affected areas (Birkett *et al.*, 1998). However, at the benchmark level this unlikely to result in the loss of the biotope *per se*. In laboratory experiments maximum rates of photosynthesis and respiration in *Palmaria palmata* were observed at a salinity 32 psu (Robbins, 1978) although photosynthetic rates were high down to a salinity of 21 psu. *Palmaria palmata* is likely to be tolerant of small changes in salinity because as an intertidal species it is regularly exposed to precipitation. *Corallina officinalis* inhabits rock pools and gullies from mid to low water. Therefore, it is likely to be exposed to short term hyposaline (freshwater runoff and rainfall) and hypersaline (evaporation) events. However, its distribution in the Baltic is restricted to increasingly deep water as the surface salinity decreases, suggesting that it requires full salinity in the long term (Kinne, 1971). Some of the fauna, including the breadcrumb sponge *Halichondria panicea*, tolerant of wide variety of salinity habitats from reduced to full salinity and are therefore unlikely to be affected by a drop in salinity at the benchmark level. However, given the evidence for kelp the intolerance has been assessed as intermediate. Recoverability is likely to be high as it is unlikely that many of the plants will be lost.
Changes in oxygenation (see benchmark)	The biotope occurs in areas where still water conditions do not occur and so some species may be intolerant of hypoxia. Cole *et al.* (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l. Kinne (1972) reports that reduced oxygen concentrations inhibit both photosynthesis and respiration, although macroalgae may tolerate a level of

	deoxygenation since they can produce their own oxygen. However, the fauna that characterize the biotope may be more intolerant. The sponges and ascidians, for example, may experience some mortality and therefore intolerance to low oxygenation (2 mg/l) in seawater for a week has been assessed as intermediate. Effects are likely to be short lasting on return to normal oxygen concentrations so recovery is assessed as high.
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	Insufficient information was found concerning the specific effects of microbial pathogens on the survival of this biotope.
Introduction of non-native species (see benchmark)	Insufficient information was found to suggest that alien and non-native species would outcompete or displace the key or important species within this biotope.
Extraction of key or important characterizing species (see benchmark)	Of the key species within this biotope only the oarweed *Laminaria digitata* is known to be targeted for extraction. Plants cast up on the shore have historically been collected and used for fertilizer. More recently *Laminaria digitata* has been cultivated commercially for alginate in Britain and in Ireland and in France it is cultivated as a sea vegetable. The loss of canopy species including Laminariales (kelps) has been shown to be detrimental to encrusting corallines below which became bleached (Hawkins & Harkin, 1985). In addition, the loss of the kelp plants would lead to loss of the associated epiphytes including bryozoans, sponge, ascidians and the red algae *Palmaria palmata*, which are commonly found growing on the stipe. The increase in irradiance associated with a loss in canopy cover could lead to the growth of fast growing filamentous green and brown algae. A sustained extraction of the kelp could therefore lead to the loss if the biotope. However, due to the sublittoral fringe position of this biotope it is unlikely that vast areas of *Laminaria digitata* will be cleared. Nevertheless there may be some extraction and accordingly, intolerance has been assessed as intermediate with a high recovery (see additional information below).
Extraction of important species (see benchmark)	Of the important characterizing species only the coral weed and dulse are targeted for extraction. Dulse *Palmaria palmata* is used as a vegetable substitute or animal fodder although harvesting on a commercial scale only takes place in Ireland and France. Recovery from extraction of 50% of the species is likely to be high because remaining plants constitute a reservoir from which recruitment can occur. In the Isle of Man recruitment of new plants to kelp cleared plots occurred within five months (Hawkins & Harkin, 1985). The coral weed *Corallina officinalis* is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.*, 1987). It is also sold as a powder for use in the cosmetic industry. An European research proposal for cultivation of *Corallina officinalis* is pending (Dr T. Wiedemann, pers. comm.). Due to the sublittoral fringe position of this biotope it is unlikely that vast areas of either of the two species will be cleared but there may be some extraction and therefore, intolerance has been assessed as intermediate with a high recovery. It is unlikely the removal of a small proportion of these two species will have any significant effects on the biotope in general.

Additional information

- *Laminaria digitata* plants are able to rapidly re-colonize any gaps in the upper infralittoral which result from storm damage (Birkett *et al.*, 1998) and have been shown, in various independent studies, to recovery rapidly after loss of population. On the Isle of Man, *Laminaria digitata* made a complete recovery within 8 months of being mowed just above the holdfast (Hawkins & Harkin, 1985). Kain (1979) reported that the standing crop was re-established within 18-20 months. Where the whole population was cleared (as opposed to just pruning the standing crop), recolonization of *Laminaria* *digitata* on concrete blocks on the Isle of Man took place within 2 years and red algae returned within a year (Kain, 1975). In Helgoland, recovery of cleared and burned plots to original density took 25 months but plants were smaller than those on undisturbed plots (Markham & Munda, 1980). This suggests that when all spores and germlings are also removed full population recovery is longer than 25 months.

- Many other characterizing species have planktonic larvae and/or are mobile and so can migrate into the affected area. The dulse *Palmaria palmata*, for example, is commonly epiphytic on *Laminaria digitata* and is therefore probably recruited form a local source (Hawkins & Harkin, 1985).
- *Halichondria panicea* increases by about 5% per week (Barthel, 1988) and exhibits high recovery following substratum loss.
- In experimental plots, up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna (Littler & Kauker, 1984).

However, although some species colonize the biotope quite rapidly, maturity of the overall community is likely to be slower. For example, encrusting coralline algae such as *Lithophyllum incrustans* are slow growing (2-7 mm per annum - see Irvine & Chamberlain 1994) and recruitment of other species to the kelp bed may take longer. In dredged kelp beds in Norway for example, although the rock between *Laminaria hyperborea* plants was uniformly covered with coralline algae after 3 years, the more diverse community of cnidarians, bryozoans and sponges associated with coralline algae seen on undredged plots was absent (Birkett *et al*., 1998). In Massachusetts, Sebens (1986) found that red crustose algae, spirorbid worms, bryozoans and erect hydroids were quick to colonize cleared patches on subtidal vertical rock walls. These species usually achieved coverage on areas that have been scraped free of fauna within 4 months. The ascidian *Dendrodoa carnea* was found to appear towards the end of the first year after clearing whilst *Halichondria panicea* was slow to colonize the area. This sponge first appeared almost one year after clearance and only reached previous levels of cover after more than two years after scraping (Sebens, 1986). Within five years, however, this biotope is likely to have reached maturity.

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors						
	Halichondria panicea	***Botryllus schlosseri***	***Corallina officinalis***	***Palmaria palmata***	***Laminaria digitata***	***Lithophyllum incrustans***
Community Importance	Important functional	Important characteri-zing	Important characteri-zing	Important characterizing	Key Structuring	Important other
Substratum Loss	High	High	High	High	High	High
Smothering	High	High	Intermediate	Intermediate	Intermediate	Low
Increase in suspended sediment	Low	High	Intermediate	Low	Intermediate	Low
Decrease in suspended sediment	Not Sensitive	See explanation	See explanation	See explanation	See explanation	Not Sensitive*
Desiccation	Intermediate	Intermediate	High	Intermediate	Intermediate	High
Increase in emergence regime	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	High
Decrease in emergence regime	Not Sensitive	See explanation	See explanation	See explanation	See explanation	Not Sensitive
Increase in water flow rate	Intermediate	Intermediate	Low	Intermediate	Low	Low
Decrease in water flow rate	Low	See explanation	See explanation	See explanation	See explanation	Low
Increase in temperature	Low	Low	Intermediate	Intermediate	Intermediate	Not Sensitive
Decrease in temperature	Low	See explanation	See explanation	See explanation	See explanation	Not Sensitive

Increase in turbidity	Not Sensitive	Low	Low	Low	Intermediate	Low
Decrease in turbidity	Not Sensitive	See explanation	See explanation	See explanation	See explanation	Not Sensitive*
Increase in wave exposure	Intermediate	Intermediate	Low	Intermediate	Low	Not Sensitive
Decrease in wave exposure	Low	See explanation	See explanation	See explanation	See explanation	Low
Noise	Not Sensitive	Not Sensitive	Not Sensitive	Not Relevant	Not Sensitive	Not Sensitive
Visual Presence	Not Sensitive	Not Sensitive	Not Sensitive	Not Relevant	Not Sensitive	Not Sensitive
Abrasion & physical disturbance	Intermediate	Intermediate	Low	Intermediate	Intermediate	Intermediate
Displacement	High	High	Low	High	High	Low
Chemical factors						
	Halichondria panicea	***Botryllus schlosseri***	***Corallina officinalis***	***Palmaria palmata***	***Laminaria digitata***	***Lithophyllum incrustans***
Community Importance	Important functional	Important characterizing	Important characteri-zing	Important characteri-zing	Key Structuring	Important other
Synthetic compound contamination	Insufficient information	Insufficient information	Intermediate	High	Intermediate	High
Heavy metal contamination	Insufficient information	Insufficient information	Insufficient information	Intermediate	Intermediate	Insufficient information
Hydrocarbon contamination	Low	Insufficient information	Low	High	Low	High
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	Insufficient information	Low	Low	Intermediate	Low	Low
Increase in salinity	Low	Intermediate	Intermediate	Intermediate	Intermediate	Insufficient information
Decrease in salinity	Low	See explanation	See explanation	See explanation	See explanation	Intermediate
Changes in oxygenation	Intermediate	Intermediate	Insufficient information	Low	Insufficient information	Insufficient information
Biological factors						
	Halichondria panicea	***Botryllus schlosseri***	***Corallina officinalis***	***Palmaria palmata***	***Laminaria digitata***	***Lithophyllum incrustans***
Community Importance	Important functional	Important characterizing	Important characteri-zing	Important characteri-zing	Key Structuring	Important other
Introduction of microbial pathogens/parasites	Insufficient information	Insufficient information	Low	Insufficient information	Low	Insufficient information
Introduction of non-native species	Insufficient information	Not Sensitive*	Not Relevant	Not Relevant	Low	Insufficient information
Extraction of this species	Not Relevant	Not Relevant	Intermediate	Intermediate	Intermediate	Not Relevant
Extraction of other species	High	High	Intermediate	Intermediate	Intermediate	Intermediate

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors						
	Halichondria panicea	***Botryllus schlosseri***	***Corallina officinalis***	***Palmaria palmata***	***Laminaria digitata***	***Lithophyllum incrustans***
Community Importance	Important functional	Important characteri-zing	Important characteri-zing	Important characterizing	Key Structuring	Important other
Substratum Loss	High	High	High	High	High	Low
Smothering	High	High	Very high	High	High	Very high
Increase in suspended sediment	Immediate	High	Very high	High	High	Very high
Decrease in suspended sediment	Not Relevant	See explanation	See explanation	See explanation	See explanation	Not Relevant
Desiccation	Very high	High	High	High	High	Low
Increase in emergence regime	Very high	High	Very high	High	High	Low
Decrease in emergence regime	Not Relevant	See explanation	See explanation	See explanation	See explanation	Not Relevant
Increase in water flow rate	Very high	High	Very high	High	High	Very high
Decrease in water flow rate	Immediate	See explanation	See explanation	See explanation	See explanation	Very high
Increase in temperature	Very high	Very high	High	High	High	Not Relevant
Decrease in temperature	Very high	See explanation	See explanation	See explanation	See explanation	Not Relevant
Increase in turbidity	Not Relevant	Immediate	Immediate	Very high	High	Very high
Decrease in turbidity	Not Relevant	See explanation	See explanation	See explanation	See explanation	Not Relevant
Increase in wave exposure	Very high	Moderate	Very high	High	High	Not Relevant
Decrease in wave exposure	Very high	See explanation	See explanation	See explanation	See explanation	Immediate
Noise	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Abrasion & physical disturbance	High	High	High	High	High	High
Displacement	High	Moderate	High	High	High	Very high
Chemical factors						
	Halichondria panicea	***Botryllus schlosseri***	***Corallina officinalis***	***Palmaria palmata***	***Laminaria digitata***	***Lithophyllum incrustans***
Community Importance	Important functional	Important characteri-zing	Important characteri-zing	Important characterizing	Key Structuring	Important other
Synthetic compound contamination	Not Relevant	Not Relevant	High	High	High	Low
Heavy metal contamination	Not Relevant	Not Relevant	Insufficient information	High	High	Not Relevant
Hydrocarbon contamination	High	Not Relevant	Very high	High	High	High
Radionuclide contamination	Not Relevant	Not Relevant	Insufficient information	Insufficient information	Insufficient information	Not Relevant
Changes in nutrient levels	Not Relevant	High	Very high	High	High	High
Increase in salinity	High	High	High	High	High	Not Relevant
Decrease in salinity	High	See	See	See	See	High

		explanation	explanation	explanation	explanation	
Changes in oxygenation	High	High	Insufficient information	Immediate	Insufficient information	Not Relevant
Biological factors						
	Halichondria panicea	***Botryllus schlosseri***	***Corallina officinalis***	***Palmaria palmata***	***Laminaria digitata***	***Lithophyllum incrustans***
Community Importance	Important functional	Important characteri-zing	Important characteri-zing	Important characterizing	Key Structuring	Important other
Introduction of microbial pathogens/parasites	Not Relevant	High	Very high	Not Relevant	High	Not Relevant
Introduction of non-native species	Not Relevant	Not Relevant	Not Relevant	Not Relevant	Insufficient information	Not Relevant
Extraction of this species	Not Relevant	Not Relevant	High	High	High	Not Relevant
Extraction of other species	High	Moderate	High	High	High	High

Importance

Marine natural heritage importance

Listed under:	**UK Biodiversity Action Plan**
National importance	Scarce
Habitat Directive feature (Annex 1)	Reefs Large shallow inlets and bays Estuaries Lagoons
UK Biodiversity Action Plan habitat	Tidal rapids

Biotope importance

The fauna associated with the holdfasts of *Laminaria digitata* are known to be highly diverse (Birkett *et al*., 1998) and may provide an important refuge for juveniles of some larger species or commercial species.

Exploitation

Laminaria digitata cast up on the shore have historically been collected and used for fertilizer. More recently *Laminaria digitata* has been cultivated commercially for alginate in Britain and, in Ireland and France, it is cultivated as a sea vegetable. This kelp is also used in the pharmaceutical industry and as an active ingredient in 'beauty products'. Dulse *Palmaria palmata* is used as a vegetable substitute or animal fodder although harvesting on a commercial scale only takes place in Ireland and in France. The coral weed *Corallina officinalis* is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al*., 1987). It is also sold as a powder for use in the cosmetic industry. A European research proposal for cultivation of *Corallina officinalis* is pending (Dr T. Wiedemann, pers. comm.).

Additional information

No text entered

This Biology and Sensitivity Key Information review can be cited as follows:
Marshall, C.E., 2005. *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/01/2005]. Available from: <http://www.marlin.ac.uk>

Laminaria saccharina, foliose red seaweeds, sponges and ascidians on tide-swept infralittoral rock (SIR.Lsac.T)

Key information authored by: Dr Keith Hiscock

Last updated 30/11/2001

This information is not refereed.

If you would be willing to supply *MarLIN* with an image of this species/habitat please contact marlin@mba.ac.uk

Recorded and expected SIR.Lsac.T distribution for Britain and Ireland

Description of biotope

Sheltered, tide-swept, rock with dense *Laminaria saccharina* forest and an under-storey (sometimes sparse) of foliose seaweeds such as *Plocamium cartilagineum*, *Brongniartella byssoides*, *Ceramium nodulosum*, *Lomentaria clavellosa* and *Cryptopleura ramosa*. On the rock surface, a rich fauna comprising sponges (particularly *Halichondria panicea*) anemones (such as *Urticina felina*), colonial ascidians (*Botryllus schlosseri*) and the bryozoan *Alcyonidium diaphanum*. Areas that are scoured by sand or shell gravel may have a less rich fauna beneath the kelp, with the rock surface characterized by encrusting coralline algae, *Balanus crenatus* or *Pomatoceros triqueter*. Good examples of this biotope may have maerl gravel or rhodoliths between cobbles and boulders. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

No text entered

Biotope classification

UK and Ireland Classification

Major habitat	IR	Infralittoral rock (and other hard substrata)
Habitat complex	SIR	Sheltered infralittoral rock
Biotope complex	SIR.K	Silted kelp (stable rock)
Biotope	SIR.Lsac.T	*Laminaria saccharina*, foliose red seaweeds, sponges and ascidians on tide-swept infralittoral rock

Similar biotopes:	IMX.LsacX

Other biotope classification schemes

European Union Nature Information System (EUNIS) code: A3.3124/B - [*Laminaria saccharina*], foliose red seaweeds, sponges and ascidians on tide-swept infralittoral rock (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

Tide-swept areas provide favourable locations for rapid growth of a variety of suspension feeding species and therefore competition for space between them. The sponges *Halichondria panicea* and *Hymeniacidon perleve* together with other sponge species especially compete for space and may overgrow each other or, more often, grow against each other in a mutual stand-off whilst extensively overgrowing other encrusting fauna especially *Balanus crenatus*. Animals such as *Halichondria panicea* and *Botryllus schlosseri* are likely to predominate over algae in growing on kelp stipes and may engulf the fronds of red algae. Where massive growths of the sponge *Halichondria panicea* occur, they may provide a significant habitat for other species especially amphipods and *Caprella linearis* appears to be chemically attracted to the sponge. The fauna associated with sponges may be a significant food source for fish (Peattie & Hoare, 1981). Grazing species, especially chitons, do occur and may maintain rocks clear of epibiota except for encrusting coralline algae.

Seasonal and longer term change

No specific information has been found in relation to this biotope. However, red algae are likely to show a seasonal change in condition of the fronds.

Habitat structure and complexity

There are a wide range of microhabitats within this biotope. They include sediments, sometimes maerl, where infauna will occur, underboulder habitats, the sides and tops of boulder which often have different dominant species, the interstices of massive sponge growths, the holdfasts of kelp plants and the fronds of kelps and other algae.

Dominant trophic groups	Photoautotrophs Suspension feeders Herbivores (grazers)

Productivity

No specific information found has been found but the communities in this biotope are likely to be highly productive. The biotope occurs in shallow depths where both high light intensity and, because of tidal flow, high supply of nutrients to algae will result in high primary productivity. Secondary productivity will also be high as the flow of suspended food is high.

Major sources of organic carbon	Photosynthesis (macroalgae and/or halophytic plants) Detritus

Recruitment processes

The characterizing species in this biotope all have planktonic larvae and are fairly short-lived. There is therefore high recruitment and high turnover.

Time for community to reach maturity

The community would probably reach maturity within 3-4 years although recruitment of additional species to the biotope would continue for some further time.

Additional information

This biotope is remarkable because, even in shallow depths where algae normally predominate, animals - especially sponges - are likely to be dominant. It seems that sponges will out-compete algae where food supply is sufficient.

Habitat preference and distribution

Distribution in Britain and Ireland

There are two main areas where this biotope occurs: in shallow waters at the entrance to marine inlets in southwest Britain and in the narrows at the entrance to sea lochs and obs in western Scotland. The biotope is also recorded from the Menai Strait and from tide-swept shallow entrances to Houbs in Shetland.

Habitat preferences

Temperature range preferences	None apparent
Water clarity preferences	High clarity / Low turbidity Medium clarity / Medium turbidity Low clarity / High turbidity
Limiting nutrients	No information found
Other preferences	

Additional information

No text entered

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Key structural	*Laminaria saccharina*	Sugar kelp
Important characterizing	*Delesseria sanguinea*	Sea beech
Important functional	*Halichondria panicea*	Breadcrumb sponge
Important other	*Botryllus schlosseri*	Star sea squirt

Explanation

The species selected to assess sensitivity in this biotope are predominantly space occupiers that characterize the biotope. *Laminaria saccharina* does and *Halichondria panicea* may include important structural features supporting other species. *Delesseria sanguinea* is selected as a representative red algae which, although not listed as characterizing species in the biotope classification, does occur in the biotope and has significant research information that should represent other red algal species. Although encrusting red algae occur in scoured situations in this biotope, they are not included as representative species here as a distinctive feature of this biotope is that overgrowth by animals is extensive.

Species found especially in biotope

No text entered

Additional information

No text entered

Biotope sensitivity					
Physical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	High	Moderate	Major Decline	Moderate
Smothering	Intermediate	High	Low	Decline	Moderate
Increase in suspended sediment	Low	Very high	Very Low	No Change	Moderate
Decrease in suspended sediment	Low	Very high	Very Low	No Change	Moderate
Desiccation	Intermediate	High	Low	Minor Decline	Moderate
Increase in emergence regime	High	High	Moderate	Major Decline	Low
Decrease in emergence regime	Tolerant*	Not Relevant	Not sensitive*	No Change	High
Increase in water flow rate	Intermediate	High	Low	Minor Decline	Low
Decrease in water flow rate	High	High	Moderate	Minor Decline	Moderate
Increase in temperature	Low	Very high	Very Low	No Change	Low
Decrease in temperature	Low	Very high	Very Low	No Change	Low
Increase in turbidity	Low	High	Low	Minor Decline	Moderate
Decrease in turbidity	Tolerant*	Not Relevant	Not sensitive*	No Change	Low
Increase in wave exposure	High	High	Moderate	Major Decline	Moderate
Decrease in wave exposure	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Noise	Tolerant	Not Relevant	Tolerant	No Change	High
Visual Presence	Tolerant	Not Relevant	Tolerant	No Change	High
Abrasion & physical disturbance	High	High	Moderate	Major Decline	High
Displacement	Intermediate	High	Low	Decline	Moderate
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	High	High	Moderate	Decline	Moderate
Heavy metal contamination	Insufficient information	Not Relevant	Insufficient information	Insufficient Information	Not Relevant
Hydrocarbon contamination	Intermediate	High	Low	Decline	Low
Radionuclide contamination	Insufficient information	Not Relevant	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	Low	High	Low	Minor Decline	Low
Increase in salinity	Tolerant	Not Relevant	Tolerant	No Change	Moderate
Decrease in salinity	Intermediate	High	Low	Minor Decline	Moderate
Changes in oxygenation	Intermediate	High	Low	Decline	Moderate
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence

Introduction of microbial pathogens/parasites	Low	High	Low	No Change	Moderate
Introduction of non-native species	Low	High	Low	Minor Decline	Moderate
Extraction of key or important characterizing species	Low	High	Low	Minor Decline	Moderate
Extraction of important species	Low	High	Low	Minor Decline	Moderate

Explanation of sensitivity and recoverability

Physical Factors	
Substratum Loss (see benchmark)	Most of the species characteristic of this biotope are permanently attached to the substratum so would be removed upon substratum loss. For recoverability, see Additional Information.
Smothering (see benchmark)	Some species, especially *Laminaria saccharina*, are likely to protrude above smothering material. Others such as the active suspension feeders and foliose algae are likely to be killed by smothering. For recoverability, see Additional Information.
Increase in suspended sediment (see benchmark)	Increased suspended sediment levels will reduce the amount of light reaching the seabed and may therefore inhibit photosynthesis of the algal component of the biotope. However, the biotope occurs in very shallow depths and algae are likely to survive. Increased suspended sediment is unlikely to have a significant effect in terms of smothering by settlement in the regime of strong water flow typical of this biotope. However, silt may clog respiratory and feeding organs (especially sea squirts). Since many of the species in this biotope live in areas of high silt content (turbid water) it is expected that they would survive increased levels of silt in the water. Both algae and animals would suffer some decrease in viability. On return to lower suspended sediment levels it is expected that recovery of condition will be rapid.
Decrease in suspended sediment (see benchmark)	Decreased suspended sediment levels will increase the amount of light reaching the seabed and may therefore increase competitiveness of the algal component of the biotope. Suspended sediment may include organic matter and a decrease may reduce the amount of food available to suspension feeding animals. Both algae and animals would suffer some decrease in viability. On return to higher suspended sediment levels it is expected that recovery of condition will be rapid.
Desiccation (see benchmark)	The biotope is predominantly sublittoral but does extend onto the shore and therefore has some ability to resist desiccation. On a sunny day at low water of spring tides, damage (bleaching) is likely to occur to the *Laminaria saccharina* plants but not destroy them completely. Species living below the kelp fronds will be protected by them from the worst effects of desiccation. Sponges, such as *Halichondria panicea*, are likely to withstand some desiccation as they hold water.
Increase in emergence regime (see benchmark)	The biotope is predominantly sublittoral and the dominant species (*Laminaria saccharina*) and many of the subordinate species, especially solitary sea squirts, are unlikely to survive an increased emergence regime. Several mobile species are likely to move away. However, providing that suitable substrata are present, the biotope is likely to re-establish further down the shore within a similar emergence regime to that which existed previously. For recoverability, see additional information below.
Decrease in emergence regime (see benchmark)	The biotope is subtidal and thrives in fully submerged conditions.

Increase in water flow rate (see benchmark)	Increase in tidal flow rates may dislodge substrata (especially where large plants of *Laminaria saccharina* subject to drag are attached to cobbles). Also, increased water flow rate may result in certain species being unable to feed when water flow is likely to damage feeding organs (see Hiscock 1983). However, it is unlikely that species attached to non-mobile substrata in the biotope will be killed by an increase in flow rate. Therefore a decline in the abundance of some species that are swept away is suggested with some reduction in viability of others depending on whether the current velocity reaches a high enough level to inhibit feeding.
Decrease in water flow rate (see benchmark)	Decreased water flow will lead to a reduced competitive advantage for suspension feeding animals especially sponges which will decline in growth rate so that seaweeds will tend to become more dominant. Reduction in water flow rate will also allow settlement of silt with associated smothering. It is therefore expected that, although there might be only a minor decline in species, the biotope will change, possibly to SIR.Lsac.Cod (Sparse *Laminaria saccharina* with *Codium* spp. and sparse red seaweeds on heavily silted very sheltered infralittoral rock). Because the biotope is likely to change, an intolerance of high is given. For recoverability, see Additional Information.
Increase in temperature (see benchmark)	The biotope occurs in warmer and colder parts of Britain and Ireland and similar assemblages of species are known to occur in Scandinavia and in Brittany so that long-term temperature change is unlikely to cause a significant impact. However, exposure to high temperatures for several days may produce stress in some component species but recovery would be expected to be rapid.
Decrease in temperature (see benchmark)	The biotope occurs in warmer and colder parts of Britain and Ireland and similar assemblages of species are known to occur in Scandinavia and in Brittany so that long-term temperature change is unlikely to cause a significant impact. There is a single record of *Halichondria panicea* being adversely affected by frost during the 1963/64 winter (Crisp, 1964).
Increase in turbidity (see benchmark)	Several of the characteristic species are algae that rely on light for photosynthesis. Reduction in light penetration as a result of higher turbidity is unlikely to be fatal to algae in the short term but in the long term will result in a reduction in downward extent and therefore overall extent of the biotope. Species richness may decline in the long-term as algae are unable to survive high turbidity and low light but reduced extent of the biotope (depth limits) is the most significant likely decline.
Decrease in turbidity (see benchmark)	Decreased turbidity and the subsequent increase in light levels is likely to result in an extension of the downward extent of the biotope. Not sensitive* is therefore indicated.
Increase in wave exposure (see benchmark)	This is a fundamentally sheltered coast biotope with species that do not appear to occur in wave exposed situations. Increased wave action is likely to dislodge *Laminaria saccharina* plants and interfere with feeding in solitary tunicates. Massive growths of *Halichondria panicea* are likely to be displaced. Although 'major decline' is indicated with regard to species richness, the results of increased wave exposure would be replacement of biotope-characteristic species with others and the development of a different biotope. A change of biotope means high intolerance. On return to previous conditions, the 'new' biotope would have to degrade before SIR.Lsac.T developed. Nevertheless, such a change should occur within five years and a recoverability of high is indicated (see additional information below). For recoverability, see Additional Information.
Decrease in wave exposure (see benchmark)	This biotope occurs in locations not subject to any significant wave exposure so that decrease in wave exposure is considered not relevant.
Noise	The macroalgae characterizing the biotope have no known sound or vibration

(see benchmark)	sensors. The response of macroinvertebrates is not known.
Visual Presence (see benchmark)	Macrophytes have no known visual sensors. Most macroinvertebrates have poor or short range perception and are unlikely to be affected by visual disturbance such as shading.
Abrasion & physical disturbance (see benchmark)	*Laminaria saccharina*, other algae, sponges and the large solitary tunicates are likely to be removed from the substratum by physical disturbance. Physical disturbance will also overturn boulders and cobbles so that the epibiota becomes buried. Mortality of species is therefore likely to be high although many, particularly mobile species, will survive. For recoverability, see additional information.
Displacement (see benchmark)	Although many of the species in the biotope are sessile and would therefore be killed if removed from their substratum, displacement will often be of the boulders or cobbles on which the community occurs in which case survival will be high. The 'Intermediate' ranking given here supposes that some individual sessile organisms will be removed and die. Mobile organisms such as the prosobranchs in the biotope are likely to survive displacement. Recovery rate assumes that the characteristic species of the biotope will remain, albeit in lower numbers. However, where species have been removed, most have a planktonic larva and/or are mobile and so can migrate into the affected area. For recoverability, see Additional Information.
Chemical Factors	
Synthetic compound contamination (see benchmark)	Several of the species characteristic of the biotope are reported as having high intolerance to synthetic chemicals. For instance, Cole *et al.* (1999) suggested that herbicides such as Simazine and Atrazine were very toxic to macrophytic algae. Hiscock & Hoare (1974) noted that almost all red algal species and many animal species were absent from Amlwch Bay in North Wales adjacent to an acidified halogenated effluent. Red algae have also been found to be sensitive to oil spill dispersants (O'Brien & Dixon 1976; Grundy quoted in Holt *et al.*, 1995). Recovery is likely to occur fairly rapidly. For recoverability, see Additional Information.
Heavy metal contamination (see benchmark)	Insufficient information.
Hydrocarbon contamination (see benchmark)	Red algae have been found to be sensitive to oil and oil spill dispersants (O'Brien & Dixon, 1976; Grundy quoted in Holt *et al.*, 1995). Foliose red algae in the biotope may therefore be subject to bleaching and death. Holt *et al.* (1995) reported that *Laminaria saccharina* had been observed to show no discernible effects from oil spills. The shallow nature of this biotope suggests that oil might diffuse in significant quantities to the biota. However, the presence of strong tidal flow makes it likely that oil will be flushed away. Overall, an intolerance of intermediate is suggested.
Radionuclide contamination (see benchmark)	Insufficient information.
Changes in nutrient levels (see benchmark)	Evidence is equivocal. For *Laminaria saccharina*, Conolly & Drew (1985) found that plants at the most eutrophic site in a study on the east coast of Scotland where nutrient levels were 25% higher than average exhibited a higher growth rate. However, Read *et al*. (1983) reported that, after removal of a major sewage pollution in the Firth of Forth, *Laminaria saccharina* became abundant where previously it had been absent. Increased nutrients may increase the abundance of ephemeral algae and result in smothering or changing the character of the biotope. Any recovery is likely to be high as species are unlikely to be completely lost and

	have planktonic larvae and high growth rates. See also Additional Information.
Increase in salinity (see benchmark)	The biotope occurs in full or variable salinity conditions and does not include species that are characteristically found in low salinity and that would be lost by an increase in salinity.
Decrease in salinity (see benchmark)	The biotope occurs in situations that are naturally subject to fluctuating or low salinities: it grows in areas where freshwater run-off dilutes near-surface waters and most components are likely to survive reduced salinity conditions. For instance, *Laminaria saccharina* can survive in salinities of 8 psu although growth is retarded below 16 psu (Kain, 1979). *Delesseria sanguinea* is also tolerant of salinities as low as 11 psu in the North Sea whilst *Halichondria panicea* occurs in the reduced salinity of the western Baltic probably as low as 14 psu. Most characteristic species are likely to survive reduced salinity but species that are lost are likely to have planktonic larvae and recolonize rapidly. See also Additional Information.
Changes in oxygenation (see benchmark)	The biotope occurs in areas where still water conditions do not occur and so some species may be intolerant of hypoxia. Cole *et al.* (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2mg/l. However, on return to oxygenated conditions, rapid recovery is likely.
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	There is little information on microbial pathogen effects on the characterizing species in this biotope. However, *Laminaria saccharina* may be infected by the microscopic brown alga *Streblonema aecidioides*. Infected algae show symptoms of Streblonema disease, i.e. alterations of the blade and stipe ranging from dark spots to heavy deformations and completely crippled thalli (Peters & Scaffelke, 1996). Infection can reduce growth rates of host algae. It is likely that microbial pathogens will have only a minor possible impact on this biotope.
Introduction of non-native species (see benchmark)	The non-native species currently (October 2000) most likely to colonize this biotope is *Sargassum muticum* which is generally considered to be a 'gap-filler'. However, it may displace some native species. Potential non-native colonists are the kelp *Undaria pinnatifida* which may significantly displace *Laminaria saccharina* but not change other components.
Extraction of key or important characterizing species (see benchmark)	Extraction of *Laminaria saccharina* may occur but the plant rapidly colonizes cleared areas of the substratum: Kain (1975) recorded that *Laminaria saccharina* was abundant six months after the substratum was cleared so recovery should be rapid. Associated species are unlikely to be affected by removal of *Laminaria saccharina* unless protection from desiccation on the lower shore is important.
Extraction of important species (see benchmark)	Extraction of *Laminaria saccharina* may occur but the plant rapidly colonizes cleared areas of the substratum: Kain (1975) recorded that *Laminaria saccharina* was abundant six months after the substratum was cleared so recovery should be rapid. Associated species are unlikely to be affected by removal of *Laminaria saccharina* unless protection from desiccation on the lower shore is important.

Additional information

Recoverability

The main characterizing species, *Laminaria saccharina*, rapidly colonizes cleared areas of the substratum and Kain (1975) recorded that *Laminaria saccharina* was abundant six months after the substratum was cleared so recovery should be rapid. The main species covering rock, *Lithophyllum incrustans*, grows at a rate of only <7 mm a year (Irvine & Chamberlain, 1994) and will take much longer to colonize. Most other characterizing species have a planktonic larva and/or are mobile and so can migrate into the affected area. Many or most of the species in the biotope grow rapidly (for instance, *Halichondria panicea* increases in size by about 5% per week (Barthel, 1988). However, coralline encrusting algae and maerl, where present, are likely to recover more slowly as growth rates are low. Although some species might not have recovered full abundance within five years, the appearance of the biotope will be much as before the impact. Overall, the community is likely to recolonize rapidly and a recoverability of high is given.

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors				
	Laminaria saccharina	***Delesseria sanguinea***	***Halichondria panicea***	***Botryllus schlosseri***
Community Importance	Key structural	Important characterizing	Important functional	Important other
Substratum Loss	High	High	High	High
Smothering	High	Intermediate	High	High
Increase in suspended sediment	Low	Low	Low	High
Decrease in suspended sediment	See explanation	See explanation	Not Sensitive	See explanation
Desiccation	High	High	Intermediate	Intermediate
Increase in emergence regime	Intermediate	Intermediate	Intermediate	Intermediate
Decrease in emergence regime	See explanation	See explanation	Not Sensitive	See explanation
Increase in water flow rate	Low	Intermediate	Intermediate	Intermediate
Decrease in water flow rate	See explanation	See explanation	Low	See explanation
Increase in temperature	Intermediate	Low	Low	Low
Decrease in temperature	See explanation	See explanation	Low	See explanation
Increase in turbidity	Low	Not Sensitive	Not Sensitive	Low
Decrease in turbidity	See explanation	See explanation	Not Sensitive	See explanation
Increase in wave exposure	High	Not Sensitive	Intermediate	Intermediate
Decrease in wave exposure	See explanation	See explanation	Low	See explanation
Noise	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive
Visual Presence	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive
Abrasion & physical disturbance	Intermediate	Intermediate	Intermediate	Intermediate
Displacement	Intermediate	High	High	High
Chemical factors				
	Laminaria saccharina	***Delesseria sanguinea***	***Halichondria panicea***	***Botryllus schlosseri***
Community Importance	Key structural	Important characterizing	Important functional	Important other
Synthetic compound contamination	Low	High	Insufficient information	Insufficient information
Heavy metal contamination	Intermediate	Low	Insufficient information	Insufficient information
Hydrocarbon contamination	Low	High	Low	Insufficient information
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	Intermediate	Low	Insufficient information	Low
Increase in salinity	High	Low	Low	Intermediate
Decrease in salinity	See explanation	See explanation	Low	See explanation
Changes in oxygenation	Insufficient information	High	Intermediate	Intermediate

Biological factors				
	Laminaria saccharina	***Delesseria sanguinea***	***Halichondria panicea***	***Botryllus schlosseri***
Community Importance	Key structural	Important characterizing	Important functional	Important other
Introduction of microbial pathogens/parasites	Intermediate	Insufficient information	Insufficient information	Insufficient information
Introduction of non-native species	Insufficient information	Not Relevant	Insufficient information	Not Sensitive*
Extraction of this species	Intermediate	Not Relevant	Not Relevant	Not Relevant
Extraction of other species	Insufficient information	Not Sensitive*	High	High

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors				
	Laminaria saccharina	***Delesseria sanguinea***	***Halichondria panicea***	***Botryllus schlosseri***
Community Importance	Key structural	Important characterizing	Important functional	Important other
Substratum Loss	High	High	High	High
Smothering	High	High	High	High
Increase in suspended sediment	High	Immediate	Immediate	High
Decrease in suspended sediment	See explanation	See explanation	Not Relevant	See explanation
Desiccation	High	High	Very high	High
Increase in emergence regime	High	High	Very high	High
Decrease in emergence regime	See explanation	See explanation	Not Relevant	See explanation
Increase in water flow rate	High	High	Very high	High
Decrease in water flow rate	See explanation	See explanation	Immediate	See explanation
Increase in temperature	High	Immediate	Very high	Very high
Decrease in temperature	See explanation	See explanation	Very high	See explanation
Increase in turbidity	High	Not Relevant	Not Relevant	Immediate
Decrease in turbidity	See explanation	See explanation	Not Relevant	See explanation
Increase in wave exposure	High	Not Relevant	Very high	Moderate
Decrease in wave exposure	See explanation	See explanation	Very high	See explanation
Noise	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Abrasion & physical disturbance	Very high	High	High	High
Displacement	High	High	High	Moderate
Chemical factors				
	Laminaria saccharina	***Delesseria sanguinea***	***Halichondria panicea***	***Botryllus schlosseri***
Community Importance	Key structural	Important characterizing	Important functional	Important other
Synthetic compound contamination	High	High	Not Relevant	Not Relevant
Heavy metal contamination	High	Very high	Not Relevant	Not Relevant
Hydrocarbon contamination	High	High	High	Not Relevant
Radionuclide contamination	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Changes in nutrient levels	High	Immediate	Not Relevant	High
Increase in salinity	High	Immediate	High	High
Decrease in salinity	See explanation	See explanation	High	See explanation

Changes in oxygenation	Not Relevant	High	High	High
Biological factors				
	Laminaria saccharina	***Delesseria sanguinea***	***Halichondria panicea***	***Botryllus schlosseri***
Community Importance	Key structural	Important characterizing	Important functional	Important other
Introduction of microbial pathogens/parasites	High	Insufficient information	Not Relevant	High
Introduction of non-native species	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Extraction of this species	High	Not Relevant	Not Relevant	Not Relevant
Extraction of other species	Not Relevant	Not Relevant	High	Moderate

Importance

Marine natural heritage importance

Listed under: **UK Biodiversity Action Plan**
EC Habitats Directive

National importance Scarce

Habitat Directive feature (Annex 1) Reefs
Large shallow inlets and bays
Estuaries
Lagoons

UK Biodiversity Action Plan habitat Tidal rapids
Saline lagoons
Inshore sublittoral rock (broad habitat statement)

Biotope importance

Where massive growths of the sponge *Halichondria panicea* occur, they may provide a significant habitat for other species especially amphipods and *Caprella linearis* appears to be chemically attracted to the sponge. The fauna associated with sponges may be a significant food source for fish (Peattie & Hoare, 1981).

Exploitation

None known.

Additional information

The biotope occurs in tidal rapids at the entrance to rock-bound lagoons (obs) in Scotland at least, where it may be particularly species rich.

This Biology and Sensitivity Key Information review can be cited as follows:
Hiscock, K., 2001. *Laminaria saccharina*, foliose red seaweeds, sponges and ascidians on tide-swept infralittoral rock. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/01/2005]. Available from: <http://www.marlin.ac.uk>

Mytilus edulis beds on reduced salinity tide-swept infralittoral rock (SIR.MytT)

Key information authored by: Dr Keith Hiscock

Last updated 30/11/2001

This information is not refereed.

If you would be willing to supply *MarLIN* with an image of this species/habitat please contact marlin@mba.ac.uk

Recorded and expected SIR.MytT distribution for Britain and Ireland

Description of biotope

This biotope is reported to occur in shallow tide-swept conditions and also in reduced salinity tide-swept conditions (may be 2 biotopes?). Some descriptions indicate a wide variety of epifaunal colonizers on the mussel valves, including seaweeds, hydroids and bryozoans. Predatory starfish *Asterias rubens* also occur in this biotope. This biotope generally appears to lack large kelp plants, although transitional examples containing mussels and kelps plants may also occur. [Further data and analysis required for this biotope]. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

This biotope appears to be distinguished from other biotopes by occurring on rock and in strong currents suggesting that it is a feature of the tidal rapids at the entrance to lagoonal habitats.

Biotope classification

UK and Ireland Classification

Major habitat	IR	Infralittoral rock (and other hard substrata)
Habitat complex	SIR	Sheltered infralittoral rock
Biotope complex	SIR.EstFa	Estuarine faunal communities (shallow rock/mixed substrata)
Biotope	SIR.MytT	*Mytilus edulis* beds on reduced salinity tide-swept infralittoral rock

Other biotope classification schemes

European Union Natural Information (EUNIS) Habitat classification code: A3.321/B- *Mytilus edulis* beds on reduced salinity tide-swept infralittoral rock (Mussel beds on reduced salinity tide-swept infralittoral rock)

(Davies & Moss, 1998).

Ecology

Ecological and functional relationships

Mussels appear to provide the predominant substratum in this biotope but no information has been found on any species living amongst the mussels or infaunal components in sediments. The mussel shells are colonized by epibiota - species that can survive reduced (but not necessarily 'low') salinity. Most species are suspension feeders and so do not interact but the predatory starfish *Asterias rubens* is likely to have a major effect on survival of the mussels. Kautsky (1981) examined subtidal mussel beds in the Baltic Sea and reported that mussels were a major food source for the flounder (*Platichthys flesus*) but probably of only minor importance for eelpout (*Zoarces viviparus*): both species that might occur in this biotope.

Seasonal and longer term change

The dominant species in the biotope can be present throughout the year except for filamentous brown and any other algae which most likely show seasonal change related to light levels. It is possible that some species in the biotope will be killed by low salinity during heavy rain in the winter. *Asterias rubens* is known to 'invade' mussel biotopes and cause high mortality but no such changes have been noted specifically for this biotope. Kautsky (1981) reported that no major fluctuations in distribution and abundance of *Mytilus edulis* was noted in the Baltic Sea over a ten year period. However, his studied population was not significantly affected by predation.

Habitat structure and complexity

The mussels provide hard substratum for a range of algae and invertebrates to settle and interstices for polychaete worms and other mobile biota to live. If sediments are present amongst the mussels, infaunal burrowing species will be supported.

Dominant trophic groups	Photoautotrophs Suspension feeders Predators Scavengers

Productivity

Mussels can be very fast growing (high productivity).

Major sources of organic carbon	Photosynthesis (macroalgae and/or halophytic plants) Detritus

Recruitment processes

All of the species named in the biotope and most likely the majority of species occurring in the biotope have planktonic propagules and are likely to settle readily. Recruitment in many *Mytilus* sp. populations is sporadic, with unpredictable pulses of recruitment, possibly from the pool of young mussels on filamentous algae (Seed & Suchanek, 1992). *Mytilus* sp. is highly gregarious and final settlement often occurs around or in between individual mussels of established populations. Competition with surrounding adults may suppress growth of the young mussels settling within the mussel bed, due to competition for food and space, until larger mussels are lost (Seed & Suchanek, 1992). Persistent mussel beds can be maintained by relatively low levels of recruitment. McGrorty *et al*. (1990) reported that adult populations were largely unaffected by large variations in spat fall between 1976-1983 in the Exe estuary.

Time for community to reach maturity

In the tidal rapids or tidal sound habitat where this species is most likely to occur, productivity and growth are likely to be high. Mussels will grow rapidly but associated species will settle at a particular time of year so that it would take in excess of one year for the community to reach maturity.

Additional information

No text entered

Habitat preference and distribution

Distribution in Britain and Ireland

Isolated locations on the west and east coast of Scotland, Outer Hebrides and Shetland. Also found on the north west coast of Wales.

Habitat preferences

Temperature range preferences	No information found
Water clarity preferences	No information found
Limiting nutrients	No information found
Other preferences	No information found

Additional information

No text entered

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Key structural	*Mytilus edulis*	Common mussel
Key structural	*Asterias rubens*	Common starfish
Important functional	*Balanus crenatus*	An acorn barnacle
Important other	*Halichondria panicea*	Breadcrumb sponge

Explanation

The biotope is dominated structurally and functionally by *Mytilus edulis*. Without *Mytilus edulis*, it would not be this biotope. The starfish *Asterias rubens* is a significant predator or *Mytilus edulis*. Other species included in those representing sensitivity are ones that are common components.

Species found especially in biotope

No text entered

Additional information

No text entered

Biotope sensitivity

Physical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	High	Moderate	Major Decline	Moderate
Smothering	Intermediate	High	Low	Decline	Moderate
Increase in suspended sediment	Low	Immediate	Not sensitive	No Change	Moderate
Decrease in suspended sediment	Low	Immediate	Not sensitive	No Change	Moderate
Desiccation	Low	Very high	Very Low	Minor Decline	Moderate
Increase in emergence regime	Low	Very high	Very Low	Minor Decline	Moderate
Decrease in emergence regime	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Increase in water flow rate	Tolerant	Not Relevant	Tolerant	Not Relevant	Moderate
Decrease in water flow rate	High	High	Moderate	Rise	Moderate
Increase in temperature	Low	High	Low	Minor Decline	Moderate
Decrease in temperature	Low	Very high	Very Low	Minor Decline	Moderate
Increase in turbidity	Low	Very high	Very Low	Minor Decline	Moderate
Decrease in turbidity	Low	Very high	Very Low	Rise	Moderate
Increase in wave exposure	Intermediate	High	Low	Decline	Low
Decrease in wave exposure	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Noise	Tolerant*	Not Relevant	Not sensitive*	No Change	Moderate
Visual Presence	Tolerant*	Not Relevant	Not sensitive*	No Change	Moderate
Abrasion & physical disturbance	Intermediate	High	Low	Decline	Moderate
Displacement	Intermediate	High	Low	Minor Decline	Moderate
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	Intermediate	Very high	Low	No Change	Low
Heavy metal contamination	Intermediate	Very high	Low	No Change	Moderate
Hydrocarbon contamination	Intermediate	Very high	Low	Minor Decline	High
Radionuclide contamination	Insufficient information	Not Relevant	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	Tolerant*	Not Relevant	Not sensitive*	No Change	Not Relevant
Increase in salinity	High	High	Moderate	Rise	Low
Decrease in salinity	Intermediate	High	Low	Minor Decline	Moderate
Changes in oxygenation	Intermediate	High	Low	Decline	Moderate
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species	Evidence /

Introduction of microbial pathogens/parasites	Intermediate	High	Low	No Change	Low
Introduction of non-native species	Low	Immediate	Not sensitive	No Change	Moderate
Extraction of key or important characterizing species	Intermediate	High	Low	Decline	Moderate
Extraction of important species	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant

Explanation of sensitivity and recoverability	
Physical Factors	
Substratum Loss (see benchmark)	Removal of the substratum will include the removal of all the species within the biotope. Therefore, an intolerance of high has been recorded. For recoverability, see additional information below.
Smothering (see benchmark)	Although smothering by sediment is unlikely in the strong tidal currents to which this biotope is exposed, mortality of mussels might occur as a result on smothering by large scale movements of sand (Daly & Mathieson, 1977; Holt *et al*., 1998). Similarly, biodeposition within a mussel bed results in suffocation or starvation of individuals that cannot re-surface. Young mussels have been shown to move up through a bed, avoiding smothering, while many others were suffocated (Dare, 1976; Holt *et al*., 1998). This suggests that a proportion of the population may be able to avoid smothering in subtidal conditions, and, therefore, an intolerance of intermediate has been recorded. Associated species will most likely also survive some smothering. Although a single good recruitment event for mussels may recolonize the substratum within a year, recovery in relation to size of mussels and presence of associated species may take up to 5 years, and is some circumstances significantly longer (see additional information below). Therefore, a recoverability of high has been recorded.
Increase in suspended sediment (see benchmark)	*Mytilus edulis* has been reported to be relatively tolerant of suspended sediment and siltation and survived over 25 days at 440 mg/l and on average 13 days at 1200 mg/l (Purchon, 1937; Moore, 1977). Similarly, *Asterias rubens* flourishes in naturally turbid conditions and is capable of cleansing itself of adherent mud particles (Moore, 1977). However, mussels and the species living on mussels probably suffer a metabolic cost resulting from the cleansing mechanisms, mucus production and interrupted or impaired feeding. Therefore, a biotope intolerance of low, at the benchmark level, has been recorded. The majority of the organisms within the biotope probably have mechanisms to deal with siltation and suspended sediment, so that recoverability of immediate has been recorded.
Decrease in suspended sediment (see benchmark)	Decrease in the amount of suspended sediment is likely to reduce available food for the suspension feeders that dominate this biotope. However, the result would be a slowing of growth and not decline.
Desiccation (see benchmark)	The dominant species in the biotope, *Mytilus edulis*, is capable of closing valves and surviving significant exposure to air. Although *Balanus crenatus* has more permeable shell plates than other littoral barnacles and therefore loses water quicker and dies sooner when exposed to air, it is still capable of surviving for long periods in air (see the *Balanus crenatus* review). *Halichondria panicea* is likely to be less resistant to desiccation. However, as this is a sublittoral biotope that would only be subject to desiccation for short periods if at all, intolerance is assessed as low and recoverability as very high.
Increase in emergence regime	The dominant species in the biotope, *Mytilus edulis*, is capable of closing valves and surviving significant exposure to air. Although *Balanus crenatus* has more permeable shell plates than other littoral barnacles and therefore loses water

(see benchmark)	quicker and dies sooner when exposed to air, it is still capable of surviving for long periods in air (see the *Balanus crenatus* review). *Halichondria panicea* is likely to be less resistant to increased emergence and therefore desiccation. However, as this is a sublittoral biotope that would only be subject to emergence for short periods if at all, intolerance is assessed as low and recoverability as very high.
Decrease in emergence regime (see benchmark)	This is a sublittoral biotope and decrease in emergence is not therefore relevant.
Increase in water flow rate (see benchmark)	The dominant species in the biotope, *Mytilus edulis*, together with other sessile species in the biotope lives in very strong tidal currents and in extremely wave exposed situations. It might be expected that an increase in water flow may dislodge a proportion of the *Mytilus edulis*. However, Young (1985) reported that *Mytilus edulis* increased byssus thread production in response to increased agitation and water flow rates. Therefore it is not expected that increased water flow rate would remove the dominant species and therefore the species attached to it. Mobile species such as *Asterias rubens* may be swept away but this seems unlikely based on the occurrence of the species in very strong flows.
Decrease in water flow rate (see benchmark)	Decreases in water flow rates are likely to increase siltation and allow increased predation pressure from crabs, lobsters and starfish such as *Asterias rubens*. The biotope is likely to suffer from competition from species adapted to more sheltered conditions. Also, the supply of food will be reduced, mussels will have to rely more on active suspension feeding and growth will be lessened. At the benchmark level of a decrease by two categories of tidal stream exposure for one year, it is likely that the biotope will be substantially altered and may no longer be SIR.EstFa.MytT. Species richness may increase as *Mytilus edulis* will no longer dominate the rock surfaces. Therefore, an intolerance of high has been recorded. On return to previous conditions, recoverability is likely to be high (see Additional information below).
Increase in temperature (see benchmark)	An upper, sustained temperature tolerance limit of about 29°C has been reported for *Mytilus edulis* in the United Kingdom (Read & Cumming, 1967; Almada-Villela *et al*., 1982). Therefore, *Mytilus edulis* is considered to be of low intolerance to temperature change. Temperatures that adversely affect *Balanus crenatus* and *Asterias rubens* are higher than the benchmark level and, even though outflow from enclosed areas might be of water that has significantly heated in sunny weather, it is unlikely to reach the levels suggested as harmful (for instance Naylor, 1965 for *Balanus crenatus*; Schäfer, 1972 for *Asterias rubens*). Overall, the biotope has been assessed as of low intolerance to increased temperatures. Recovery is likely to be rapid (see additional information below).
Decrease in temperature (see benchmark)	*Mytilus edulis* tolerates decreases in temperature and even freezing for short periods. Similarly, *Balanus crenatus* and *Asterias rubens* were unaffected by the severe winter of 1962/63 (Crisp, 1964) when average temperatures were 5 to 6 °C below normal. However, *Halichondria panicea* was recorded as being killed by frost in North Wales. It appears, therefore, that most of the characterizing species within the biotope are tolerant of an acute short term temperature decrease and a biotope intolerance of low has been recorded.
Increase in turbidity (see benchmark)	Filamentous brown algae are present in this biotope (Hiscock, 1984). However, the biotope is primarily an animal dominated community, dependant on secondary production and not dependant on light. Therefore, the biotope is probably only intolerant of changes in turbidity and light attenuation in that some algae might be reduced in abundance or lost.
Decrease in turbidity (see benchmark)	Decrease in turbidity will increase light penetration and therefore the possibility that abundance of algae might increase. Seaweed growth may adversely affect the

	survival of mussels. Suchanek (1985) found that urchin grazing removed seaweeds and increased survival of mussel beds. However, the overwhelming dominance of mussels in the conditions of tidal stream exposure make it unlikely that addition of algae will change the biotope present. Thus an intolerance of low is suggested.
Increase in wave exposure (see benchmark)	Oscillatory water movement is potentially far more destructive than tidal streams due to the 'to and fro' motion that is more likely to loosen mussels. Although, mussels occur in extremely wave exposed situations, the large and loosely attached mussels likely to occur in this biotope will be easily dislodged. However, Young (1985) reported that *Mytilus edulis* increased byssus thread production in response to increased agitation and water flow rates. Any loss of mussels will result in loss of associated species and therefore at least a reduction in extent of the biotope. Therefore, an intolerance of intermediate has been recorded. For recoverability see 'Additional Information below'.
Decrease in wave exposure (see benchmark)	This biotope already occurs in extremely sheltered conditions so that further decrease in wave exposure is probably not relevant.
Noise (see benchmark)	The species in this biotope are insensitive to noise disturbance at the levels of the benchmark. However, wildfowl are a major predator and several species are highly intolerant of noise. Therefore, noise at the level of the benchmark may disturb predatory wildfowl, so that the mussel populations and the species that live attached to them may benefit indirectly.
Visual Presence (see benchmark)	The species living in the biotope are unlikely to be sensitive to visual disturbance. However, wildfowl are highly intolerant of visual presence and are likely to be scared away by increased human activity, therefore reducing the predation pressure on the mussels and the species attached to them. Therefore, visual disturbance may be of indirect benefit to the biotope.
Abrasion & physical disturbance (see benchmark)	It is likely that abrasion or impact at the level of the benchmark would damage or remove patches of the population of mussels and the species attached to the mussels. Several long term studies have shown that gaps took a long time to heal in intertidal populations, and in some cases enlarged (presumably due to wave action and predation), with little recovery within 3-5 years, leading to estimated recovery times of 8-34 years (Pain & Levin, 1981) or several hundreds of years (Seed & Suchanek, 1992). However, enlargement of gaps due to wave action will not occur in the sheltered situations where this biotope occurs and settlement rates of mussels in tide-swept sublittoral situations is rapid. Taking account of time for mussels to grow to a significant size and to be colonized by the associated species (see further information below), a recoverability of 'high' has been reported.
Displacement (see benchmark)	The dominant species in the biotope, *Mytilus edulis*, is capable of re-attaching itself to suitable substrata once displaced. Overall, however, displacement will result in loss of mussels and associated species from this biotope. Displaced starfish are unlikely to be adversely affected and could probably return. Overall, a proportion of the mussel bed would probably survive displacement and an intolerance of intermediate has been recorded. However, other members of the community are probably more intolerant, resulting in a decline in species richness until they are able to recolonize. Recovery is dependant on recruitment of *Mytilus edulis* from outside the biotope and a recoverability of high has been reported (see additional information below).
Chemical Factors	
Synthetic compound contamination (see benchmark)	The effects of contaminants on *Mytilus edulis* were extensively reviewed by Widdows & Donkin (1992) and Livingstone & Pipe (1992). Overall, *Mytilus edulis* is probably relatively tolerant of contaminants, although mortalities have

	been recorded (see species review for details). For example, • Widdows *et al*. (1995) noted that polar organics, and organo-chlorines reduced scope for growth in *Mytilus edulis*; • *Mytilus edulis* has been shown to accumulate PCBs and ivermecten (Hummel *et al*., 1989; Holt *et al*., 1995; Cole *et al*., 1999); • the presence of poly-aromatic hydrocarbons, *cis*-chlordane pesticides and cadmium gas been associated with an increase in tumours in *Mytilus edulis* (Hillman, 1993; Holt *et al*., 1998), and • mussels may be absent from areas of high boating activity, presumably due to TBT (Holt *et al*., 1998). Barnacles, such as *Balanus crenatus* were considered to be highly sensitive to chemical contaminants (Holt *et al.*, 1995). PCB exposure resulted in defective larvae in *Asterias rubens* (Besten *et al*., 1989). Although only filamentous brown algae are named in the biotope description, kelp plants may occur and possibly some other algal species. Cole *et al*. 1999 report the following as very toxic to macrophytes: atrazine; simazine; diuron; and linuron (herbicides). It is likely therefore that Laminariales such as *Laminaria hyperborea* have an intermediate intolerance to atrazine and some other herbicides. No information was found concerning the effect of contaminants on other named species in the biotope. Therefore, chemical contamination may cause mortalities and sub-lethal effects in the *Mytilus edulis* bed but affect other members of the community to varying degrees, and an overall intolerance of intermediate has been recorded. Since likely effects at the benchmark level are generally sublethal, a recoverability of very high is recorded.
Heavy metal contamination (see benchmark)	Lethal threshold concentrations for several heavy metals have been determined in *Mytilus edulis* (see species review; Widdows & Donkin (1992) and Livingstone & Pipe (1992) for reviews). Mussels were also reported to be missing from a wider area of the Cumbrian coast than other organisms in the vicinity of a phosphate rich effluent contaminated by heavy metals (Holt *et al*., 1998). Widdows & Donkin (1992) noted that lethal responses give a false impression of high tolerance. However, *Mytilus edulis* is probably relatively tolerant of heavy metal contamination. Besten *et al*. (1989) suggested that cadmium (Cd) pollution posed a significant threat to populations of *Asterias rubens* since it affected reproduction. Little information concerning heavy metal toxicity was found for other animal species in the biotope. Although only filamentous brown algae are named in the biotope description, kelp plants may occur and possibly some other algal species. Hopkin & Kain (1978) examined the effect of Cu, Zn, Hg and Cd on *Laminaria hyperborea* gametophytes and sporophytes. Sublethal effects on sporophyte development, growth and respiration were shown at concentrations higher than the short term benchmark for Hg, Zn and Cd. Hg was found to be lethal at 0.05 mg/l. However, Cu affected sporophyte development at 0.01 mg/l but was lethal at 0.1 mg/l. Given the evidence of sub-lethal and lethal effects of heavy metals in *Mytilus edulis* especially, a biotope intolerance of intermediate has been reported. Effects are likely to be sublethal and recovery rapid.
Hydrocarbon contamination (see benchmark)	The effects of contaminants including hydrocarbons on *Mytilus edulis* were extensively reviewed by Widdows & Donkin (1992) and Livingstone & Pipe (1992). Overall, *Mytilus edulis* is probably relatively tolerant of contaminants, although mortalities have been recorded (see species review for details). Hydrocarbon contamination in infralittoral populations is limited to exposure to lighter oil fractions and PAHs in solution or as droplets as a result of turbulent flow or adsorbed onto particulates. • Toxic hydrocarbons and PAHs contribute to a decline on the scope for growth in *Mytilus edulis* (Widows & Donkin, 1992; Widdows *et al.*, 1995). • The presence of poly-aromatic hydrocarbons, *cis*-chlordane pesticides and

	cadmium gas been associated with an increase in tumours in *Mytilus edulis* (Hillman, 1993; Holt *et al.*, 1998). • Mesocosm experiments have shown high mortalities of *Mytilus edulis* exposed to the water accommodated fraction of diesel (Widdows *et al.*, 1987; Bokn *et al.*, 1993). • Ingestion of droplets of sunflower oil, from a tanker spill off the Anglesey coast resulted in mortalities after spawning in *Mytilus edulis* (Mudge *et al.*, 1993; Holt *et al.*, 1998). • *Asterias rubens* suffered mass mortalities after the *Torrey Canyon* oil spill and was reported to be lost from mesocosms treated with the water accommodated fraction of diesel (Smith, 1968; Bokn *et al.*, 1993). • Whilst it is unclear what the full species complement of this biotope is, it seems likely that some likely species including crustaceans and echinoderms may be adversely affected by oil which might cause narcotization and possible mortality. • *Mytilus edulis* dominated jetty piles immediately adjacent to an oil refinery effluent in Milford Haven, suggesting a high tolerance of hydrocarbon contamination (K. Hiscock, pers. comm.). Overall, *Mytilus edulis* and many of the associated species in this biotope are appear to be relatively tolerant of hydrocarbon pollution. However, due to the incidence of mortality after exposure to diesel and oils *Mytilus edulis* was regarded as of intermediate intolerance to hydrocarbon contamination. Although, *Asterias rubens* has been assessed as highly intolerant, the mussel bed may benefit from a reduction in starfish predation. An overall biotope intolerance of intermediate has been recorded. Since dominant species and most other species at least are likely to survive hydrocarbon contamination, a recoverability of very high is recorded.
Radionuclide contamination (see benchmark)	No information has been found.
Changes in nutrient levels (see benchmark)	Moderate nutrient enrichment, especially in the form of organic particulates and dissolved organic material, is likely to increase food availability for all the suspension feeders within the biotope. Therefore a 'tolerant*' has been recorded. However, long term or high levels of organic enrichment may result in deoxygenation and algal blooms. *Mytilus edulis* has been reported to suffer mortalities due to algal blooms of *Gyrodinium aureolum* and *Phaeocystis poucheri* (Holt *et al.*, 1998). In this biotope, there is unlikely to be any danger of de-oxygenation as a result of the death of algal blooms caused by nutrient enrichment because of the strong tidal flow and water mixing to which the biotope is exposed.
Increase in salinity (see benchmark)	The dominant species, *Mytilus edulis*, thrives in strong tidal currents whether or not subject to low salinity. However, *Mytilus* is able to tolerate low salinity conditions much more than some other species likely to thrive in full salinity. Those other species, for instance *Halichondria panicea*, other encrusting sponges and *Tubularia indivisa*, may out-compete and dominate in the place of *Mytilus edulis* and therefore the biotope will no longer be SIR.EstFa.MytT.
Decrease in salinity (see benchmark)	*Mytilus edulis* thrives in brackish lagoons and estuaries, including the reduced salinity that this biotope is exposed to. Overall, *Mytilus edulis* can acclimate to a wide range of salinities and a change of salinity at the benchmark level is unlikely to adversely affect this species. However, some of the associated species in this biotope do not penetrate far into estuarine or reduced salinity situations and are most likely intolerant of a fall in salinity below that to which the biotope is usually exposed. Therefore an intolerance of intermediate is indicated. Once conditions return to normal, most of the associated species will recolonize from planktonic

	stages. A recoverability of high is given.
Changes in oxygenation (see benchmark)	*Mytilus edulis* was regarded to be tolerant of a wide range of oxygen concentrations including zero (Zwaan de & Mathieu, 1992; Diaz & Rosenberg, 1995; see species review). However, echinoderms such as *Asterias rubens* are highly intolerant of anoxic conditions. Similarly, *Balanus crenatus* was considered to be highly intolerant to anoxia. Although *Mytilus edulis* is likely to tolerate hypoxic conditions, an intolerance of intermediate has been recorded due to the likely intolerance of the other members of the community. It should be noted that in the presence of strong to moderate tidal streams, anoxic conditions are unlikely to occur unless combined with reduced water flow rates. Recoverability of the associated species is likely to be rapid (see additional information below).
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	The diseases and parasites of *Mytilus edulis* were reviewed by Bower (1992) and Bower & McGladdery (1996) (see the species review). *Asterias rubens* may be parasitised by the ciliate *Orchitophyra stellarum* (Vevers, 1951; Bouland & Clareboudt, 1994) resulting in castration of males, and subsequent reduction in population size (Vevers, 1951). However, little information on diseases of other members of the community has been found. Therefore, an intolerance of intermediate has been recorded. Recovery of the mussel beds will be dependant on recruitment from other populations and a recoverability of high has been recorded (see additional information below).
Introduction of non-native species (see benchmark)	*Mytilus edulis* is an effective space occupier and few other species are able to out-compete it. The South American mytilid *Aulocomya ater*, which has been reported recently in the Moray Firth (Eno *et al.*, 2000), is not expected to be a threat to this reduced salinity populations.
Extraction of key or important characterizing species (see benchmark)	Subtidal mussel beds may be exploited by dredging. Holt *et al.,* (1998) suggest that in particular embayments over-exploitation may reduce subsequent recruitment leading to long term reduction in the population or stock. Extraction of *Mytilus edulis* is likely to remove much of the epifaunal and infaunal community, resulting in a decline in species richness. Overall, an intolerance of intermediate has been recorded at the benchmark level of extraction. However, recovery is likely to occur within 5 years and a recoverability of high has been recorded (see additional information below).
Extraction of important species (see benchmark)	This biotope is unlikely to be subject to targeted extraction or fishing activity for species other than *Mytilus edulis* (see above).

Additional information

Recoverability
Recovery will depend mainly on recruitment of the dominant species, *Mytilus edulis*. Although a single good recruitment event for mussels may recolonize the substratum within a year, recovery in relation to size of mussels and presence of some associated species may take up to 5 years, and is some circumstances significantly longer. In the case of *Balanus crenatus*, the species is an important early colonizer of sublittoral rock surfaces (Kitching, 1937) and it densely colonized a site that had been dredged for gravel within 7 months (Kenny & Rees, 1994). *Halichondria panicea* also appears to be a rapid colonizer, suggested by its presence dominating kelp stipes that would not be more than a few years old. Therefore, recovery is predicted to be high.

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors				
	Mytilus edulis	***Asterias rubens***	***Balanus crenatus***	***Halichondria panicea***
Community Importance	Key structural	Key structural	Important functional	Important other
Substratum Loss	High	High	High	High
Smothering	Intermediate	Low	High	High
Increase in suspended sediment	Low	Low	Low	Low
Decrease in suspended sediment	Low	See explanation	See explanation	Not Sensitive
Desiccation	Low	High	High	Intermediate
Increase in emergence regime	Low	Not Sensitive	High	Intermediate
Decrease in emergence regime	Low	See explanation	See explanation	Not Sensitive
Increase in water flow rate	Low	Intermediate	Low	Intermediate
Decrease in water flow rate	Low	See explanation	See explanation	Low
Increase in temperature	Low	High	High	Low
Decrease in temperature	Low	Low	See explanation	Low
Increase in turbidity	Not Sensitive	Low	Low	Not Sensitive
Decrease in turbidity	Not Sensitive	See explanation	See explanation	Not Sensitive
Increase in wave exposure	Intermediate	Intermediate	Low	Intermediate
Decrease in wave exposure	Intermediate	Low	See explanation	Low
Noise	Not Sensitive*	Not Sensitive	Not Sensitive	Not Sensitive
Visual Presence	Not Sensitive*	Not Sensitive	Not Sensitive	Not Sensitive
Abrasion & physical disturbance	Intermediate	Intermediate	Intermediate	Intermediate
Displacement	Intermediate	Low	High	High
Chemical factors				
	Mytilus edulis	***Asterias rubens***	***Balanus crenatus***	***Halichondria panicea***
Community Importance	Key structural	Key structural	Important functional	Important other
Synthetic compound contamination	Intermediate	Intermediate	High	Insufficient information
Heavy metal contamination	Intermediate	Intermediate	Intermediate	Insufficient information
Hydrocarbon contamination	Intermediate	High	Low	Low
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	Intermediate	Low	Intermediate	Insufficient information
Increase in salinity	Low	High	Low	Low
Decrease in salinity	Low	See explanation	See explanation	Low
Changes in oxygenation	Low	High	High	Intermediate

Biological factors				
	Mytilus edulis	***Asterias rubens***	***Balanus crenatus***	***Halichondria panicea***
Community Importance	Key structural	Key structural	Important functional	Important other
Introduction of microbial pathogens/parasites	Intermediate	Intermediate	Insufficient information	Insufficient information
Introduction of non-native species	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Extraction of this species	Intermediate	Not Relevant	Not Relevant	Not Relevant
Extraction of other species	Low	Low	Not Relevant	High

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors				
	Mytilus edulis	***Asterias rubens***	***Balanus crenatus***	***Halichondria panicea***
Community Importance	Key structural	Key structural	Important functional	Important other
Substratum Loss	High	High	High	High
Smothering	High	Very high	High	High
Increase in suspended sediment	Immediate	High	High	Immediate
Decrease in suspended sediment	Immediate	See explanation	See explanation	Not Relevant
Desiccation	Immediate	High	High	Very high
Increase in emergence regime	Very high	Not Relevant	High	Very high
Decrease in emergence regime	Very high	See explanation	See explanation	Not Relevant
Increase in water flow rate	Very high	High	Very high	Very high
Decrease in water flow rate	Very high	See explanation	See explanation	Immediate
Increase in temperature	Very high	High	High	Very high
Decrease in temperature	Very high	High	See explanation	Very high
Increase in turbidity	Not Relevant	Very high	Very high	Not Relevant
Decrease in turbidity	Not Relevant	See explanation	See explanation	Not Relevant
Increase in wave exposure	High	High	Very high	Very high
Decrease in wave exposure	High	High	See explanation	Very high
Noise	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Abrasion & physical disturbance	High	High	High	High
Displacement	High	Immediate	High	High
Chemical factors				
	Mytilus edulis	***Asterias rubens***	***Balanus crenatus***	***Halichondria panicea***
Community Importance	Key structural	Key structural	Important functional	Important other
Synthetic compound contamination	High	High	High	Not Relevant
Heavy metal contamination	High	High	High	Not Relevant
Hydrocarbon contamination	High	High	High	High
Radionuclide contamination	Not Relevant	Insufficient information	Not Relevant	Not Relevant
Changes in nutrient levels	High	High	High	Not Relevant
Increase in salinity	Very high	High	Very high	High
Decrease in salinity	Very high	See explanation	See explanation	High

Changes in oxygenation	Very high	High	High	High
Biological factors				
	Mytilus edulis	***Asterias rubens***	***Balanus crenatus***	***Halichondria panicea***
Community Importance	Key structural	Key structural	Important functional	Important other
Introduction of microbial pathogens/parasites	High	High	Not Relevant	Not Relevant
Introduction of non-native species	Not Relevant	Insufficient information	Not Relevant	Not Relevant
Extraction of this species	High	Not Relevant	Not Relevant	Not Relevant
Extraction of other species	Very high	High	Not Relevant	High

Importance

Marine natural heritage importance

Listed under:	**UK Biodiversity Action Plan** **EC Habitats Directive**
National importance	Scarce
Habitat Directive feature (Annex 1)	Reefs Estuaries
UK Biodiversity Action Plan habitat	Tidal rapids Inshore sublittoral rock (broad habitat statement)

Biotope importance

The biotope may provide an important food source for starfish *Asterias rubens* and for flounder *Platichthys flesus*.

Exploitation

Mussels have been harvested for food and bait since early times. British mussel production is relatively small, comprising only 5% of total European Community production (Edwards, 1997). Edwards (1997) reported 10,347 tonnes of mussels landed in 1994 with a value of £32 million. However, collection in the strong tidal flow conditions that occur in this biotope is not believed to take place.

Additional information

The biotope relies on flowing water being present and so that factor should not be obstructed.

This Biology and Sensitivity Key Information review can be cited as follows:
Hiscock, K., 2001. *Mytilus edulis* beds on reduced salinity tide-swept infralittoral rock. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/01/2005]. Available from: <http://www.marlin.ac.uk>

Zostera marina/*angustifolia* beds in lower shore or infralittoral clean or muddy sand (IMS.Zmar)

Key information authored by: Dr Harvey Tyler-Walters

Last updated 25/11/2004

Refereed by: Dr Leigh Jones

Current swept bed of *Zostera marina*. Image width ca 2 m in foreground.
Image: Keith Hiscock

Recorded and expected IMS.Zmar distribution for Britain and Ireland

Description of biotope

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 *Zostera angustifolia* is currently under consideration]. In IMS.Zmar the community composition may be dominated by these *Zostera* species and therefore characterized 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* may be more readily characterized by their infaunal community. Beds of this biotope in the south-west of 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. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh Variation

Some seagrass beds exist in Wales, e.g. the Severn Estuary, where *Zostera noltii* and *Zostera marina* occur together. In these seagrass beds, *Zostera marina* is found in the wet channels and *Zostera noltii* is found on the raised beds (between the small channels) that dry between tides. See Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

None entered

Biotope classification

UK and Ireland Classification

Major habitat	SS	Sublittoral sediments
Habitat complex	IMS	Infralittoral muddy sands
Biotope complex	IMS.Sgr	Seagrass beds (sublittoral/lower shore)
Biotope	IMS.Zmar	*Zostera marina*/*angustifolia* beds in lower shore or infralittoral clean or muddy

	sand
Similar biotopes:	IMS.EcorEns

Other biotope classification schemes

- European Union Nature Information System code: A4.5/B-IMS.Sgr.Zmar (Davies & Moss,1998).
- Wadden Sea (1996) classification code 03.02.05: Benthic zone of the shallow coastal waters with muddy and sandy bottom, rich in macrophytes (von Nordheim *et al.*, 1996).
- France (ZNIEFF-MER) classification code II.3.3: Herbiers de *Zostera marina*, *Zostera noltii* (=*Z. nana* pro parte) du mediolittoral inferieur. France (ZNIEFF-MER) classification code III.3.4: Herbiers de *Zostera marina* (Dauvin *et al.*, 195).

Ecology

Ecological and functional relationships

- *Zostera marina* provides shelter or substratum for a wide range of species including fish such as wrasse and goby species (also associated with kelp).
- Leaves slow currents and water flow rates under the canopy and encourage settlement of fine sediments, detritus and larvae (Turner & Kendall, 1999).
- Seagrass rhizomes stabilize the sediment and protect against wave disturbance and favour sedentary species that require stable substrata and may, therefore, increase species diversity;.
- The leaves are grazed by small prosobranch molluscs, for example, *Rissoa* spp., *Lacuna vincta*, *Hydrobia* spp. and *Littorina littorea*.
- *Zostera marina* bed assemblages may include, in particular, Pipe fish (*Syngnathus typhle*, *Entelurus aequoraeus*), the sea anemones (*Cereus pedunculatus, Cerianthus lloydii*) and the neogastropod *Hinia reticulatus*.
- Cuttlefish (*Sepia officinalis*) may lay their eggs amongst sea grass;
- Beds on the south east cost of England may contain distinctive assemblages of Lusitanian fauna such as the hydroid *Laomedea angulata*, Stauromedusae (stalked hydroids) and, rarely, sea horses *Hippocampus guttulatus*.

Seasonal and longer term change

Zostera beds are naturally dynamic. The population is still recovering from loss of 90 percent of *Zostera marina* beds in 1920s and 1930s as a result of wasting disease, May show marked annual change, for example in the brackish conditions in the Fleet Lagoon (Dorset, UK) leaves die back in autumn and regrow in spring to early summer (Dyrynda, 1997).

Habitat structure and complexity

Seagrasses provide shelter and hiding places. Leaves and rhizomes provide substrata for epibenthic species. These epibenthic species may be grazed by other species (Davison & Hughes, 1998). The sediment supports a rich infauna of polychaetes, bivalve molluscs and burrowing anemones. Amphipods and mysids are important mobile epifauna in seagrass beds. Cockle beds (*Cerastoderma edule*) are often associated with seagrass beds.

Dominant trophic groups	Photoautotrophs Herbivores

Productivity

Seagrass meadows are considered to be the most productive of shallow, sedimentary environments (Davison & Hughes, 1998). The species richness of *Zostera marina* beds in the River Yealm, Devon, UK was significantly higher than that of adjacent sediment (Turner & Kendall, 1999). *Zostera* is directly grazed by ducks and geese. Epiphytes may be as productive as the seagrass they inhabit and are grazed by gastropods. Seagrasses are an important source of organic matter whose decomposition supports detritus based food chains. Seagrass detritus may make an important contribution to ecosystems far removed from the bed itself.

Major sources of organic carbon	Photosynthesis (macroalgae and/or halophytic plants)

Detritus

Recruitment processes

Zostera spp. are perennials but may act as annuals under stressful conditions. Seedlings rarely occur in seagrass beds except in areas cleared by storms, blow-out or excessive herbivory (Phillips & Menez, 1988). Seed mortality is very high (Phillips & Menez, 1988; Fishman & Orth, 1996). Seed may be dispersed through the gut of wildfowl (Fishman & Orth, 1996), or float long distances (up to 200 m in some cases) on attached gas bubbles. The generative stalk may be released and can also float long distances. If displaced pieces of shoot or rhizome float and may root if they settle on suitable substrata. However, vegetative reproduction probably exceeds seedling recruitment except in areas of sediment disturbance (Phillips & Menez, 1988; Reusch *et al.*, 1998). *Zostera marina* provides refuges for some species and nursery areas for some, e.g. the two-spot goby *Gobiusculus flavescens* and the 15-spined sticklebacks *Spinachia spinachia*. Some commercially important species use seagrass beds as feeding ground, e.g.; bass *Dicentrachus labrax*. Seahorses *Hippocampus* spp. reach their northern limit in seagrass beds along the south coast England (Davison & Hughes, 1998).

Time for community to reach maturity

Zostera marina beds are unlikely to seed and establish rapidly. There has been little recovery of these beds since the 1930s. In Danish waters *Zostera marina* beds could take at least 5 years to establish even when near to established beds. Seeding over distances is likely to be slow.

Additional information

Seagrass beds may act as corridor habitats for species moving from warm waters. Seasonal die back resulted in sediment destabilization as well as loss of cover for fish in the Fleet, Dorset, UK (Dyrynda, 1997).

Habitat preference and distribution

Distribution in Britain and Ireland

Present in enclosed areas (harbours, bays, sounds and inlets) in southwest England, Wales, western Ireland, western and eastern Scotland including Orkney and Shetland Islands

Habitat preferences

Temperature range preferences	5 to 30 °C
Water clarity preferences	High clarity / Low turbidity
Limiting nutrients	Nitrogen (nitrates) Phosphorous (phosphates)
Other preferences	

Additional information

Intertidal *Zostera marina* beds may be damaged by frost, although rhizomes most likely survive. In carbonate based sediments phosphate may be limiting due to adsorption onto sediment particles. *Zostera marina* is also found in reduced salinities, for example brackish lagoons (Dyrynda, 1997).

The presence of *Zostera marina* does not always indicate the presence of IMS.Zmar. However, Kay (1998) provides a detailed account of the distribution of *Zostera marina* in Wales.

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Key structural	*Zostera marina*	Common eelgrass

Important structural	*Lacuna vincta*	Banded Chink shell
Important structural	*Hydrobia ulvae*	Laver spire shell

Explanation

Zostera marina/angustifolia stabilizes the sediment and provides a distinct habitat. *Zostera marina* is the dominant source of organic matter (through grazing and as detritus). Loss of *Zostera* spp. would result in rapid change in and loss of the associated community. The fungus *Labrynthula macrocystis* causes wasting disease and may cause long lasting declines in *Zostera* sp. beds. It does not appear to cause disease in low salinity conditions. However, *Zostera marina* is often found in fully saline conditions. Epiphytic grazers, such as *Hydrobia ulvae, Rissoa* spp. and *Lacuna vincta* remove fouling epiphytic algae that would otherwise smother *Zostera* spp. *Hydrobia ulvae* and *Lacuna* spp. have been shown to reduce the density of epiphytes on *Zostera noltii* in the Dutch Wadden Sea (Philippart, 1995) and *Zostera marina* in Puget Sound (Nelson, 1997) respectively with subsequent enhancement of the productivity of sea grass.

Species found especially in biotope

Laomedia angulata A hydroid
Rhodophysema georgii An epiphytic seaweed
Halothrix lumbricalis An epiphytic seaweed
Leblondiella densa An epiphytic seaweed
Myrionema magnusii An epiphytic seaweed
Cladosiphon zosterae An epiphytic seaweed
Punctaria crispate An epiphytic seaweed
Entocladia perforans An endophytic seaweed

Rare or scarce species associated with this biotope

Nationally scarce	*Laomedia angulata*
Nationally rare	*Halothrix lumbricalis*
Nationally rare	*Leblondiella densa*

Additional information

Species richness is derived from the number of species recorded in MNCR database for this biotope. *Zostera* beds, in particular *Zostera marina,* are species rich habitats. Species diversity is highest in subtidal, fully marine, perennial populations of *Zostera marina* when compared to intertidal, estuarine or annual beds of *Zostera* spp. Representative and characteristic species are listed by Davison & Hughes (1998). Species lists for major eelgrass beds are available for the Helford Passage (Sutton & Tompsett, 2000) and Isles of Scilly (Hiscock, 1984). Hiscock S. (1987) listed 67 algae in *Zostera marina* beds in the Isles of Scilly. Proctor (1999) lists 63 species of fauna in *Zostera* sp. beds in Torbay. Hiscock S. (1987) noted that colonial diatoms were the most abundant algae on *Zostera marina* leaves in the Isles of Scilly. However, it should be noted that species lists are likely to underestimate the total number of species present, especially with respect to microalgae epiphytes, bacteria and meiofauna.

Biotope sensitivity

Physical Factors	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	Very low	Very High	Major Decline	Moderate
Smothering	High	Very low	Very High	Major Decline	Moderate
Change in suspended sediment	Intermediate	Moderate	Moderate	Decline	Moderate
Desiccation	Intermediate	High	Low	Decline	Low

Change in emergence regime	Intermediate	High	Low	Minor Decline	Low
Change in water flow rate	Intermediate	Moderate	Moderate	Minor Decline	Low
Change in temperature	Low	Very high	Very Low	Minor Decline	Low
Change in turbidity	High	Very low	Very High	Major Decline	Moderate
Change in wave exposure	High	Very low	Very High	Major Decline	Low
Noise	Tolerant	Not Relevant	Tolerant	Minor Decline	Very low
Visual Presence	Tolerant	Not Relevant	Tolerant	No Change	Very low
Abrasion & physical disturbance	Intermediate	Moderate	Moderate	Decline	Low
Displacement	High	Low	High	Major Decline	Low
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	Intermediate	Moderate	Moderate	Decline	Moderate
Heavy metal contamination	Low	High	Low	No Change	Low
Hydrocarbon contamination	Intermediate	High	Low	Decline	Moderate
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	High	Very low	Very High	Major Decline	Moderate
Change in salinity	Low	Very high	Very Low	No Change	Moderate
Changes in oxygenation	Intermediate	High	Low	Minor Decline	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	High	Very low	Very High	Major Decline	High
Introduction of non-native species	Intermediate	Low	High	Minor Decline	Low
Extraction of key or important characterizing species	Intermediate	Moderate	Moderate	Minor Decline	Low
Extraction of important species	Intermediate	Moderate	Moderate	Decline	Low

Explanation of sensitivity and recoverability

Physical Factors	
Substratum Loss (see benchmark)	Substratum loss will result in the loss of the shoots, rhizome and probably the seed bank of *Zostera marina* together with its associated biotope. Recoverability of *Zostera marina* will depend on recruitment from other populations. Although *Zostera marina* seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease suggests that, once lost, seagrass beds take considerable time to re-establish.
Smothering (see benchmark)	Sediment disturbance, siltation, erosion and turbidity resulting from coastal engineering and dredging activities have been implicated in the decline of seagrass

	beds world wide (Holt *et al.*, 1997; Davison & Hughes, 1998). Seagrasses are intolerant of smothering and typically bend over with addition of sediment and are buried in a few centimetres of sediment (Fonseca, 1992). Epiphytes and macroalgae are also likely to be intolerant of smothering. Infaunal species within the community are unlikely to be intolerant of smothering itself. However, the community will probably be intolerant of loss of the source of primary production on substratum. Recoverability will depend on recruitment from other populations. Although *Zostera marina* seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. The slow recovery of *Zostera* populations since the 1920s - 30s outbreak of wasting disease suggests that, once lost, seagrass beds take considerable time to re-establish.
Change in suspended sediment (see benchmark)	Increased sediment erosion or accretion have been associated with loss of seagrass beds in the Australia, the Mediterranean and USA. Increased sediment availability may result in raised seagrass beds, more likely to be exposed to low tide, desiccation and high temperatures. Seagrass beds demonstrate a balance of sediment accretion and erosion. Sediment deposited during summer months may be lost again due to winter storms, resuspension by grazing wildfowl, and increased erosion due to die back of leaves and shoots in autumn and winter. Seagrass beds should be considered intolerant of any activity that changes the sediment regime where the change is greater than expected due to natural events.
Desiccation (see benchmark)	*Zostera marina* is mainly subtidal and intolerant to desiccation compared to other species of seagrass. If exposed at low tide the shoot bases are stiff and upright for a few centimetres, and leaf bases will be killed by 30 min exposure on a warm, sunny day (Holt *et al.*, 1997). Even short periods of drying kill the flowers. If the rhizomes are undamaged the leaves will grow back but repeated exposure to desiccation may exhaust the energy stores in the rhizomes. *Zostera marina* may be more intolerant of than other *Zostera* sp. to activities that cause the sediment to drain or dry. Therefore the seagrass and its associated biotope will be intolerant of desiccation.
Change in emergence regime (see benchmark)	Decreased emergence may allow the seagrass beds to extend further up the shore. Increased emergence will reduce the upper extent of the biotope. Populations on the lower shore are likely to be highly intolerant of increases in emergence (see desiccation).
Change in water flow rate (see benchmark)	Seagrasses require sheltered environments, with gentle long shore currents and tidal flux. Where populations are found in moderately strong currents they are smaller, patchy and vulnerable to storm damage and blow outs. Increased water flow may also increase sediment erosion (see siltation above). Populations present in moderately strong currents may benefit from decreased water flow rates.
Change in temperature (see benchmark)	Increased temperatures may encourage growth of epiphytes and ephemeral algae while important grazers such as *Hydrobia ulvae* and *Lacuna vincta* are intolerant of temperature change. Although *Zostera marina* is tolerant of temperature change increased algal growth before the grazers can recover will reduce primary productivity. Prolonged temperature change and may result in smothering of *Zostera marina* and reduction in extent or loss of the seagrass bed.
Change in turbidity (see benchmark)	Light attenuation limits the depth to which *Zostera marina* can grow and light is a requirement for photosynthesis. Turbidity resulting from dredging and eutrophication caused a massive decline of *Zostera* populations in the Wadden Sea (Giesen *et al.*, 1990; Davison & Hughes, 1998). Seagrass populations are likely to survive short term increases in turbidity, however prolonged increase in light attenuation, especially at the lower depths of its distribution, will probably result in loss or damage of the population.
Change in wave exposure	Seagrasses require sheltered environments, with gentle long shore currents and tidal flux. Where populations are found in moderately strong currents they are smaller,

(see benchmark)	patchy and vulnerable to storm damage and blow outs. Increased wave exposure may also increase sediment erosion (see siltation above). Populations present in moderately strong currents may benefit from decreased water flow rates. Small patchy populations or recently established population and seedling may be highly intolerant of increased wave action since they lack an extensive rhizome system.
Noise (see benchmark)	The effect of sound waves and vibration on plants is poorly studied. However, it is likely that sound waves will have little effect on *Zostera marina* at the benchmark levels suggested. However, fish species and grazing wildfowl are likely to be disturbed by noise at the benchmark level.
Visual Presence (see benchmark)	Continuous shading will affect photosynthesis and therefore viability. However, occasional shading caused by surface movements of vessels at the level of this benchmark is unlikely to have an effect on seagrass beds.
Abrasion & physical disturbance (see benchmark)	Small scale sediment disturbance may stimulate growth and small patches of sediment allow recolonization by seedlings (Davison & Hughes, 1998). However, seagrasses are not physically robust and rhizomes are likely to be damaged, and seeds buried too deep to germinate, by activities such as trampling, anchoring, digging, dredging, and power boat and jet-ski wash (Fonseca, 1992). Suction dredging for cockles in the Solway Firth removed *Zostera* in affected areas while *Zostera* was abundant in un-dredged areas (Perkins, 1988). Physical disturbance and removal of plants can lead to increased patchiness and destabilization of the seagrass bed, which in turn can lead to reduced sedimentation within the seagrass bed, increased erosion, and loss of larger areas of *Zostera* (Davison & Hughes, 1998). Therefore, the impact from a scallop dredge is likely to remove a proportion of the population and result in increased erosion of the bed. Therefore, intolerance has been recorded as intermediate. Grazing gastropods and other epifauna are small but likely to be displaced or removed attached to the leaves of *Zostera*. Reduction in numbers of grazers may result in unchecked and potentially smothering growth of epiphytes and other algae, especially in the spring and summer months.
Displacement (see benchmark)	Seagrass rhizomes are easily damaged by trampling, anchoring, dredging and other activities that disturb the sediment such as storms. Although rhizomes and shoots can root and re-establish themselves if they settle on sediment long enough (Phillips & Menez, 1988) displacement is likely to result in loss of the seagrass and its associated biotope.
Chemical Factors	
Synthetic compound contamination (see benchmark)	*Zostera marina* is known to accumulate TBT but no damage was observable in the field. Naphthalene, pentachlorophenol, Aldicarb and Kepone reduce nitrogen fixation and may affect *Zostera marina* viability. Triazine herbicides (e.g. Irgarol) inhibit photosynthesis and sublethal effects have been detected. Terrestrial herbicides may damage seagrass beds in the marine environment. For example, the herbicide Atrazine is reported to cause growth inhibition and 50 percent mortality in *Zostera marina* exposed to 100 ppb (ng/ l) Atrazine for 21 days (Davison & Hughes, 1998). TBT contamination is likely to adversely affect grazing gastropods resulting in increased algal growth, reduced primary productivity and potential smothering of the biotope.
Heavy metal contamination (see benchmark)	The concentration and toxicity of heavy metals in salt marsh plants, including *Zostera marina* was reviewed by Williams *et al.* 1994. Growth of *Zostera marina* is inhibited by 0.32 mg/l Cu and 10 mg/l Hg. Davison & Hughes (1998) report that Hg, Ni and Pb reduce nitrogen fixation which may affect viability. However, leaves and rhizomes accumulate heavy metals, especially in winter. Williams *et al.* (1994) did not observe any damage to *Zostera marina* in the field. Lead in sediment from, for example shotgun pellets, may stress *Zostera marina* plants (Jones *et al.*, 2000). Gastropods are thought to be relatively tolerant of heavy metals (Bryan, 1984).

Hydrocarbon contamination (see benchmark)	• Healthy populations of *Zostera* can occur in the presence of long term, low level, hydrocarbon effluent, for example in Milford Haven, Wales (Hiscock, K.,1987) • *Zostera marina* may be partially protected from direct contact by oil due to its subtidal habitat. • The Amoco Cadiz oil spill off Roscoff caused *Zostera marina* leaves to blacken for 1-2 weeks but had little effect on growth, production or reproduction after the leaves were covered in oil for six hours (Jacobs, 1980). • The Amoco Cadiz oil spill resulted in virtual disappearance of Amphipods, Tanaidacea and Echinodermata from *Zostera marina* beds in Roscoff and a decrease in numbers of Gastropoda, sedentary Polychaeta and Bivalvia. The numbers of most groups returned to normal within a year except Echinoderms which recovered slowly and Amphipods which had not recovered after one year (Jacobs, 1980) • Removal of oil intolerant of gastropod grazers may result in smothering of seagrasses by epiphytes (Davison & Hughes, 1998). Jacobs (1980) noted a larger algal bloom than in previous years after the Amoco Cadiz spill in Roscoff, probably as a result in increased nutrients (from dead organisms and breakdown of oil) and the reduction of algal grazers. However, in his study the herbivores recolonized and the situation returned to 'normal' within a few months. • Experimental treatment of *Zostera* sp. with crude oil and dispersants halted growth but had little effect on cover whereas pre-mixed oil and dispersant caused rapid death and significant decline in cover within 1 week suggesting that dispersant treatments should be avoided (Davison & Hughes, 1998).
Radionuclide contamination (see benchmark)	Insufficient information
Changes in nutrient levels (see benchmark)	Where nutrients are limiting, additional low levels of nutrients may improve growth of *Zostera marina*. The reported effects of nutrient enrichment include: • High nitrate concentrations implicated in decline of *Zostera marina* (Davison & Hughes, 1998). Burkholder *et al*. (1992) demonstrated that nitrate enrichment could cause decline of *Zostera marina* in poorly flushed areas. In addition they noted that increasing or high temperatures associated with spring exacerbated the adverse effects of nitrate enrichment and that growth and survival were significantly reduced by nutrient enrichment levels of between 3.5 and 35 micro Molar nitrate per day with the most rapid decline (weeks) at high nitrate levels. Plant loss resulted from death of the meristem tissue. • van Katwijk *et al.* (1999) noted that adverse effects of nitrate were dependant on salinity. Estuarine *Zostera marina* plants were more intolerant of high nitrate concentration than marine *Zostera marina* plants at high (30 psu) salinity than at lower salinities (23 or 26 psu) and that both populations benefited from nitrate enrichment (0-4 to 6.3 micro Molar nitrate per day) at 23 or 26 psu. • Increased growth of epiphytes or blanketing algae. Den Hartog (1994) reported the growth of a dense blanket of *Ulva radiata* in Langstone Harbour in 1991 that resulted in the loss of 10ha of *Zostera marina* and *Zostera noltii* ; by summer 1992 the *Zostera* sp. were absent, however this may have been exacerbated by grazing by Brent geese • Encouragement of phytoplankton blooms which increase turbidity and reduce light penetration (Davison & Hughes, 1998). • The levels of phenolic compounds in *Zostera* sp. (involved in disease resistance) are reduced under nutrient enrichment and may increase their susceptibility to infection by wasting disease (Davison & Hughes, 1998).

Change in salinity (see benchmark)	*Zostera* sp. Has a wide tolerance of salinity from 10 -39 ppt (Davison & Hughes, 1998). Germination in *Zostera marina* occurs over a range of salinities. *Hydrobia ulvae* and *Lacuna vincta* are tolerant of wide range of salinities. The biotope is probably tolerant of changes in salinity, however, not all members of the community have been assessed and some species may be intolerant of changes in salinity.
Changes in oxygenation (see benchmark)	Loss of grazers due to low oxygen levels will result in unchecked growth of epiphytes and other algae which may smother *Zostera marina*. Prolonged deoxygenation is likely to damage the seagrass itself (Jones *et al.*, 2000).
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	A major outbreak of wasting disease resulted in significant declines of *Zostera marina* beds in 1920s to 1930s. Wasting disease is thought to be caused by the marine fungus, *Labyrinthula macrocystis*. The disease is less likely at low salinities. However, *Zostera marina* is often found in fully salinity waters. The disease causes death of leaves and, after 2-3 seasons, death of regenerative shoots, rhizomes and loss of up to 90 percent of the population and its associated biotope.
Introduction of non-native species (see benchmark)	*Spartina anglica* (a cord grass) is an invasive pioneer species, a hybrid of introduced and native cord grass species. Its rapid growth consolidates sediment, raises mudflats and reduces sediment availability elsewhere. It has been implicated in the reduction of *Zostera* sp. cover in Lindisfarne, Northumberland due to encroachment and changes in sediment dynamics (Davison & Hughes, 1998). Japanese weed (*Sargassum muticum*) invades open substratum and may prevent recolonization of areas of seagrass beds left open by disturbance (Davison & Hughes, 1998). *Zostera marina* and *Sargassum muticum* may compete for space in the lower shore lagoons of the Solent. However, evidence for competition is conflicting and requires further research. If the invasive species prevent recolonization then the recoverability from other factors will be reduced.
Extraction of key or important characterizing species (see benchmark)	Wildfowl grazing can consume significant amounts of seagrass and reduce cover mainly in autumn and winter. Grazing probably causes part of the natural seasonal fluctuation in seagrass cover and *Zostera* sp. can recover from typical levels of grazing. However, where a bed is stressed by other factors it may not be able to withstand grazing (Holt *et al.*, 1997; Davison & Hughes, 1998). Seagrass rhizomes are easily damaged by trampling, anchoring, dredging and other activities that disturb the sediment. The seagrass bed is unlikely to survive displacement (see above) or extraction.
Extraction of important species (see benchmark)	Seagrass rhizomes are easily damaged by trampling, anchoring, dredging and other activates that disturb the sediment. Seeds may be buried too deep to germinate. Mechanical dredging of cockles in the Solway Firth, in intertidal *Zostera* beds, resulted in the loss of the seagrass bed and was closed. Dredging for bivalves has been implicated in the decline of seagrass beds in the Dutch, Wadden Sea. Damage of *Zostera noltii* beds after the *Sea Empress* oil spill was reported as limited to the ruts left by clean up vehicles.

Additional information

None entered

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors			
	Zostera marina	***Lacuna vincta***	***Hydrobia ulvae***
Community Importance	Key structural	Important structural	Important structural
Substratum Loss	High	High	High
Smothering	High	Intermediate	Intermediate
Increase in suspended sediment	Intermediate	Low	Not Sensitive
Decrease in suspended sediment	See explanation	See explanation	See explanation
Desiccation	Intermediate	Intermediate	Low
Increase in emergence regime	Intermediate	Intermediate	Low
Decrease in emergence regime	See explanation	See explanation	See explanation
Increase in water flow rate	Intermediate	Intermediate	Intermediate
Decrease in water flow rate	See explanation	See explanation	See explanation
Increase in temperature	Not Sensitive	Intermediate	Intermediate
Decrease in temperature	See explanation	See explanation	See explanation
Increase in turbidity	High	Low	Not Sensitive
Decrease in turbidity	See explanation	See explanation	See explanation
Increase in wave exposure	High	Intermediate	High
Decrease in wave exposure	See explanation	See explanation	See explanation
Noise	Not Sensitive	Not Sensitive	Not Sensitive
Visual Presence	Not Sensitive	Not Sensitive	Not Sensitive
Abrasion & physical disturbance	Intermediate	High	Low
Displacement	High	Not Sensitive	Not Sensitive
Chemical factors			
	Zostera marina	***Lacuna vincta***	***Hydrobia ulvae***
Community Importance	Key structural	Important structural	Important structural
Synthetic compound contamination	Intermediate	Insufficient information	Low
Heavy metal contamination	Low	Insufficient information	Insufficient information
Hydrocarbon contamination	Low	Intermediate	Intermediate
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	High	Not Sensitive	Low
Increase in salinity	Low	Not Sensitive	Not Sensitive
Decrease in salinity	See explanation	See explanation	See explanation
Changes in oxygenation	Low	Intermediate	Intermediate
Biological factors			
	Zostera marina	***Lacuna vincta***	***Hydrobia ulvae***
Community Importance	Key structural	Important structural	Important structural
Introduction of microbial pathogens/parasites	High	Insufficient information	High
Introduction of non-native species	Intermediate	Insufficient information	Insufficient information
Extraction of this species	Intermediate	Not Relevant	Not Relevant
Extraction of other species	Intermediate	Intermediate	Not Sensitive

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors			
	Zostera marina	***Lacuna vincta***	***Hydrobia ulvae***
Community Importance	Key structural	Important structural	Important structural
Substratum Loss	Very low	High	High
Smothering	Very low	High	Very high
Increase in suspended sediment	Moderate	Immediate	Not Relevant
Decrease in suspended sediment	See explanation	See explanation	See explanation
Desiccation	High	High	Immediate
Increase in emergence regime	High	High	Immediate
Decrease in emergence regime	See explanation	See explanation	See explanation
Increase in water flow rate	Moderate	High	Very high
Decrease in water flow rate	See explanation	See explanation	See explanation
Increase in temperature	Not Relevant	High	Immediate
Decrease in temperature	See explanation	See explanation	See explanation
Increase in turbidity	Very low	Very high	Not Relevant
Decrease in turbidity	See explanation	See explanation	See explanation
Increase in wave exposure	Very low	High	High
Decrease in wave exposure	See explanation	See explanation	See explanation
Noise	Not Relevant	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Not Relevant	Not Relevant
Abrasion & physical disturbance	Moderate	High	Very high
Displacement	Low	Not Relevant	Not Relevant
Chemical factors			
	Zostera marina	***Lacuna vincta***	***Hydrobia ulvae***
Community Importance	Key structural	Important structural	Important structural
Synthetic compound contamination	Moderate	Insufficient information	Immediate
Heavy metal contamination	Very high	Insufficient information	Insufficient information
Hydrocarbon contamination	Very high	High	Very high
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	Very low	Not Relevant	Immediate
Increase in salinity	Very high	Not Relevant	Not Relevant
Decrease in salinity	See explanation	See explanation	See explanation
Changes in oxygenation	Very high	High	Very high
Biological factors			
	Zostera marina	***Lacuna vincta***	***Hydrobia ulvae***
Community Importance	Key structural	Important structural	Important structural
Introduction of microbial pathogens/parasites	Very low	Insufficient information	High
Introduction of non-native species	Low	Insufficient information	Insufficient information
Extraction of this species	Moderate	Not Relevant	Not Relevant
Extraction of other species	Moderate	High	Not Relevant

Importance

Marine natural heritage importance

Listed under:	**Berne Convention** **UK Biodiversity Action Plan** **EC Habitats Directive**
National importance	Uncommon
Habitat Directive feature (Annex 1)	Mudflats and sandflats not covered by seawater at low tide Sandbanks which are slightly covered by sea water all the time Large shallow inlets and bays Estuaries Lagoons
UK Biodiversity Action Plan habitat	Seagrass beds Saline lagoons Inshore sublittoral sediment (broad habitat statement)
OSPAR Priority Habitat	*Zostera* beds

Biotope importance

Intertidal and probably shallow subtidal *Zostera marina* beds provide food for a variety of wildfowl. Brent and Canadian geese rely on *Zostera marina* for a large proportion of their food. Declines in Brent geese and wigeon parallel the decline of *Zostera marina*. Little evidence to support the hypothesis that *Zostera marina* beds are nursery areas for fish

Exploitation

- Seagrass beds are often associated with cockle beds. Suction dredging for bivalves, such as cockles and *Mercenaria* sp., has been reported to damage eelgrass beds (Davison & Hughes, 1998).
- The decline in seagrass beds in the 1920s and1930s together with their importance in coastal processes has resulted in scientific research use and experimental management studies.
- Seagrasses have been put to a number of uses world-wide, for example, sound-proofing, insulation, roofing thatch, binding soil, packaging, basket weaving and in the manufacture of 'coir' matting.

Additional information

The presence of seagrass beds reduces water flow and increases sedimentation in their locality and may be important in coastal defense. Their loss may increase wave energy reaching the shore and accelerate erosion.*Zostera marina* is also protected under the Berne convention.

This Biology and Sensitivity Key Information review can be cited as follows:
Tyler-Walters, H., 2004. *Zostera marina*/*angustifolia* beds in lower shore or infralittoral clean or muddy sand. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 25/01/2005]. Available from: <http://www.marlin.ac.uk>

Burrowing anemones in sublittoral muddy gravel (IMX.An)

Key information authored by: Jacqueline Hill

Last updated 22/08/2001

This information is not refereed.

If you would be willing to supply *MarLIN* with an image of this species/habitat please contact marlin@mba.ac.uk

Recorded and expected IMX.An distribution for Britain and Ireland

Description of biotope

Sublittoral muddy gravel or shell gravel can contain conspicuous communities of burrowing anemones such as *Mesacmaea mitchellii*, *Aureliania heterocera*, *Cereus pedunculatus* and *Cerianthus lloydii*. Some ascidians such as *Corella parallelogramma* may also be present in the substratum if surface features such as shell material is large enough. There may be more than one variety of this biotope, influenced by the strength of the currents and the composition of the sediment. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

No text entered

Biotope classification

UK and Ireland Classification

Major habitat	SS	Sublittoral sediments
Habitat complex	IMX	Infralittoral mixed sediments
Biotope complex	IMX.FaMx	Shallow mixed sediment faunal communities
Biotope	IMX.An	Burrowing anemones in sublittoral muddy gravel

Other biotope classification schemes

European Union Nature Information System (EUNIS) code: A4.4/B-IMX.FaMx Animal communities in shallow mixed infralittoral sediments (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

- The characterizing and other species in this biotope occupy space in the habitat but their presence is most likely primarily determined by the occurrence of a suitable substratum rather by interspecific interactions. No single species can be considered a keystone species whose activity is essential to the structure of the community. In addition to the anemones the biotope may support a rich fauna of smaller less conspicuous species, such as polychaetes, nematodes and bivalves that live within the sediment.
- There are however, some interspecific relationships within the biotope. Associations between amphipods and anemones are well known. The burrowing anemone *Peachia hastata* Gosse has been observed to be associated with the lysianassid amphipod *Acidostoma neglectum* Dahl (Ansell, 1969) and more recently Moore & Cameron (1999) identified a tubiculous amphipod *Photis longicaudata* associated with *Cerianthus lloydii*.
- Anemones have few predators, the most notable being nudibranchs (sea slugs), some of which feed only on a single species. Anemones are found amongst the stomach contents of fishes but whether they constitute a regular item of diet is uncertain (Manuel, 1988). *Cerianthus lloydii* secretes a soft, felt-like, mucous tube up to 400mm in length in which it lives. The species is able to move freely within the tube and can contract rapidly when it comes into contact with other organisms. The other species that may live in the biotope, such as infaunal organisms, are often cryptic in nature and not usually subject to predation.
- The density of anemones is probably determined by sediment type, current conditions and food availability.
- The hydrodynamic regime, which in turn controls sediment type, is the primary physical environmental factor structuring benthic communities such as IMX.An. The hydrography also affects the water characteristics in terms of salinity, temperature and dissolved oxygen. It is also widely accepted that food availability (see Rosenberg, 1995) and disturbance, such as that created by storms, (see Hall, 1994) are also important factors determining the distribution of species in benthic habitats.

Seasonal and longer term change

Burrowing anemone communities probably persist over long periods at the same location. There are no reports of significant seasonal or temporal changes in the biotope.

- Continuous observations over several 24 hour periods by divers and underwater TV indicated the absence of any diurnal rhythmic activity in *Cerianthus lloydii*. Observations over a tidal cycle gave no evidence of a tidal feeding rhythm (Eleftheriou & Basford, 1983). An absence of an activity rhythm has also been described in edwardsiid anemones (Ellehauge, 1978).
- Anemones are generally very slow growing and long lived species so the biotope is not likely to undergo any significant seasonal changes. For example, Stephenson (1935) observed some specimens of *Cereus pedunculatus* survived in the laboratory for 70 years and suggested that it seems probable that in the wild, anemones could live for hundreds of years under suitable conditions.
- Some individuals may be washed out if there are severe winter gales in shallow water but temporal changes are expected to be minimal.

Habitat structure and complexity

The biotope has very little structural complexity with most species living partially buried in the sediment. There are no prominent features on the sediment surface such as burrows or mounds. With the exception of a few associations between anemones and other invertebrates (see ecology) burrowing anemones do not provide significant habitat for other fauna.

Dominant trophic groups Suspension feeders

Productivity

Productivity in subtidal sediments is often quite low. Macroalgae are absent from IMX.An and so productivity is mostly secondary, derived from planktonic organisms.

- Burrowing anemones are generally opportunistic omnivorous suspension feeders living on a range of zooplankton including copepods, cladocerans, ostracods and bivalves. *Cereus pedunculatus* feeds mainly on crustaceans. Larger anemones such as *Cerianthus lloydii* are able to take larger prey and can be considered to be predatory, although the species has also been observed to capture and phagocytose fine detrital particles and bacteria (Tiffon, 1974 cited in Chintiroglou & Koukouras, 1992).
- The role of sea anemones in the marine benthic food web may be important and they should be considered as both primary and secondary consumers.
- Eleftheriou & Basford (1983) suggest that the higher densities of meiofauna in the immediate vicinity of *Cerianthus lloydii* was because an enrichment of the sediment with digestible wastes and dissolved organic components stimulated a bacterial growth near the tube aperture where nematodes, gastrotrichs, tardigrades and copepods were attracted and multiplied.
- *Cereus pedunculatus* contains populations of unicellular zooxanthellae (dinoflagellates) which can make an important contribution to the cnidarian metabolism.

Major sources of organic carbon Plankton

Recruitment processes

- The literature (e.g. Stephenson, 1935) suggests that most sea anemones occupy preferred locations in particular ecological situations. However, there is little information available about the means by which these animals come to settle in such locations. However, there is some evidence to suggest that behaviour patterns do exist which makes it possible for certain sea anemones to select particular habitats (Ross, 1967). However, other species may encounter a random assortment of locations but that survival depends on a few of the young coming into contact with the location in which they are normally found.
- Sexual and asexual reproduction occurs in anemones, however, such is the complexity of reproduction in sea-anemones that in some species the method differs from one population to another (Fish & Fish, 1996). There is no asexual reproduction in cerianthid anemones.
- *Cerianthus lloydii* has pelagic larvae, the arachnactis, which has been recorded in the plankton from January to August having a planktonic life of about 3 months (Fish & Fish, 1996).
- For the daisy anemone *Cereus pedunculatus* young are brooded in the parent and Stephenson (1935) reports it to be prolific even after 70 years of growth in the laboratory.

Time for community to reach maturity

There is very little known about community development for this biotope. Almost nothing is known about the life cycle and population dynamics of British burrowing anemones. However, many are slow growing and very long lived and may have patchy and intermittent recruitment. For example, in many localities burrowing anemones lost with the disappearance of eelgrass beds in the 1930's have not returned despite the recovery of *Zostera* in some regions (Manuel, 1988). Therefore, it seems likely that it could take many years for such a community to develop.

Additional information

No text entered

Habitat preference and distribution

Distribution in Britain and Ireland

Recorded from the Isles of Scilly, Skomer, Lundy and Kilkeiran Bay.

Habitat preferences

Temperature range preferences	No information found
Water clarity preferences	Medium clarity / Medium turbidity
Limiting nutrients	No information found
Other preferences	No information found

Additional information

No text entered

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name

Explanation

There is little information available on the biology and sensitivity of the burrowing anemones in the IMX.An biotope so it has not been possible to select individual species to be indicative of sensitivity. Assessment of the ecology and sensitivity of the biotope has been carried out from general knowledge of the species present.

Species found especially in biotope

No text entered

Additional information

No text entered

Biotope sensitivity

Physical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	Moderate	Moderate	Major Decline	Low
Smothering	Intermediate	Moderate	Moderate	Decline	Low
Increase in suspended sediment	Low	Immediate	Not sensitive	No Change	Moderate
Decrease in suspended sediment	Low	Very high	Very Low	No Change	Moderate
Desiccation	Not Relevant	Not Relevant	Not relevant	No Change	Moderate
Increase in emergence regime	Not Relevant	Not Relevant	Not relevant	No Change	Moderate
Decrease in emergence regime	Not Relevant	Not Relevant	Not relevant	No Change	Moderate
Increase in water flow rate	High	Moderate	Moderate	Decline	Low
Decrease in water flow rate	Low	Very high	Very Low	Minor Decline	Moderate
Increase in temperature	Intermediate	Moderate	Moderate	Decline	Very low
Decrease in temperature	Intermediate	Moderate	Moderate	Decline	Very low
Increase in turbidity	Tolerant	Not Relevant	Tolerant	No Change	Moderate
Decrease in turbidity	Tolerant	Not Relevant	Tolerant	No Change	Moderate
Increase in wave exposure	Intermediate	Moderate	Moderate	Decline	Low
Decrease in wave exposure	Not Relevant	Not Relevant	Not relevant	No Change	Moderate
Noise	Low	Immediate	Not sensitive	No Change	Moderate

Visual Presence	Tolerant	Not Relevant	Tolerant	No Change	Moderate
Abrasion & physical disturbance	Intermediate	Moderate	Moderate	No Change	Moderate
Displacement	Low	Immediate	Not sensitive	No Change	Moderate
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not relevant
Heavy metal contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Hydrocarbon contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	Low	High	Low	Minor Decline	Moderate
Increase in salinity	High	Moderate	Moderate	Major Decline	Low
Decrease in salinity	Intermediate	Moderate	Moderate	Decline	Low
Changes in oxygenation	Low	Immediate	Not sensitive	No Change	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	Low	Moderate	Low	No Change	Low
Introduction of non-native species	Low	Moderate	Low	No Change	Low
Extraction of key or important characterizing species	Intermediate	Moderate	Moderate	No Change	Low
Extraction of important species	Not Relevant	Not Relevant	Not relevant	NR	Not Relevant

Explanation of sensitivity and recoverability	
Physical Factors	
Substratum Loss (see benchmark)	The species in the biotope are burrowing and will be lost if the substratum is removed so the overall intolerance of the biotope is high. Recovery could be very slow and is reported to be moderate - see additional information for full rationale.
Smothering (see benchmark)	Several species in the biotope, including the anemones, feed at the sediment surface and will be completely smothered by 5 cm of sediment. Many of the species are able to move by a limited amount and may be able to rise above the smothering material. For example, *Cereus pedunculatus* can adapt to the accretion of silt by extending the column to maintain the disc at a level above the silt. However, it is also likely that some species may die and so intolerance is reported to be intermediate. See additional information for recovery.
Increase in suspended sediment (see benchmark)	The species in the biotope are epibenthic organisms so are likely to be affected by some natural changes in suspended sediment in the water column. Increases in suspended sediment may interfere with feeding and an energetic cost may result from efforts to clean off silt particles, e.g. through mucus production and

	sloughing. Repeated energetic expenditure in cleaning away silt particles may cause loss of condition and a reduction in growth and fecundity. If suspended sediment has a high organic content food availability could improve. However, the overall effects of a one month acute increase in suspended sediment are sub-lethal so intolerance is reported to be low. Recovery will be rapid as particles are cleaned away.
Decrease in suspended sediment (see benchmark)	A decrease in suspended sediment and siltation will reduce the flux of particulate material to the seabed. Since this may also include a component of organic matter the supply of nutrients to the biotope could be reduced reducing growth and fecundity. However, the benchmark is a reduction in suspended sediment of 100mg/l for a month which is unlikely to have a significant effect on the biotope and would not alter species composition. Intolerance is therefore, assessed as low. On return to normal conditions, recovery will be rapid and rank of very high is recorded.
Desiccation (see benchmark)	The biotope is a sublittoral community and so a change in desiccation is not relevant.
Increase in emergence regime (see benchmark)	The biotope is a sublittoral community and so an increase in emergence is not relevant.
Decrease in emergence regime (see benchmark)	The biotope is sublittoral so a decrease in emergence is not relevant.
Increase in water flow rate (see benchmark)	Eleftheriou & Basford (1983) observed *Cerianthus lloydii* feeding under a wide range of hydrodynamic conditions which showed a great degree of adaptation to the prevailing conditions. Under conditions of heavy swell, *Cerianthus lloydii* exhibited behaviour to minimize drag by clumping tentacles in a semi-expanded state with the animal progressively withdrawing into the tube as velocity increased. When a threshold of between 2 and 3 knots was reached the species withdrew totally into the tube. Therefore, the species can tolerate some increase in water flow rate however, if water flow increases to strong then *Cerianthus lloydii* will be unable to feed and if such an increase lasted for a year the species would probably die. The athenarian burrowing anemones in the biotope however, prefer stable sediments that are rarely disturbed by strong water. Therefore, an increase in water flow rates is likely to result in the loss of many species of anemone reducing species diversity. Intolerance is therefore, reported to be high. See additional information for recovery.
Decrease in water flow rate (see benchmark)	The biotope is found in areas of moderately strong and weak tidal currents so is not likely to be very intolerant of a decrease in water flow. The supply of food particles may decrease in low flow conditions but this should only affect sub-lethal processes of growth and reproduction so intolerance of the biotope is expected to be low. The species composition within the biotope may change. On return to pre-impact conditions normal growth etc. should recover rapidly.
Increase in temperature (see benchmark)	There is no information on the response of the biotope to an increase in temperature. The biotope is found in the shallow sublittoral where the temperature may fluctuate by about 10 °C over the period of a year because of seasonal changes. Therefore, the biotope is likely to be able to tolerate a long term increase in temperature. For example, *Cereus pedunculatus* is a southern species extending north into Britain so it will probably be able to tolerate an increase. However, other species may be more intolerant. Also intolerance to a short term increase of 5 °C may be higher. The overall effect of an increase in temperature is likely to be the loss of the more intolerant species reducing species diversity y and so intolerance is reported to be intermediate. See additional information below for recovery.

Decrease in temperature (see benchmark)	There is no information on the response of the biotope to a decrease in temperature. The biotope is found in the shallow subtidal where temperatures may fluctuate by 10 °C over the period of a year because of seasonal changes. Therefore, the biotope is expected to be able to tolerate a long term decrease in temperature of 2 °C. Some of the warmer water southern species such as *Cereus pedunculatus* may be more intolerant and large short term increases may be more damaging. During the severe winter of 1962-3 many *Cereus pedunculatus* were found to have died although *Cerianthus lloydii* were apparently unaffected (Crisp, 1964). The survival of *Cerianthus lloydii* is consistent with a distribution that extends as far north as Greenland. Therefore, the overall effect of a decrease in temperature on the biotope is the loss of the more intolerant species leading to a loss of species diversity and so intolerance is reported to be intermediate. See additional information below for recovery.
Increase in turbidity (see benchmark)	An increase in turbidity, reducing light availability may reduce primary production by phytoplankton in the water column. However, productivity in the IMX.An biotope is secondary (zooplankton) and is not likely to be affected by an increase in local turbidity and so the biotope is considered to be not sensitive.
Decrease in turbidity (see benchmark)	A decrease in turbidity, increasing light availability may reduce primary production by phytoplankton in the water column. However, productivity in the IMX.An biotope is secondary (zooplankton) and is not likely to be affected by an increase in local turbidity and so the biotope is considered to be not sensitive.
Increase in wave exposure (see benchmark)	The biotope is found in sheltered or very sheltered locations and would therefore, be expected to be intolerant of an increase in wave exposure. The burrowing athenarian anemones in particular only survive in fairly stable substrata. An increase in wave exposure would probably mobilize the sediment and make it unsuitable for some of the anemones. However, ceriantids, such as *Cerianthus lloydii*, live in permanent tubes and can exist in relatively unstable substrata. Thus, an increase in wave exposure is likely to favour cerianthid anemones and lead to a much lower diversity of species. Intolerance of the biotope is therefore, considered to be intermediate. Recovery to original diversity may be very slow and a rank of moderate is reported - see additional information below for full rationale of recovery.
Decrease in wave exposure (see benchmark)	The biotope is found in sheltered or very sheltered locations so a decrease in wave exposure is not relevant.
Noise (see benchmark)	Anemones are not known to possess a mechanism for the perception of noise. However, they may respond to vibrations caused by noise by retracting tentacles or withdrawing into a burrow. In investigations of several species of burrowing actinaria, Ellehauge (1978) found sudden movements in the water made animals contract. However, intolerance will not be significant and a rank of low is reported. Recovery will be immediate.
Visual Presence (see benchmark)	Anemones have no known mechanism for visual perception and are not likely to be sensitive to the factor. In investigations of several species of burrowing actinaria, Ellehauge (1978) found that light or shadow did not evoke a withdrawal response.
Abrasion & physical disturbance (see benchmark)	Burrowing and tube dwelling infauna, such as burrowing anemones, may be less affected by dredging than other epifauna (Gubbay & Knapman, 1999). In a study carried out in the Skomer Marine Nature Reserve the numbers of sea anemones, *Cerianthus lloydii* and *Mesacmaea mitchellii*, within and alongside dredge paths were similar to pre-dredge levels several weeks later. However, the biotope includes several epifaunal species, such as the encrusting anemone *Epizoanthus couchii*, hermit crabs, scallops and brittlestars. Epifauna is likely to be damaged and the sediment changed by a passing scallop dredge (see benchmark).

	Therefore, while several characterizing species are probably tolerant of physical disturbance, a proportion of other species may be damaged or lost, and an intolerance of intermediate has been recorded. Withdrawn burrowing anemones are likely to reappear and dislodged individuals reburrow. However, other sea anemone species are probably slow to recover (see additional information below). Damaged anemones may be subject to predation by fish or other animals.
Displacement (see benchmark)	Cerianthid anemones are capable of burrowing again and constructing a new tube if dug up. The other burrowing anemones do not build tubes and therefore, to a greater or lesser extent, are able to shift their position. Thus, if displaced the anemones in the biotope should be able to re-burrow. *Peachia hastata* for example, is able to reburrow in about one hour (Trueman & Ansell, 1969). The time taken for some other species, such as *Cerianthus lloydii*, to reburrow is longer and may place individuals at greater risk of predation. Although anthozoans do not feature prominently on the menu of many predatory animals they have been found amongst the stomach contents of fish. Most other species likely to occur in the biotope, for instance worms and bivalve molluscs, will be able to reburrow. However, the intolerance of the biotope is reported to be low because it is likely that many individuals can re-burrow and survive displacement. Recovery is expected to be immediate as individuals are likely to re-burrow as soon as they have been displaced.
Chemical Factors	
Synthetic compound contamination (see benchmark)	Insufficient information.
Heavy metal contamination (see benchmark)	Insufficient information.
Hydrocarbon contamination (see benchmark)	Insufficient information.
Radionuclide contamination (see benchmark)	Insufficient information.
Changes in nutrient levels (see benchmark)	Pearson & Rosenberg (1978) observed *Cerianthus lloydii* and other cerianthid anemones to be present in areas at the edges of grossly and highly organically polluted sites. Therefore, an increase in nutrient levels of 50% is not likely to cause the loss of cerianthid anemones and so intolerance is reported to be low. Some other types of anemones may be more intolerant of nutrient increases leading to a decline in diversity.
Increase in salinity (see benchmark)	Several of the anemone species in the biotope are also found in rock pools where salinity is likely to be variable because of precipitation and evaporation. However, the biotope is unlikely to be able to tolerate a long term increase in salinity and so a rank of high is reported. See additional information for recovery.
Decrease in salinity (see benchmark)	The biotope is subtidal and found in areas of full salinity so may be intolerant of a decrease. However, some species of anemone, such as *Cereus pedunculatus*, are sometimes found at the mouth of estuaries and in Danish waters *Cerianthus lloydii* inhabits salinities in the range 17 to 34 psu. Several species are also found on the lower shore where salinity is variable because of precipitation and evaporation. Therefore, many of the species in the biotope must have some tolerance to short term decreases. However, a long term decrease is likely to result in a significant loss of species diversity and so intolerance is reported to be intermediate. Recovery could take a long time and is assessed as moderate - see

	additional information below for full rationale.
Changes in oxygenation (see benchmark)	Some infaunal species which require ventilation of burrows may be adversely affected by a drop in oxygenation levels. Cole *et al*. (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l. There was no information found regarding the tolerance of sea anemones to a decrease in the oxygenation of the water column. However, anemones are very slow growing and are likely to have a very low metabolic rate. An oxygenation level of 2 mg/l for a period of a week may have an impact on the biotope and so intolerance is considered to be low. Recovery will be rapid as oxygen levels increase.
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	No known viral or bacterial diseases are known to occur among marine cnidarians (Kinne, 1980). However, even though a number of cnidarians are capable of secreting antimicrobial substances it is possible that such diseases could occur.
Introduction of non-native species (see benchmark)	There are no records of any non-native species invading the biotope and so is assessed as not sensitive. However, as several species have become established in British waters there is always the potential for new introduced non-native species to have an effect on the biotope.
Extraction of key or important characterizing species (see benchmark)	Removal of 50% of the community will only affect the density of component species. Other effects are not likely because there are no interspecific relationships between component species in the biotope. See additional information for recovery.
Extraction of important species (see benchmark)	There are no other important structural or functional species in the biotope.

Additional information

Recoverability
There is very little known of the community development or recovery of this biotope. In addition very little is known of the life history and population dynamics of British sea anemones. However, many are slow growing and very long lived and it is possible that they have patchy and intermittent recruitment. For example, in many localities burrowing anemones were lost with the disappearance of eel-grass beds in the 1930's have not returned despite the recovery of *Zostera* in some regions (Manuel, 1988). Therefore, it seems likely that a community of burrowing anemones could take many years to develop and recover from environmental perturbations. Many anemones can reproduce asexually and such budding could significantly aid recovery. However, the cues for asexual reproduction are unknown. Some species also brood their young releasing miniature anemones into the water column so recruitment may be more rapid in areas where local adult populations are still present.

Species used to indicate biotope intolerance

No species have been selected to indicate intolerance but the biology of the component species of the biotope has been taken into account wherever information was known to the researcher. Please view individual sensitivity assessment rationale for a discussion of the sensitivity of component or associated species.

Species used to indicate biotope recoverability

No species have been selected to indicate intolerance but the biology of the component species of the biotope has been taken into account wherever information was known to the researcher. Please view individual sensitivity assessment rationale for a discussion of the sensitivity of component or associated species.

Importance

Marine natural heritage importance

Listed under:	**UK Biodiversity Action Plan** **EC Habitats Directive**
National importance	Not available
Habitat Directive feature (Annex 1)	Large shallow inlets and bays Estuaries
UK Biodiversity Action Plan habitat	Sheltered muddy gravels Inshore sublittoral sediment (broad habitat statement)

Biotope importance

No text entered

Exploitation

The biotope is not likely to be exploited because there are no species of commercial importance.

Additional information

No text entered

This Biology and Sensitivity Key Information review can be cited as follows:
Hill, J.M., 2001. Burrowing anemones in sublittoral muddy gravel. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/01/2005]. Available from: <http://www.marlin.ac.uk>

Ostrea edulis beds on shallow sublittoral muddy sediment (IMX.Ost)

Key information authored by: Dr Harvey Tyler-Walters

Last updated 30/11/2001

This information is not refereed.

Ostrea edulis beds on shallow sublittoral muddy sediment. Image width ca 25 cm.
Image: Bernard Picton / Joint Nature Conservation Committee

Recorded and expected IMX.Ost distribution for Britain and Ireland

Description of biotope

Dense beds of the oyster *Ostrea edulis* can occur on muddy fine sand. There may be considerable quantities of dead oyster shell making up a substantial portion of the substratum. The clumps of dead shells and oysters can support large numbers of *Ascidiella aspersa* and *Ascidiella scabra*. Several conspicuously large polychaetes may be present, such as *Chaetopterus variopedatus* and terebellids, as well as additional suspension-feeding polychaetes such as *Myxicola infundibulum*, *Sabella pavonina* and *Lanice conchilega*. A turf of seaweeds such as *Plocamium cartilagineum*, *Nitophyllum punctatum* and *Spyridia filamentosa* may also be present. This biotope description may need expansion to account for oyster beds in England. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

The native, flat oyster (*Ostrea edulis*) has been extensively studied due to its commercial importance. Therefore, this review is based on past reviews, to which the reader should refer to further detail (e.g. Korringa, 1952; Yonge, 1960).

Biotope classification

UK and Ireland Classification

Major habitat	SS	Sublittoral sediments
Habitat complex	IMX	Infralittoral mixed sediments
Biotope complex	IMX.Oy	Oyster beds
Biotope	IMX.Ost	*Ostrea edulis* beds on shallow sublittoral muddy sediment

Other biotope classification schemes

European Nature Information System (EUNIS) Habitat classification code: A4.631/B-IMX.Oy.Ost - *Ostrea edulis* beds on shallow sublittoral muddy sediment (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

Oyster beds are dominated by suspension feeding invertebrates.

- *Ostrea edulis* is an active suspension feeder on phytoplankton, bacteria, particulate detritus and dissolved organic matter (DOM) (Korringa, 1952; Yonge, 1960). The production of faeces and pseudofaeces enriches the underlying sediment, providing a rich food source for infaunal detritivores, deposit feeders, meiofauna and bacteria.
- Dense beds of suspension feeding bivalves are important in nutrient cycling in estuarine and coastal ecosystems, transferring phytoplankton primary production and nutrients to benthic secondary production (pelagic-benthic coupling) (Dame, 1996).
- A model food web for an oyster reef (based on intertidal *Crassostrea* sp. beds) was presented by Dame (1996).
- Other suspension feeding epifauna include the ascidians (e.g. *Ascidiella aspersa*, *Ascidiella scabra* and *Dendrodoa grossularia*) and sponges (e.g. *Halichondria bowerbanki*), hydroids, barnacles (e.g. *Balanus balanus*), and tube worms such as *Pomatoceros triqueter* and *Polydora ciliata*.
- Infaunal suspension feeders include the tube worms *Chaetopterus variopedatus*, *Sabella pavonina*, *Myxicola infundibulum*, and *Lanice conchilega* and where present *Abra* sp. and the tellinids *Angulus tenuis* and *Fabulina fabula*.
- *Lanice conchilega*, *Fabulina fabula* and *Polydora ciliata* are also surface deposit feeders on organic particulates and detritus.
- The enriched sediment probably supports a diverse meiofauna, including nematodes and polychaetes (e.g. *Scoloplos armiger* and terebellids).
- The sediment may also support amphipods such as *Bathyporeia guilliamsoniana* and *Ampelisca brevicornis*, which have been recorded in native oyster beds (Millar, 1961).
- Hermit crabs such as *Pagurus bernhardus* and the common whelk *Buccinum undatum* may be scavengers on the bed.

A variety of predators feed in oyster beds.

- *Asterias rubens* is a general predator occasionally taking oyster spat and oysters but with a preference for mussels and, in their absence, *Crepidula fornicata* and the American oyster drill *Urosalpinx cinerea*. Young *Asterias rubens* feeds on barnacles in preference to oyster spat (Hancock, 1955). Hancock (1955) suggested that *Asterias rubens* fed significantly more on predators and competitors of the native oyster than on the oysters themselves. However, he also noted that the starfish was still likely to cause severe damage on highly cultivated areas with a high abundance of oysters and their spat. *Asterias rubens* is itself preyed on by the sun star *Crossaster papposus* (Hancock, 1958).
- Predatory gastropods such as the native Sting winkle *Ocenebra erinacea* and the introduced American oyster drill *Urosalpinx cinerea* prey on small oysters and oyster spat. For example, 55 - 58% of the oyster spat settling in 1953 in Essex oyster beds were destroyed by *Urosalpinx cinerea*. The dog whelk *Nucella lapillus* may occasionally take oyster spat (Korringa, 1952; Hancock, 1954; Yonge, 1960). However, only 10% of adults of 3 years of age were taken by *Urosalpinx cinerea* (Hancock, 1954), suggesting that the risk of predation decreases with increasing oyster size. A similar size refuge from predation is seen in other bivalve beds e.g. *Mytilus edulis* and the horse mussel *Modiolus modiolus*.
- Crabs, such as *Carcinus maenas* and *Hyas araneus* are mobile omnivores that prey on oysters and their spat and also on the other fauna associated with oyster beds, including the drills, whelks and starfish (Yonge, 1960).
- Predatory fish may also enter the bed to feed on the associated species, although Yonge (1960) suggested that fish were not a significant predator of the oysters themselves.

Several species compete with the oyster spat for settlement space on the shells of adult oysters, especially those species that breed at the same time of the year.

- *Ascidiella* sp. are know to settle at the same time as oyster spat, competing for the available hard substratum such as oyster shells (living or dead), and subsequently overgrowing spat that are able to settle. However, this may only seriously affect the oyster recruitment where the ascidians occur in any abundance.
- Barnacles (e.g. *Balanus balanus* and *Elminius modestus*), the tube worm *Pomatoceros triqueter* and the ascidian *Dendrodoa grossularia* were also reported to compete for settlement space, especially the barnacles (Korringa, 1952; Yonge, 1960; Millar, 1961).
- The introduced slipper limpet *Crepidula fornicata* competes with the oyster for space and food, and its pseudofaeces may smother the oyster. Where *Crepidula fornicata* has become abundant the oyster beds have been lost (see sensitivity to introduced species) (Blanchard, 1997).

Seasonal and longer term change

Fish and crabs predators probably migrate further offshore in winter months, reducing predation pressure. Changes in the average summer temperature may have significant effects on recruitment (see recruitment processes below). In addition, Spärck (1951) noted marked changes in the populations of *Ostrea edulis* in the Limfjord, Denmark between 1852 and 1949. In periods of poor recruitment and the absence of fishing pressure, populations gradually declined, becoming restricted to the most favourable areas of the Limfjord. In some areas there was a 90% decrease in stock. Temperature was probably the most important controlling factor in recruitment in the Limfjord population (see recruitment) (Spärck, 1951). Korringa (1952) noted that while temperature was probably the most important factor in populations at their northern most range of the species, other factors were important in more temperate waters. However, Spärck (1951) demonstrated the importance of recruitment in natural populations of the native oyster and the potential for large fluctuations in population size over time.

Habitat structure and complexity

Oyster beds provide hard substratum for settlement in an otherwise sedimentary habitat and therefore support a diverse range of invertebrates. The oyster bed also modifies the sediment, increasing the amount of shell debris and organically enriching the sediment with faeces and pseudofaeces. *Ostrea edulis* preferentially settles on adult of the same species (i.e. it is gregarious) resulting in layer upon layer of oysters in the absence of fishing pressure. The layer of living and dead oyster shell probably alters the water flowing over the sediment surface and protects it from erosion. The layers of shell debris and living oyster provide interstices for other organisms. For example, the American oyster *Crassostrea virginica* can form extensive reefs several metres in height that have been shown to affect the local hydrodynamics and hence larval dispersal and settlement and hence community composition (Lenihan, 1999; Peterson *et al.*, 2000). While, no information concerning the scale of native oyster reefs was found, it is likely that they also affect the local hydrographic regime to some extent.

- Oyster beds support a diverse epifauna consisting of protozoa, sponges, hydroids, the benthic stages of *Aurelia* sp., flatworms, ribbon worms, nematodes polychaetes, amphipods and ostracod crustaceans, crabs, sea spiders, gastropod molluscs, ascidians, bryozoans, starfish and sea urchins (Korringa, 1951; Yonge, 1960). Korringa (1951) also noted that the flanges or flaps of the oyster shell provided refuges for some species. Although the exact fauna found will depend on locality, a detailed account of the epifauna of oyster beds in the Oosterschelde is given by Korringa (1951).
- The sediment surface may be punctuated by burrowing tube worms such as *Chaetopterus variopedatus*, *Sabella pavonina*, *Myxicola infundibulum*, and *Lanice conchilega*.
- Burrowing amphipods may occupy the top few cm of the sediment e.g. *Bathyporeia guilliamsoniana* and *Ampelisca brevicornis*.
- The sediment below the oyster bed is enriched by faeces and pseudofaeces and usually contains shell debris accumulated from dead oysters. The infauna will vary with nature of the underlying sediment and the relative proportions of shell debris and faecal deposits. However, macroinfauna probably includes burrowing polychaetes, nematodes, and bivalves (see ecological relationships above)

Dominant trophic groups Suspension feeders

Productivity

Dame (1996) suggested that dense beds of bivalve suspension feeders increase turnover of nutrients and organic carbon in estuarine (and presumably coastal) environments by effectively transferring pelagic

phytoplanktonic primary production to secondary production in the sediments (pelagic-benthic coupling). Increased microbial activity within the enriched sediments underlying the beds, increases the rate of nutrient turnover and hence the productivity of the ecosystem as a whole (Dame, 1996).
Epifloral macroalgae provide some primary productivity to the ecosystem, however, the majority of production with the biotope is secondary production, with organic carbon derived from phytoplankton and organic particulates consumed by suspension feeders, especially the oysters. No estimate of the overall productivity of native oyster beds was found. However, before over-fishing and disease (see importance) oysters beds supported fisheries, suggesting that there are potentially highly productive.

Major sources of organic carbon Dissolved organic matter
Photosynthesis (microalgae)
Detritus

Recruitment processes

The flat oyster
In *Ostrea edulis*, spawning occurs in the summer months (June to September) and is coincident with spring tides (and the new or full moon) (Korringa, 1952; Yonge, 1960). Spawning is thought to require a minimum temperature (which also probably controls gametogenesis) of 15-16 °C (Yonge, 1960) although the exact temperature probably varies with area and local adaptation (Korringa, 1952). Eggs are fertilized internally and incubated to the veliger stage (7-10 days) at which point they are released into the plankton.

Ostrea edulis is highly fecund producing an average of between 91,000 to up to 2 million eggs with increasing age and size. However, good fertilization efficiency requires a minimum population size, so that in small populations not all the eggs may be fertilized (Spärck, 1951). The larvae are pelagic for 11-30 days, providing potentially high levels of dispersal, depending on the local hydrographic regime. Subsequent recruitment however, is dependant on larval growth and mortality due to predation in the plankton, the availability of settlement sites and post-settlement and juvenile mortality.

Good recruitment (settlement) is associated with warm summers whereas poor recruitment occurred in cold summers in the Oosterschelde and Limfjord (Spärck, 1951; Korringa, 1952), and is probably related to larval food availability and developmental time. Widdows (1991) states that any environmental or genetic factor that reduces the rate of growth or development of *Mytilus edulis* larvae will increase the time spent in the plankton and hence significantly decrease larval survival, which may also be true of most pelagic bivalve larvae.

In areas of strong currents larvae may be swept away form the adult populations to other oyster beds or to areas of unsuitable substratum and lost. Oyster beds on open coasts may be dependent on recruitment from other areas. Oyster beds in enclosed embayments may be self recruiting. Due to the high numbers of larvae produced, a single good recruitment event could potentially significantly increase the population. Oyster larvae will settle on available hard substrata but are gregarious and prefer to settle on adult shells, especially the new growth. However, competition for space (substratum for settlement) from other species that settle at the same time of year e.g. barnacles and ascidians (see ecological relationships), results in high levels of larval and juvenile mortality. Newly settled *Ascidiella* sp., are known to overgrow and hence kill oyster larvae. In addition, newly settled spat and juveniles are subject to intense mortality due to predation, especially by the oyster drills (*Urosalpinx cinerea* and *Ocenebra erinacea*) and starfish. For example, in the Oosterschelde, Korringa (1952) reported 90% mortality in oyster spat by their first winter, with up to 75% being taken by *Urosalpinx cinerea*, while Hancock (1955) noted that 73% of spat settling in summer 1953 died by December, 55 -58% being taken by *Urosalpinx cinerea*.

Overall, recruitment in *Ostrea edulis* is sporadic and dependant of local environmental conditions, including the average summer sea water temperature, predation intensity and the hydrographic regime. Spärck, (1951) reported marked changes in population size due to recruitment failure. In unfavourable year stocks declined naturally (in the absence of fishing pressure) and the population in the Limfjord became restricted to the most favourable sites. In favourable years the stock increased and the population slowly spread from the most favoured locations. However, he concluded that a long series of favourable years was required for recovery of stocks after depletion. For example, after closure of the oyster fishery in 1925, stocks did not recovery their fishery potential until 1947/48, ca 20 years. However, the Limfjord population of *Ostrea edulis* is at the northern most extent of its range where recruitment may be more dependant on summer temperatures than more southerly temperate populations. Nevertheless, Spärck's data (1951) suggest that several years of favourable recruitment would be required for an *Ostrea edulis* population to recover.

Other species
The other characterizing species are widespread species, with pelagic larvae, potentially capable of wide dispersal and are therefore, likely to be able to recolonize available substratum rapidly. Although the ascidian tadpole larva is short lived and has a low dispersal capability, fertilization is external in the most conspicuous ascidians in the biotope, *Ascidiella* sp., which are widespread in distribution and probably capable of rapid recolonization from adjacent or nearby populations.

Time for community to reach maturity

Korringa (1951) noted that many of the *Ostrea edulis* epifauna were dependant on the oyster for substratum. It is also likely that some burrowing species are dependant of the conditions provided by the bed of *Ostrea edulis*. Therefore, the time taken for the community to reach maturity will depend primarily on the time taken for the oyster bed to develop (see recruitment processes above), after which recolonization will probably be rapid, and in the order of 1-2 years.

Additional information

No text entered

Habitat preference and distribution

Distribution in Britain and Ireland

Native, flat oyster beds are sparsely distributed and are recorded from the River Crouch in east England; Dawlish Warren, the Dart estuary and the River Fal in the south west England; Milford Haven in Wales; Loch Ryan in Scotland; Strangford Lough, Lough Foyle, and the west coast of Ireland.

Habitat preferences

Temperature range preferences	Data deficient
Water clarity preferences	Very high clarity / Very low turbidity High clarity / Low turbidity Medium clarity / Medium turbidity
Limiting nutrients	No information found
Other preferences	No information found

Additional information

The main UK shellfish stocks of the native oyster are now located in the inlets and flats bordering the Thames Estuary, The Solent, River Fal, the west coast of Scotland and Lough Foyle (Anon., 1999d).

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Key structural	*Ostrea edulis*	Native oyster

Explanation

The native oyster forms beds providing substratum and interstices for a diversity of other organisms. Accumulation of shell material, faeces and pseudofaeces further modify and enrich the sediment. The other characterizing members of the biotope have a widespread distribution and take advantage of the substratum or stabilized sediment provided by the population of *Ostrea edulis*. The ascidian *Ascidiella aspersa* is commonly found on oyster beds but is generally regarded as a competitor with the oysters and is not restricted to this biotope. Therefore, only *Ostrea edulis* has been chosen to indicate the sensitivity of the

biotope, as loss or damage to populations of the native oyster will affect the biotope as a whole.
In undertaking an assessment of sensitivity of this biotope, account is taken of knowledge of the biology of all characterizing species in the biotope. However, the selected 'indicative species' is particularly important in undertaking the assessment because it has been subject to detailed research.

Species found especially in biotope

Ostrea edulis Native oyster
Ascidiella aspersa A sea squirt

Additional information

The MNCR recorded a total of 246 species within this biotope, although not all occurred in a single record. Studies of the fauna of native oyster have been reported for the Oosterschelde (Korringa, 1951), Scottish waters (Millar, 1961), Loch Ryan (Millar, 1963; Howson *et al.*, 1994); and the Essex oyster beds (Mistakidis, 1951). Korringa (1951) listed over 250 species of epifauna on the shells of *Ostrea edulis* in the Oosterschelde.

Biotope sensitivity

Physical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	Very low	Very High	Major Decline	Moderate
Smothering	High	Very low	Very High	Major Decline	Moderate
Increase in suspended sediment	Low	Very high	Very Low	No Change	Low
Decrease in suspended sediment	Low	Very high	Very Low	No Change	Low
Desiccation	Low	High	Low	Decline	Very low
Increase in emergence regime	Low	High	Low	Decline	Very low
Decrease in emergence regime	Tolerant*	Not Relevant	Not sensitive*	Not Relevant	Very low
Increase in water flow rate	Intermediate	Low	High	Major Decline	Very low
Decrease in water flow rate	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Increase in temperature	Low	High	Low	Minor Decline	Low
Decrease in temperature	Intermediate	Low	High	Major Decline	Moderate
Increase in turbidity	Low	Very high	Very Low	Minor Decline	Low
Decrease in turbidity	Tolerant*	Not Relevant	Not sensitive*	No Change	Very low
Increase in wave exposure	High	Very low	Very High	Decline	Low
Decrease in wave exposure	Tolerant	Not Relevant	Tolerant	No Change	Low
Noise	Tolerant	Not Relevant	Tolerant	No Change	High
Visual Presence	Tolerant	Not Relevant	Tolerant	No Change	High
Abrasion & physical disturbance	Intermediate	Moderate	Moderate	Decline	Low
Displacement	Low	Very high	Very Low	Minor Decline	Low

Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	High	Very low	Very High	Major Decline	Moderate
Heavy metal contamination	Intermediate	Low	High	Decline	Moderate
Hydrocarbon contamination	Intermediate	Moderate	Moderate	Decline	Low
Radionuclide contamination	Insufficient information	Not Relevant	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	Tolerant*	Not Relevant	Not sensitive*	No Change	Low
Increase in salinity	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant
Decrease in salinity	Low	High	Low	Decline	Moderate
Changes in oxygenation	Low	High	Low	Decline	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	High	Very low	Very High	Major Decline	High
Introduction of non-native species	High	Very low	Very High	Decline	High
Extraction of key or important characterizing species	High	Very low	Very High	Major Decline	High
Extraction of important species	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant

Explanation of sensitivity and recoverability

Physical Factors	
Substratum Loss (see benchmark)	*Ostrea edulis* cements its lower valve to the substratum permanently. Loss of the substratum would result in loss of the oyster bed and its associated community and hence the biotope. Therefore, an intolerance of high has been recorded. Loss of the substratum would also result in loss of the epifauna and infauna and, hence a major decline in species richness. Recovery is dependant on larval recruitment since adult *Ostrea edulis* are permanently attached and incapable of migration. Recruitment of *Ostrea edulis* is sporadic and dependant on the local environmental conditions, hydrographic regime and the presence of suitable substratum, especially adult shells or shell debris, and has probably been inhibited by the presence of competition from non native species (see additional information below). Since the biotope is dependant on the presence of *Ostrea edulis* a recoverability of very low has been suggested.
Smothering (see benchmark)	Smothering by 5 cm of sediment would prevent the flow of water through the oyster that permits respiration, feeding and removal of waste. *Ostrea edulis* is permanently fixed to the substratum and would not be able to burrow up through the deposited material. *Ostrea edulis* can respire anaerobically, and is known to be able to survive for many weeks (Yonge, 1960) or 24 days (Korringa, 1952) out of water at low temperatures used for storage after collection. However, it is likely that at normal environmental temperatures, the population would be killed by smothering. Yonge (1960) reported death of populations of *Ostrea edulis* due to smothering of oyster beds by sediment and debris from the land as a result of flooding. Therefore, an intolerance of high has been recorded.

	Smothering will probably also kill the sessile, fixed members of the epifauna, unless large enough to protrude above the deposited layer, e.g. *Ascidiella* sp. However, burrowing infauna will probably burrow to the surface. Death of the oyster bed will exacerbate changes in the sediment surface and nutrient levels in the long term, so that the characterizing species may be replaced by others. Therefore, species richness is likely to decline markedly. Recruitment in *Ostrea edulis* is potentially good due to its high fecundity and high dispersal potential, however, dependency of the hydrographic regime, and environmental conditions of (e.g. temperature, food availability), high larval and juvenile mortality, competition for settlement space with native species results in sporadic recruitment, which together with competition for suitable substratum with non native species such as *Crepidula fornicata* results in a potentially long recovery time (see additional information below). In addition, a layer of settled material of 1-2 mm in depth was reported to prevent satisfactory oyster sets, i.e. settlement, reducing effective recruitment (Galtsoff, 1964, cited in Wilbur, 1971). Therefore, a recoverability of very low has been recorded.
Increase in suspended sediment (see benchmark)	Oysters respond to an increase in suspended sediment by increasing pseudofaeces production with occasional rapid closure of their valves to expel accumulated silt (Yonge, 1960) both of which exert an energetic cost. Korringa (1952) reported that an increase in suspended sediment decreased the filtration rate in oysters. Suspended sediment was also shown to reduce the growth rate of adult *Ostrea edulis* and to result in shell thickening (Moore, 1977). Reduced growth probably results from increased shell deposition and an inability to feed efficiently. Hutchinson & Hawkins (1992) reported that filtration was completely inhibited by 10mg/l of particulate organic matter and significantly reduced by 5mg/l. *Ostrea edulis* larvae survived 7 days exposure to up to 4 g/l silt with little mortality. However, their growth was impaired at 0.75 g/l or above (Moore, 1977). Yonge (1960) and Korringa (1952) considered *Ostrea edulis* to be intolerant of turbid (silt laden) environments. However, oyster beds are found in the relatively turbid estuarine environments and the values of suspended sediment quoted above are high in comparison to the benchmark value. Therefore, a change in suspended sediment at the benchmark level may only result in sub-lethal effects. However, Moore (1977) reported that variation in suspended sediment and silted substratum and resultant scour was an important factor restricting oyster spat fall, i.e. recruitment. Therefore, an increase in suspended sediment may have longer term effects of the population by inhibiting recruitment, especially if the increase coincided with the peak settlement period in summer. The other suspension feeders characteristic of this biotope are probably tolerant of a degree of suspended sediment but an increase, especially of fine silt, would probably interfere with feeding mechanisms, resulting in reduced feeding and a loss of energy through mechanisms to shed or remove silt. Overall, an increase in suspended sediment at the level of the benchmark for a period of a month, may not adversely affect the biotope. Therefore, an intolerance of low has been recorded. However, high levels of suspended sediment or a protracted increase may be detrimental. Recovery will depend on clearance of filtration apparatus and return to condition, which will probably be relatively rapid.
Decrease in suspended sediment (see benchmark)	In areas of high suspended sediment, a decrease may result in improved condition and recruitment due to a reduction in the clogging of filtration apparatus of suspension feeders and an increase in the relative proportion of organic particulates. However, a decrease in suspended sediments in some areas may reduce food availability resulting in lower growth or reduced energy for reproduction. Therefore, an intolerance of low has been recorded at the level of the benchmark.

Desiccation (see benchmark)	Beds of the native oyster *Ostrea edulis* may occur low on the shore and are exposed for a proportion of the tidal cycle. *Ostrea edulis* is known to be able to survive aerial exposure at low temperatures during storage and are known to be capable of anaerobic respiration (Korringa, 1952; Yonge, 1960), which suggests that they can tolerate aerial exposure. In addition, in the mariculture of oysters (native and introduced species) oyster trays are position in the low intertidal, and regularly exposed to the air. Therefore, an increase in desiccation in this biotope is unlikely to result in death of the oysters themselves at the level of the benchmark. However, exposure to the air prevents feeding, and anaerobic respiration usually results in an oxygen debt, an energetic cost that the organism must make up on return to aerated water, resulting in reduced growth and reproductive capacity. However, the associated epifauna may be more intolerant, such as ascidians (e.g. *Ascidiella* spp.) and *Asterias rubens*. Burrowing infauna are likely to be protected from desiccation by their infaunal habit and species such as *Lanice conchilega*, *Myxicola infundibulum* and *Chaetopterus variopedatus* may be found at low water. Mobile epifaunal species would probably move to deeper water while delicate hydroids and bryozoans may be damaged or killed by desiccation. Therefore, oyster beds may tolerate an increase in desiccation at the benchmark level and an intolerance of low has been recorded, while the epifauna and the species richness reduced. Recovery will depend on return to original condition by the oysters and recolonization by epifauna, both of which are likely to be rapid.
Increase in emergence regime (see benchmark)	The adult oyster can close the valves of its shell tightly when exposed. Some populations are found in the lower intertidal. A change of one hour in emergence would mean that the valves are kept shut for a greater time, resulting in less time available for feeding, and hence reduced growth and reproductive capacity, and an increased risk of desiccation. However, the epifauna are likely to be more intolerant of increases in emergence, resulting in loss of some species and a reduction in species richness. The infauna species are likely to be protected by their burrowing habit. Overall, therefore, the biotope may suffer a decrease in the diversity of epifauna but the oyster bed would not be markedly affected at the level of the benchmark. Therefore an intolerance of low has been recorded. The oysters would probably recover condition rapidly, and the epifauna will probably also recolonize available habitat quickly.
Decrease in emergence regime (see benchmark)	This biotope is subtidal so that an increase in emergence is unlikely to have an adverse effect on the community. However, increased emergence may allow the oyster bed to spread further up the shore, although at a slow rate. Therefore, the biotope may benefit from the factor.
Increase in water flow rate (see benchmark)	This biotope occurs in weak to very weak tidal streams. An increase in water flow from, for example weak to strong is likely to remove (erode) fine particulates, leaving coarser substrata and making more hard substratum available for settlement by oysters and other members of the community, e.g. *Ascidiella* spp. and epifauna. The effects of increased water flow are most likely to be in reducing the time oysters are able to feed. Oysters may be swept away by strong tidal flow if the substratum to which they are attached is removed. Therefore, a proportion of the oyster bed may be lost, depending on the nature of the substratum, and an intolerance of intermediate has been recorded. Overall, the nature of the biotope is likely to change significantly. Recruitment in *Ostrea edulis* is sporadic and dependant of the hydrographic regime and local environmental conditions but will be enhanced by the presence of adults and shell material. Therefore, a recoverability of low has been recorded (see additional information below).

Decrease in water flow rate (see benchmark)	The biotope is found in weak to very weak tidal streams, so that any further decrease is unlikely.
Increase in temperature (see benchmark)	Filtration rate, metabolic rate, assimilation efficiency and growth rates of adult *Ostrea edulis* increase with temperature. Growth was predicted to be optimal at 17 °C or, for short periods, at 25 °C (Korringa, 1952; Yonge, 1960; Buxton *et al.*, 1981; Hutchinson & Hawkins, 1992). Huchinson & Hawkins (1992) noted that temperature and salinity were co-dependant, so that high temperatures and low salinity resulted in marked mortality, no individuals surviving more than 7 days at 16 psu and 25 °C, although these conditions rarely occurred in nature. No upper lethal temperature was found but Kinne (1970) reported that gill tissue activity fell to zero between 40-42 °C; although values derived from single tissue studies should be viewed with caution. Buxton *et al.* 1981 reported that specimens survived short term exposure to 30 °C. *Ostrea edulis* and many of the other species in the biotope occur from the Mediterranean to the Norwegian coast and are unlikely to be adversely affected by long term changes in temperatures in Britain and Ireland. Spärck's data (1951) suggest that temperature is an important factor in recruitment of *Ostrea edulis*, especially at the northern extremes of its range and Korringa (1952) reported that warm summers resulted in good recruitment. Spawning is initiated once the temperature has risen to 15-16 °C, although local adaptation is likely (Korringa, 1952; Yonge, 1960). Davis & Calabrese (1969) reported that larvae grew faster with increasing temperature and that survival was optimal between from 12.5 - 27.5 °C but that survival was poor at 30 °C. Therefore, recruitment and the long term survival of an oyster bed is probably affected by temperature and may benefit from both short and long term increases. Most of the other characterizing species within the biotope have a wide distribution in Europe suggesting that they are able tolerate a wider range of temperatures than found in British waters. Delicate species may not be so tolerant and mobile species may leave the biotope temporarily resulting in a decline in species richness. However, an overall biotope intolerance of low has been recorded to represent the effects of temperature on feeding and growth. Once the temperature returns to normal limits the characterizing species will probably regain their condition rapidly.
Decrease in temperature (see benchmark)	Hutchinson & Hawkins (1992) suggested that *Ostrea edulis*, the dominant species in this biotope, switched to a reduced, winter metabolic state below 10 °C that enabled it to survive low temperatures and low salinities encountered in shallow coastal waters around Britain. Davis & Calabrese (1969) also noted that larval survival was poor at 10 °C. Korringa (1952) reported that British, Dutch and Danish oysters can withstand 1.5°C for several weeks. However, heavy mortalities of native oyster were reported after the severe winters of 1939/40 (Orton, 1940) and 1962/63 (Waugh, 1964). Mortality was attributed to relaxation of the adductor muscle so that the shell gaped, resulting in increased susceptibility to low salinities or to clogging with silt. Low temperatures and cold summers are correlated with poor recruitment in *Ostrea edulis*, presumably due to reduced food availability and longer larval developmental time, especially at the northern limits of its range. Therefore, a reduction in temperature may result in reduced recruitment and a greater variation in the populations of *Ostrea edulis*. The severe winters of 1939/40 and 1962/63 (Orton, 1940; Waugh, 1964) also resulted in the death of associated fauna, e.g. *Sabella pavonina* and other polychaetes died in great numbers, *Crepidula fornicata* incurred about 25% mortality and *Ocenebra erinacea* died in large numbers, while only small *Carcinus maenas* remained on the beds (Orton, 1940; Waugh, 1964). However,

	starfish, crabs such as *Hyas araneus* and *Urosalpinx cinerea* and *Ascidiella aspersa* were little affected (Orton, 1940; Waugh, 1964). Decreases in temperature experienced in a severe winter are more extreme than our benchmark. However, long term decreases in temperature could potentially effects overall recruitment and other members of the community are intolerant of short term acute decreases in temperature. Therefore, an overall biotope intolerance of intermediate intolerance has been suggested at the benchmark level. Recruitment in *Ostrea edulis* is sporadic and dependant of the hydrographic regime and local environmental conditions but will be enhanced by the presence of adults and shell material. Therefore a recoverability of low has been recorded (see additional information below).
Increase in turbidity (see benchmark)	The native oyster has no dependence on light availability so changes in turbidity would have no effect. However, increased turbidity may decrease primary production by phytoplankton and hence food availability. The characteristic red algae found in this biotope will suffer reduced primary production and growth but are probably shade tolerant but may be lost from deeper examples of this biotope. Therefore, an intolerance of low has been recorded. Once conditions returned to prior levels condition would probably be recovered rapidly.
Decrease in turbidity (see benchmark)	A decrease in turbidity and hence increased light penetration may result in increased phytoplankton production and hence increased food availability for suspension feeders, including *Ostrea edulis*. Therefore, reduced turbidity may be beneficial. However, increased fouling by red algae may result and compete with juveniles and settling spat for space.
Increase in wave exposure (see benchmark)	This biotope is found in sheltered to extremely sheltered conditions. Although subtidal, wave action in shallow water results in oscillatory water flow, the magnitude of which is greatest in shallow water and attenuated with depth. While the oysters' attachment is permanent, increased wave action may result in erosion of its substratum and the oysters with it. Areas where sufficient shell debris has accumulated may be less vulnerable to this disturbance. However, a proportion of the bed is likely to be displaced by an increase in wave action. Similarly, infaunal species, burrowing polychaetes and epifauna are characteristic of wave sheltered conditions and may be lost, e.g. *Ascidiella* sp. The biotope may be replaced by communities characteristic of stronger wave action and coarser sediments. Therefore, an intolerance of high has been recorded. Recruitment in *Ostrea edulis* is sporadic and dependant of the hydrographic regime and local environmental conditions but will be enhanced by the presence of adults and shell material. Therefore a recoverability of very low has been recorded (see additional information below).
Decrease in wave exposure (see benchmark)	This biotope is found in sheltered to extremely sheltered conditions. Therefore, a further reduction in wave exposure is unlikely to have any adverse effects.
Noise (see benchmark)	The majority of invertebrates within this biotope are probably unable to distinguish noise at the level of the benchmark.
Visual Presence (see benchmark)	While most invertebrates can detect light and react to shading as indicative of an approaching predator, they have very limited visual acuity or range and are unlikely to be adversely affected by visual presence.
Abrasion & physical disturbance (see benchmark)	Abrasion may cause damage to the shell of *Ostrea edulis*, particularly to the growing edge. Regeneration and repair abilities of the oyster are quite good. Power washing of cultivated oysters routinely causes chips to the edge of the shell increasing the risk of desiccation. This damage is soon repaired by the mantle. Oysters were often harvested by dredging in the past, which their shells survived relatively intact. However, a passing scallop dredge is likely to remove a

	proportion of the population. On mixed sediments, the dredge may remove the underlying sediment, and cobbles and shell material with effects similar to substratum loss above. Polychaetes and other segmented worms were reported to be badly affected by oyster dredging while any bivalves were displaced (Gubbay & Knapman, 1999). In addition, the epifauna associated with horse mussel beds (*Modiolus modiolus*) was found to be particularly sensitive to abrasion due to scallop dredging (see MCR.ModT; Service & Magorrian, 1997). Therefore *Ostrea edulis* and the other characterizing species are probably sensitive to physical disturbance at the benchmark level and a biotope intolerance of intermediate has been recorded. See 'extraction' below for the effects of fishing on native oyster populations. Recovery will depend on recolonization by the epifaunal and infaunal species, most of which are widespread with dispersive pelagic larvae. However, recruitment in *Ostrea edulis* is sporadic and dependant of the hydrographic regime and local environmental conditions but will be enhanced by the presence of adults and shell material. Therefore a recoverability of moderate has been recorded (see additional information below).
Displacement (see benchmark)	Although individuals are cemented to the substratum removal from the substratum (provided it does not damage the shell) will have little effect. Often oysters attach to non-fixed objects like old shells. Oyster beds used to be maintained by raking and harrowing. More modern methods involve keeping oysters in trays or bags, placing them in suitable conditions, sorting them and generally moving them around. Such disturbance may restrict feeding and affect the timing of spawning but suggests a low intolerance to displacement. Displacement of *Ostrea edulis* will affect the associated epifauna, and probably result in loss of several of the more delicate species with a resultant loss of species richness. Burrowing species will probably be able to reburrow relatively quickly. Epifauna will probably recolonize the shells of *Ostrea edulis* rapidly. Therefore, an overall intolerance of low has been recorded.
Chemical Factors	

Synthetic compound contamination
(see benchmark)
	Suspension feeding organisms process large volumes of sea water and remove organic and inorganic particulates from the water column. Therefore, they are vulnerable to both water soluble contaminants and contaminants adsorbed onto particulates. The effect of pollutants on oysters has been extensively studied. Particular examples follow:
	• *Crassostrea virginica* was found to be intolerant of halogenated by-products of chlorinated power station cooling waters, larval growth was adversely affected, up to 20% larval mortality occurred at 0.05 mg/l (LC_{50} 48 hrs of 1 mg/l. (Cole *et al.*, 1999).
	• Bromoform reduced feeding and gametogenesis at 25 µg/l in *Crassostrea virginica* (Cole *et al.*, 1999).
	• Various detergents, previously used to treat oil spills, were shown to halve the normal development rate of *Ostrea edulis* larvae over the range 2.5 - 7.5 ppm, depending on the type of detergent (Smith, 1968). An increase in development time is likely to increase larval mortality prior to settlement (see *Mytilus edulis* review).
	• Rees *et al.* (2001) suggested that TBT contamination may have locally reduced population sizes of *Ostrea edulis*.
	• In *Ostrea edulis*, TBT has been reported to cause:
	    o reduced growth of new spat at 20 ng/l, a 50% reduction in growth at 60 ng/l;, although older spat grew normally at 240 ng/l for 7 days, and
	    o the prevention of larval production in adults exposed to 240 and

	2620 ng/l for 74 days (Thain & Waldock, 1986; Bryan & Gibbs, 1991). • Adults bioaccumulate TBT. Thain & Waldock (1986) and Thain *et al.* (1986) noted that TBT retarded normal sex change (male to female) in *Ostrea edulis*. TBT also has marked effects on other marine organisms. For example TBT causes imposex in prosobranch gastropods, especially the neogastropods such as *Nucella lapillus*, *Ocenebra erinacea* and *Urosalpinx cinerea* resulting in markedly reduced reproductive capacity and population decline. Ascidian larval stages were reported to be intolerant of TBT (Mansueto *et al.*, 1993 cited in Rees *et al.*, 2001). Beaumont *et al.* (1989) investigated the effects of tri-butyl tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* (family Cirratulidae) after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum and hence there is some evidence that TBT had an effect on the larval and/or juvenile stages of these polychaetes. However, no information concerning the polychaetes characteristic of this biotope were found. However, recent surveys of the Crouch estuary suggested that benthic epifauna were recovering since a reduction in TBT contamination suggesting that populations of several epifaunal species, including *Ascidiella* sp., had previously been reduced (Rees *et al.*, 1999; 2001). While loss of predatory neogastropods (which are particularly intolerant of TBT) may be of benefit to *Ostrea edulis* populations, TBT has been show to reduce reproduction and the growth of spat. Spärck, (1951) demonstrated marked fluctuations and decreases in oyster population in the Limfjord due to variation in recruitment success, therefore any factor that significantly interferes with reproduction and recruitment in *Ostrea edulis* is likely to result in a marked effect on the population. Therefore, an overall intolerance of high has been recorded. Rees *et al.* (1999; 2001) reported that the epifauna of the inner Crouch estuary had largely recovered within 5 years (1987-1992) after the ban on the use of TBT on small boats in 1987. Increases in the abundance of *Ascidiella* sp. and *Ciona intestinalis* were especially noted. *Ostrea edulis* numbers increased between 1987 -1992 with a further increase by 1997. However, they noted that the continued increase in *Ostrea edulis* numbers and the continued absence of neogastropods suggested that recovery was still incomplete at the population level. Clark (1997) suggested that temperate water benthos would probably take 6-10 years to recover after pollution had stopped. Overall, therefore, given the sporadic nature of recruitment in *Ostrea edulis* and its exclusion from otherwise suitable sediment by competitors (e.g. *Crepidula fornicata*) (see additional information below) a recoverability of very low has been recorded.
Heavy metal contamination (see benchmark)	In heavily polluted estuaries, e.g. Restronguet Creek in the Fal estuary, oyster flesh is known to turn green due to the accumulation of copper Cu. (Yonge, 1960; Bryan *et al.* 1987). Bryan *et al.* (1987) noted that in the Cu and Zn were accumulated in the tissues of *Ostrea edulis*, estimates ranging form ca 1000 to ca 16,500 µg/g dry weight, which would probably toxic for human consumption. *Ostrea edulis* is therefore tolerant of high levels of Cu and Zn and is able to survive in the lower reaches of Restronguet Creek, where other species are excluded by the heavy metal pollution. However, larval stages may be more intolerant, especially to Hg, Cu, Cd and Zn. Bryan (1984) reported at 48 hr LC_{50} for Hg of 1-3.3 ppb in *Ostrea edulis* larvae compared with a 48 hr LC_{50} for Hg of 4200 ppb in adults. Little information on the tolerance of ascidians or sponges was found. However, polychaetes are though to be relatively tolerant of heavy metal pollution, even though some heavy metals may suppress reproduction (Bryan, 1984). Similarly,

	Bryan (1984) suggested that adult gastropod molluscs were also relatively tolerant of heavy metal pollution. Therefore, most other characteristic species in this biotope may be relatively tolerant of heavy metal pollution. Although the adult *Ostrea edulis* may be tolerant of heavy metal pollution the larval effects suggest that recruitment may be impaired resulting in a reduction in the population over time, and hence a reduction in the associated fauna. Therefore, an overall intolerance of intermediate has been recorded. Recruitment in *Ostrea edulis* is sporadic and dependant of the hydrographic regime and local environmental conditions but will be enhanced by the presence of adults and shell material. Therefore a recoverability of low has been recorded (see additional information below).
Hydrocarbon contamination (see benchmark)	This biotope will probably be partly protected from the direct effects of an oil spill by its subtidal position. However, in sheltered areas oil is likely to persist, and reach the shallow sea bed adsorbed to particulates or in solution. Oil and its fractions has been shown to result in reduced feeding rates in bivalves (e.g. *Crassostrea* sp.) (Bayne *et al.*, 1992; Suchanek, 1993). Oils and their fractions have also been shown to cause genetic abnormalities in *Crassostrea virginica*. Oysters and other bivalves are known to accumulate hydrocarbons in their tissues (Clark, 1997). Polyaromatic hydrocarbons were show to reduce the scope for growth in *Mytilus edulis* and may have a similar effect in other bivalves. Polychaetes, bivalves and amphipods are generally particularly affected by oil spills in infaunal habits, and echinoderms are also particularly intolerant of oil contamination (Suchanek, 1993). Hydrocarbons in the environment probably also affect growth but no information concerning their effects on reproduction were found. Overall, hydrocarbon contamination would probably affect growth rates of juveniles and adult *Ostrea edulis*, while an oil spill is likely to kill a proportion of the associated community. Therefore, an intolerance of intermediate has been recorded in the absence of further evidence, to represent the effects on the infauna and epifauna rather than the oysters themselves. Recovery will depend on recolonization of the sediments by infauna and epifauna once the hydrocarbons levels have returned to normal levels, and is likely to rapid, although oil will persist in sheltered sediments for some time. Therefore, an overall recoverability of moderate has been recorded.
Radionuclide contamination (see benchmark)	Insufficient information
Changes in nutrient levels (see benchmark)	Moderate nutrient enrichment, especially in the form of organic particulates and dissolved organic material, is likely to increase food availability for all the suspension feeders within the biotope. Therefore, an intolerance of 'not sensitive*' has been recorded. However, long term or high levels of organic enrichment may result in eutrophication and have indirect adverse effects, such as increased turbidity, increased suspended sediment (see above), increased risk of deoxygenation (see below) and the risk of algal blooms. *Ostrea edulis* has been reported to suffer mortality due to toxic algal blooms, e.g. blooms of *Gonyaulax* sp. and *Gymnodinium* sp. (Shumway, 1990). The subsequent death of toxic and non-toxic algal blooms may result in large numbers of dead algal cells collecting on the sea bottom, resulting in local de-oxygenation as the algal decompose, especially in sheltered areas with little water movement where this biotope is found. *Ostrea edulis* may be relatively tolerant of low oxygen concentrations other species within the community may be more intolerant (see below).
Increase in salinity (see benchmark)	This biotope is found subtidally in full to variable salinity waters and is unlikely to experience increased salinity waters. Hyper-saline effluent may be damaging but no information concerning the effects of increased salinity on oyster beds was

	found.
Decrease in salinity (see benchmark)	*Ostrea edulis* is euryhaline and colonizes estuaries and coastal waters exposed to freshwater influence (Yonge, 1960). Yonge (1960) reported that the flat oyster could not withstand salinities below 23 psu. However, Hutchinson & Hawkins (1992) noted that scope for growth was severely affected below 22 psu, probably because the oyster's valves were closed, but that 19 -16 psu could be tolerated if the temperature did not exceed 20 °C. At 25 °C animals did not survive more than 7 days at 16 psu. Hutchinson & Hawkins (1992) noted that at low temperatures (10 °C or less) the metabolic rate was minimal, which would help *Ostrea edulis* survive in low salinities associated with storm runoff in the winter months. Several of the characterizing species in this biotope are commonly found in estuarine and full salinity waters and are probably tolerant of reduced salinity, e.g. *Lanice conchilega* and *Ascidiella aspersa* will tolerate salinities as low as 18 psu (Fish & Fish, 1996). However, this biotope has only been recorded from full salinity habitats, therefore, a proportion of the epifauna and infauna may not tolerate a reduction in salinity and may be lost. Predatory starfish and other echinoderms are generally not able to tolerate low salinity are may be excluded. Overall, therefore, the oyster bed itself may not be adversely damaged by a decrease in salinity comparable to the benchmark, and can probably tolerate short term acute reductions in salinity due to runoff, and an intolerance of low has been recorded. However, the diversity of the oyster bed will be reduced. Recovery will depend on recolonization by the associated fauna and flora and will probably be rapid (see additional information below).
Changes in oxygenation (see benchmark)	Oysters were considered to be tolerant of long periods of anaerobiosis due to their ability to survive out of water during transportation for long periods of time, and many weeks at low temperatures (Korringa, 1952; Yonge, 1960). For example, Lenihan (1999) reported that *Crassostrea virginica* could withstand hypoxic conditions (< 2mg O_2 /l) for 7-10 days at 18 °C but last for several weeks at <5 °C. However, Lenihan (1999) also suggested that many days (26) of hypoxia, contributed to the high rate of mortality observed at the base reefs at 6m depth together with poor condition, parasitism and reduced food availability. In addition, a prolonged period of hypoxia in the River Neuse (North Carolina) resulted in mass mortality of oysters (Lenihan, 1999). Members of the characterizing species that occur in estuaries e.g. *Ascidiella aspersa* are probably tolerant of a degree of hypoxia and occasional anoxia. Similarly, most polychaetes are capable of a degree of anaerobic respiration (Diaz & Rosenberg, 1995). However, periods of hypoxia and anoxia are likely to result in loss of some members of the infauna and epifauna within this biotope. Overall, oysters are probably tolerant of hypoxia at the level of the benchmark and an intolerance of low has been recorded, although the biotope is likely to experience a decrease in species richness. Recovery will depend on recolonization by the associated fauna and flora and is likely to be rapid.
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	Numerous diseases and parasites have been identified in oysters, partly due to their commercial importance and partly because of incidences of disease related mass mortalities in oyster beds. Diseases in oysters and other commercial bivalve species may be caused by bacteria (especially in larvae), protists, fungi, coccidians, gregarines, trematodes, while annelids and copepods may be parasite. The reader should refer to reviews by Lauckner (1983) and Bower & McGladdery (1996) for further detail. For example The following species have caused mortalities in *Ostrea edulis* populations in the UK: • *Polydora ciliata* burrows into the shell, weakening the shell and increasing the oysters vulnerability to predation and physical damage, whereas

	Polydora hoplura causes shell blisters; • boring sponges of the genus *Cliona* may bore the shell of oysters caused shell weakening, especially in older specimens; • the flagellate protozoan *Heximata* sp. resulted in mass mortalities on natural and cultivated beds of oysters in Europe in the 1920-21, from which many population did not recover (Yonge, 1960); • The parasitic protozoan *Bonamia ostreae* caused mass mortalities in France, the Netherlands, Spain, Iceland and England after its accidental introduction in 1980's resulting a further reduction in oyster production (Edwards, 1997); • another protozoan parasite *Marteilia refingens*, present in France has not yet affected stocks in the British Isles, and • the copepod parasite, *Mytilicola intestinalis*, of mussels, has also been found to infect *Ostrea edulis* potentially causing considerable loss of condition, although in most infections there is no evidence of pathology. No information on the effects of diseases and parasites on the associated species was found. However, various diseases are associated with mass mortality in oyster beds and an overall intolerance of high has been recorded. Recovery is dependant on larval recruitment since the adults are permanently attached and incapable of migration. Recruitment is sporadic and dependant on the local environmental conditions, hydrographic regime and the presence of suitable substratum, especially adult shells or shell debris, and has probably been inhibited by the presence of competition from non native species (see additional information below). Therefore, a recoverability of very low has been suggested.
Introduction of non-native species (see benchmark)	The slipper limpet *Crepidula fornicata* was introduced with American oyster between 1887-1890 and has became a serious pest on oyster beds. *Crepidula fornicata* competes for space with oyster, and the build up of its faeces and pseudofaeces smothers oysters and renders the substratum unsuitable for settlement (Blanchard, 1997; Eno *et al.*, 1997, 2000). Where abundant, *Crepidula fornicata* may prevent recolonization by *Ostrea edulis*. The American oyster drill *Urosalpinx cinerea* was first recorded in 1927 and occurs in south east and south west of the UK. *Urosalpinx cinerea* is a major predator of oyster spat and was considered to be a major pest on native and cultured oyster beds (Korringa, 1952; Yonge, 1960) and contributed to the decline in oyster populations in the first half of the 20th century. The above species may cause marked effects on UK oyster beds, especially *Crepidula fornicata* that may change the entire biotope, to produce a *Crepidula fornicata* dominated biotope (see IMX.CreAph). Therefore, an intolerance of high has been recorded. The loss of the oyster population will result in loss of the biotope and many of its associated species. Recovery is dependant on larval recruitment since the adults are permanently attached and incapable of migration. Recruitment is sporadic and dependant on the local environmental conditions, hydrographic regime and the presence of suitable substratum, especially adult shells or shell debris, and has probably been inhibited by the presence of competition from non native species (see additional information below). Therefore, a recoverability of very low has been suggested.
Extraction of key or important characterizing species (see benchmark)	The introduction of oyster dredging in the mid 19th century developed the oyster beds into a major fishery. However, by the late 19th century stocks were beginning to be depleted so that by the 1950s the native oyster beds were regarded as scarce (Korringa, 1952; Yonge, 1960; Edwards, 1997). This biotope is still regarded as scarce today. Over-fishing, combined with reductions in water quality, cold winters (hence poor spat fall), flooding, the introduction of non-native competitors and pests (see above), outbreaks of disease and severe winters was blamed for the decline (Korringa, 1952; Yonge, 1960; Edwards, 1997). As a result, although 700 million oysters were consumed in London alone in 1864, the

	catch fell from 40 million in 1920 to 3 million in the 1960s, from which the catch has not recovered (Edwards, 1997). Loss of the *Ostrea edulis* population would result in loss of the associated biotope. Therefore, while over-fishing was not the sole cause of the overall decline of UK *Ostrea edulis* population it was nevertheless a major contributing factor. Hence, while the benchmark would otherwise result in an intolerance of intermediate, due to the demonstrable potential effects of fishing on this biotope, an intolerance of high has been recorded. Recovery is dependant on larval recruitment since the adults are permanently attached and incapable of migration. Recruitment is sporadic and dependant on the local environmental conditions, hydrographic regime and the presence of suitable substratum, especially adult shells or shell debris, and has probably been inhibited by the presence of competition from non native species (see additional information below). Therefore, a recoverability of very low has been suggested.
Extraction of important species (see benchmark)	No other characterizing species in this biotope are known to be subject to extraction.

Additional information

Recoverability
Recovery of *Ostrea edulis* populations is dependant on larval recruitment, since newly settled juveniles and adults cement themselves to the substratum and are subsequently incapable of migration. Recruitment in *Ostrea edulis* is sporadic and dependant on local environmental conditions, including the average summer sea water temperature, predation intensity and the hydrographic regime. Spärck, (1951) reported marked changes in population size due to recruitment failure. In unfavourable year stocks declined naturally (in the absence of fishing pressure) and the population in the Limfjord became restricted to the most favourable sites. In favourable years the stock increased and the population slowly spread from the most favoured locations. He concluded that a long series of favourable years was required for recovery, for example after closure of the oyster fishery in 1925, stocks did not recovery their fishery potential until 1947/48, ca 20 years. However, the Limfjord population of *Ostrea edulis* is at the northern most extent of its range where recruitment may be more dependant on summer temperatures than more southerly temperate populations. Rees *et al.* (2001) reported that the population of native oysters in the Crouch estuary was increasing (between 1992 -1997) since the reduction in TBT concentration in the water column. Nevertheless, Spärck's data (1951) suggest that several years of favourable recruitment would be required for a *Ostrea edulis* population to recover. Native oyster beds were considered scarce in Europe as early as the 1950s (Korringa, 1952, Yonge, 1960) and are still regarded as scarce today (Connor *et al.*, 1999a). Dominance of other species such as *Crepidula fornicata* following loss of the oyster population can prevent re-establishment, through changes to the environment and competition, and together with introduced and native predators has probably inhibited recovery of natural populations. Recovery is likely to be slow even within or from established populations (see Spärck's, 1951). However, since larvae require hard substratum for settlement with a significant preference for the shells of adults, where the adult population has been removed, especially where shell debris has also been removed, recovery is likely to be very slow, i.e. 10 -25 years or more.

Other species
The other characterizing species are widespread species, with pelagic larvae, potentially capable of wide dispersal and are therefore, likely to be able to recolonize available substratum rapidly. Although the ascidian tadpole larva is short lived and has a low dispersal capability, fertilization is external in the most conspicuous ascidians in the biotope, *Ascidiella* sp., which are widespread in distribution and probably capable of rapid recolonization from adjacent or nearby populations.

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors	
	Ostrea edulis
Community Importance	Key structural
Substratum Loss	High
Smothering	High
Increase in suspended sediment	Low
Decrease in suspended sediment	See explanation
Desiccation	Intermediate
Increase in emergence regime	Intermediate
Decrease in emergence regime	Not Sensitive*
Increase in water flow rate	Low
Decrease in water flow rate	See explanation
Increase in temperature	Low
Decrease in temperature	Intermediate
Increase in turbidity	Low
Decrease in turbidity	See explanation
Increase in wave exposure	Intermediate
Decrease in wave exposure	Not Sensitive
Noise	Not Sensitive
Visual Presence	Not Sensitive
Abrasion & physical disturbance	Intermediate
Displacement	Low
Chemical factors	
	Ostrea edulis
Community Importance	Key structural
Synthetic compound contamination	High
Heavy metal contamination	Intermediate
Hydrocarbon contamination	Low
Radionuclide contamination	Insufficient information
Changes in nutrient levels	Not Sensitive*
Increase in salinity	Low
Decrease in salinity	Low
Changes in oxygenation	Intermediate
Biological factors	
	Ostrea edulis
Community Importance	Key structural
Introduction of microbial pathogens/parasites	High
Introduction of non-native species	High
Extraction of this species	High
Extraction of other species	Not Relevant

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors	
	Ostrea edulis
Community Importance	Key structural
Substratum Loss	Very low
Smothering	Very low
Increase in suspended sediment	Very high
Decrease in suspended sediment	See explanation
Desiccation	Low
Increase in emergence regime	Low
Decrease in emergence regime	Not Relevant
Increase in water flow rate	Very high
Decrease in water flow rate	See explanation
Increase in temperature	Very high
Decrease in temperature	Low
Increase in turbidity	Very high
Decrease in turbidity	See explanation
Increase in wave exposure	Low
Decrease in wave exposure	Not Relevant
Noise	Not Relevant
Visual Presence	Not Relevant
Abrasion & physical disturbance	Low
Displacement	Very high
Chemical factors	
	Ostrea edulis
Community Importance	Key structural
Synthetic compound contamination	Very low
Heavy metal contamination	Low
Hydrocarbon contamination	Very high
Radionuclide contamination	Insufficient information
Changes in nutrient levels	Not Relevant
Increase in salinity	Very high
Decrease in salinity	Very high
Changes in oxygenation	Low
Biological factors	
	Ostrea edulis
Community Importance	Key structural
Introduction of microbial pathogens/parasites	Very low
Introduction of non-native species	Very low
Extraction of this species	Very low
Extraction of other species	Not Relevant

Importance

Marine natural heritage importance

Listed under:	**UK Biodiversity Action Plan** **EC Habitats Directive**
National importance	Scarce
Habitat Directive feature (Annex 1)	Large shallow inlets and bays Estuaries
UK Biodiversity Action Plan habitat	Sheltered muddy gravels Inshore sublittoral sediment (broad habitat statement)
OSPAR Priority Habitat	*Ostrea edulis* beds

Biotope importance

Dame (1996) suggested that dense beds of bivalve suspension feeders were important for pelagic-benthic coupling in estuarine ecosystems, resulting in increased rates of nutrient and organic carbon turnover and an overall increase in the productivity of the ecosystem. Newell (1988; cited in Dame, 1996) suggested that the *Crassostrea edulis* population in Chesapeake Bay were an important grazer of phytoplankton and that the destruction of the oyster reefs resulted in reduced grazing of the phytoplankton, spring blooms that increased turbidity and the risk of anoxia, and an increase in summer zooplankton and pelagic predators such as jelly fish and ctenophores, essentially changing aspects of the ecosystem. Similarly, the increase in nutrients and suspended sediments in Chesapeake Bay due to agricultural runoff and coastal development was exacerbated by the decline in the major filter feeding species, the oyster reefs (Dame, 1992).

Native oyster beds, although scarce, are probably of similar importance to their local ecosystems, as a major grazer of the phytoplankton, contributing to pelagic-benthic coupling, stabilizing sediment and providing substratum for numerous species in what might otherwise be bare sediment. The introduction of such hard substrata, therefore, markedly increases species diversity at a location.

Exploitation

British native oyster beds (characteristic of this biotope) were exploited in Roman times. The introduction of oyster dredging in the mid 19th century developed the oyster beds into one of Britain's largest fisheries, employing about 120,000 men around the coast in the 1880's. However, by the late 19th century stocks were beginning to be depleted so that by the 1950s the native oyster beds were regarded as scarce (Korringa, 1952; Yonge, 1960; Edwards, 1997). This biotope is still regarded as scarce today. Over-fishing, combined with reductions in water quality, cold winters (hence poor spat fall), flooding, the introduction of non-native competitors and pests (see sensitivity), outbreaks of disease and severe winters were blamed for the decline (Korringa, 1952; Yonge, 1960; Edwards, 1997). As a result, although 700 million oysters were consumed in London alone in 1864, the catch fell from 40 million in 1920 to 3 million in the 1960s, from which the catch has not recovered (Edwards, 1997). The European flat oyster (Ostrea edulis) fishery continues to use traditional techniques, however, most oysters reaching the market come from 'relays' or from mariculture (Edwards, 1997).

Additional information

Native oyster fisheries are subject primarily to UK shellfisheries conservation legislation; the species is not named in any national or international nature conservation legislation or conventions. However, *Ostrea edulis* is included in a Species Action Plan under the UK Biodiversity Action Plan (Anon, 1999c). Commercial native and non-native oyster transplantation has been recorded as a dispersal mechanism for non-native species, including serious pests such as *Crepidula fornicata* and *Urosalpinx cinerea* (Anon., 1999d; Blanchard, 1997; Eno *et al.*, 2000).

This Biology and Sensitivity Key Information review can be cited as follows:

Tyler-Walters, H., 2001. *Ostrea edulis* beds on shallow sublittoral muddy sediment. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/01/2005]. Available from: <http://www.marlin.ac.uk>

Venerupis senegalensis and *Mya truncata* in lower shore or infralittoral muddy gravel (IMX.VsenMtru)

Key information authored by: Will Rayment

Last updated 17/09/2001

This information is not refereed.

If you would be willing to supply *MarLIN* with an image of this species/habitat please contact marlin@mba.ac.uk

Recorded and expected IMX.VsenMtru distribution for Britain and Ireland

Description of biotope

Intertidal and shallow sublittoral muddy gravel in sheltered inlets that do not have a significantly reduced salinity (sea lochs) with *Venerupis senegalensis* and occasionally with *Mya truncata*. This biotope is perhaps best considered as an extension onto the extreme lower shore of a sublittoral biotope. Other typical components of the community include the polychaetes *Notomastus latericeus*, *Aphelochaeta marioni* and *Tubificoides benedii*. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Welsh variation

Although the Welsh examples of many of the biotopes in this report follow the British and Irish classification description closely, some regional variation may exist. Reference should be made to Rohan Holt (in prep.) for details. Alternatively, contact the CCW Marine Monitoring Team.

Additional information

No text entered

Biotope classification

UK and Ireland Classification

Major habitat	SS	Sublittoral sediments
Habitat complex	IMX	Infralittoral mixed sediments
Biotope complex	IMX.FaMx	Shallow mixed sediment faunal communities
Biotope	IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel

Other biotope classification schemes

European Union Nature Information System (EUNIS) classification: A4.421/B - IMX.FaMX.VsenMtru - *Venerupis senegalensis* and *Mya truncata* in lower shore or shallow-water muddy gravel (Davies & Moss, 1998).

Ecology

Ecological and functional relationships

- The species composition of the biotope is probably determined largely by the substratum characteristics and therefore the hydrodynamic regime and sediment supply, rather than the interspecific relationships. Sediment is the most extensive sub-habitat within the biotope and hence infauna dominate.
- The suspension feeding infaunal bivalves, e.g. *Venerupis senegalensis, Abra alba, Mysella bidentata* and *Mya truncata*, compete for nutrients among themselves and with epifauna, e.g. *Mytilus edulis*.
- Spatial competition probably occurs between infaunal suspension feeders and deposit feeders. Reworking of sediment by deposit feeders, e.g. *Arenicola marina*, makes the substratum less stable, increases the suspended sediment and makes the environment less suitable for suspension feeders (Rhoads & Young, 1970). Tube building, e.g. by *Lanice conchilega*, and byssal attachment, e.g. by *Venerupis senegalensis*, stabilize the sediment and arrest the shift towards a community dominated by deposit feeders.
- Amphipods, e.g. *Corophium* sp., and the infaunal annelid species in this biotope probably interfere strongly with each other. Adult worms probably reduce amphipod numbers by disturbing their burrows, while high densities of amphipods can prevent establishment of worms by consuming larvae and juveniles (Olafsson & Persson, 1986). *Arenicola marina* has been shown to have a strong negative effect on *Corophium volutator* due to reworking of sediment causing the amphipod to emigrate (Flach, 1992).
- *Carcinus maenas* is a significant predator in the biotope. It has been shown to reduce the density of *Mya arenaria*, *Cerastoderma edule*, *Abra alba*, *Tubificoides benedii*, *Aphelochaeta marioni* and *Corophium volutator* (Reise, 1985). A population of *Carcinus maenas* from a Scottish sea-loch preyed predominantly on annelids (85% frequency of occurrence in captured crabs) and less so on molluscs (18%) and crustaceans (18%) (Feder & Pearson, 1988).
- Carnivorous annelids such as *Nephtys hombergii* and *Pholoe inornata* operate at the trophic level below *Carcinus maenas* (Reise, 1985). They predate the smaller annelids and crustaceans.
- *Cerastoderma edule* and *Mya arenaria* are common prey for several bird species. *Ensis* sp. and *Venerupis* sp. are also heavily predated (Meire, 1993). The main bird predator in the biotope is probably the oystercatcher, *Haematopus ostralegus*. Drianan (1957; cited in Meire, 1993) estimated that oystercatchers remove 22% of the cockle population annually in Morecambe Bay. It should be noted that only the upper portion of the biotope will be vulnerable to predation by shore birds at low tide.
- Macroalgae, e.g. *Fucus serratus*, colonize the hard substrata where present. The low energy environment allows colonization of gravel and pebbles which in higher energy environments would be too unstable.
- *Littorina littorea* and *Gibbula cineraria* graze microalgae and ephemeral green algae, preventing domination by the faster growing species. Calcareous species, e.g. the Corallinaceae, are resistant to grazing.

Seasonal and longer term change

Seasonal changes occur in the abundance of the fauna due to seasonal recruitment processes. *Venerupis senegalensis* exhibits pronounced year class variability in abundance (Johannessen, 1973b; Perez Camacho, 1980) probably due to patchy recruitment and/or variable post recruitment processes. Variation in abundance is very pronounced in the polychaete *Aphelochaeta marioni*. In the Wadden Sea, peak abundance occurred in January (71,200 individuals per m^2) and minimum abundance occurred in July (22,500 individuals per m^2) following maximum spawning activity between May and July (Farke, 1979). However, the spawning period varies according to environmental conditions and so peak abundances will not necessarily occur at the same time each year. Adult densities of the bivalve, *Abra alba*, may exceed 1000 per m^2 in favourable conditions but typically fluctuate widely from year to year due to variation in recruitment success or adult mortality (see review by Rees & Dare, 1993).

Macroalgal cover typically varies through the year due to temperature and light availability. *Fucus serratus* plants, for example, lose fronds in the winter, followed by regrowth from existing plants in late spring and summer, so that summer cover can be about 250% of the winter level (Hartnoll & Hawkins, 1980). Production by microphytobenthos and microalgae is also likely to be higher in spring and summer, increasing food availability for grazers, deposit feeders and suspension feeders.
One of the key factors affecting benthic habitats is disturbance, which in shallow subtidal habitats increases in winter due to weather conditions. Storms may cause dramatic changes in distribution of macro-infauna by washing out dominant species, opening the sediment to recolonization by adults and/or available spat/larvae (Eagle, 1975; Rees *et al.*, 1977; Hall, 1994) and by reducing success of recruitment by newly settled spat or larvae (see Hall, 1994 for review). For example, during winter gales along the North Wales coast, large numbers of *Abra alba* were cast ashore and over winter survival rate was as low as 7% in the more exposed locations. The survival rates of the bivalve, *Mysella bidentata*, and the polychaete, *Notomastus latericeus*, were 50% and 12% respectively (Rees *et al.*, 1977). Sediment transport and the risk of smothering also occurs. A storm event at a silt/sand substratum site in Long Island Sound resulted in the deposition of a 1cm layer of shell fragments and quartz grains (McCall, 1977).

Habitat structure and complexity

- The mixed sediment in this biotope is the important structural component, providing the complexity required by the associated community. Epifauna and algae are attached to the gravel and pebbles and infauna burrow in the soft underlying sediment. Sediment deposition, and therefore the spatial extent of the biotope, is dictated by the physiography and underlying geology coupled with the hydrodynamic regime (Elliott *et al.*, 1998).
- There is a traditional view that the distribution of infaunal invertebrates is correlated solely with sediment grain size. In reality, and in this biotope, it is likely that a number of additional factors, including organic content, microbial content, food supply and trophic interactions, interact to determine the distribution of the infauna (Snelgrove & Butman, 1994).
- Reworking of sediments by deposit feeders, such as *Arenicola marina*, increases bioturbation and potentially causes a change in the substratum characteristics and the associated community (e.g. Rhoads & Young, 1970). The presence of tube builders, such as *Lanice conchilega*, stabilizes the sediment and provides additional structural complexity.
- The presence of macroalgae, such as *Fucus serratus* and *Osmundea pinnatifida*, increases structural complexity in the biotope, providing shelter and cover for mobile fauna. The fronds increase the area available for attachment of epifauna and epiphytes.

Dominant trophic groups	Suspension feeders Deposit feeders (detritivores)

Productivity

Primary production in this biotope comes predominantly from benthic microalgae (microphytobenthos e.g. diatoms, flagellates and euglenoides) and water column phytoplankton. Macroalgae, although not very abundant in the biotope also contribute to primary production. They exude considerable amounts of dissolved organic carbon which are taken up readily by bacteria and possibly by some larger invertebrates. Only about 10% of the primary production on rocky shores is directly cropped by herbivores (Raffaelli & Hawkins, 1999) and the figure is likely to be similar or less in this biotope. Photosynthetic processes may be light limited due to the turbidity of the water (Elliott *et al.*, 1998) and *in situ* primary production overall is likely to be low. Large allochthonous inputs of nutrients, sediment and organic matter come from river water and the sea, containing both naturally derived nutrients and anthropogenic nutrients (e.g. sewage) (Elliott *et al.*, 1998). The allochthonous nutrient input results in enriched sediments and explains the high biomass of detritivores and deposit feeders.

Major sources of organic carbon	Photosynthesis (microalgae) Dissolved organic matter

Recruitment processes

Characteristic and other species in the biotope recruit as larvae and spores from the plankton. More detailed information is given for dominant and characteristic species below.

- *Venerupis senegalensis* is a long lived, fast growing species that reaches maturity within one year and spawns several times in one season (Johannessen, 1973b; Perez Camacho, 1980). No information was found concerning number of gametes produced, but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). The larvae remain in the plankton for up to 30 days (Fish & Fish, 1996) and hence have a high potential for dispersal. The species exhibits pronounced year class variability in abundance (Johannessen, 1973b; Perez Camacho, 1980) which suggests that recruitment is patchy and/or post settlement processes are highly variable. Olafsson *et al.* (1994) reviewed the potential effects of pre and post recruitment processes. Recruitment may be limited by predation of the larval stage or inhibition of settlement due to intraspecific density dependent competition. Post settlement processes affecting survivability include predation by epibenthic consumers, physical disturbance of the substratum and density dependent starvation of recent recruits. Hence, for *Venerupis senegalensis*, annual predictable recruitment is unlikely to occur.

- Recruitment of shallow burrowing infaunal species can depend on adult movement by bedload sediment transport and not just spat settlement. Emerson & Grant (1991) investigated recruitment in *Mya arenaria* and found that bedload transport was positively correlated with clam transport. They concluded that clam transport at a high energy site accounted for large changes in clam density. Furthermore, clam transport was not restricted to storm events and the significance is not restricted to *Mya arenaria* recruitment. Many infauna, e.g. polychaetes, gastropods, nematodes and other bivalves, will be susceptible to movement of their substratum.
- The infaunal polychaetes *Arenicola marina* and *Aphelochaeta marioni* have high fecundity and the eggs develop lecithotrophically within the sediment or at the sediment surface (Farke, 1979; Beukema & de Vlas, 1979). There is no pelagic larval phase and the juveniles disperse by burrowing. Recruitment must occur from local populations or by longer distance dispersal during periods of bedload transport. Recruitment is therefore likely to be predictable if local populations exist but patchy and sporadic otherwise.
- The epifaunal gastropods in the biotope, such as *Littorina littorea*, are iteroparous, highly fecund and disperse via a lengthy pelagic larval phase. Recruitment is probably sporadic and opportunistic, large spat fall occurring when a suitable substratum and food supply becomes available.
- Recruitment of *Fucus serratus* from minute pelagic sporelings takes place from late spring until October. There is a reproductive peak in the period August **-** October and dispersal may occur over long distances (up to 10 km). However, weak tidal streams may result in a smaller supply of pelagic sporelings and most recruitment probably comes from local populations.

Time for community to reach maturity

Venerupis senegalensis is the important characterizing species in the biotope. It is highly fecund and fast growing (Johannessen, 1973; Perez Camacho, 1980; Olafsson *et al.*, 1994) and therefore is likely to attain high numbers in the community rapidly. The same is true for the majority of other infauna, epifauna and flora in the biotope. It is predicted therefore that the community will reach maturity in less than 5 years.

Additional information

no text entered.

Habitat preference and distribution

Distribution in Britain and Ireland

Patchily distributed around the coasts of Britain and Ireland. Recorded from the Shetland Islands, north east England, south west England, south west Wales, western Scotland and southern Ireland.

Habitat preferences

Temperature range preferences	No information found
Water clarity preferences	Medium clarity / Medium turbidity Low clarity / High turbidity
Limiting nutrients	Nitrogen (nitrates) Phosphorus (phosphates)
Other preferences	No information found

Additional information

No text entered

Species composition

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3). The biology of other component species of the biotope is also taken into account wherever information is known to the researcher.

Community Importance	Species name	Common Name
Important characterizing	*Venerupis senegalensis*	Pullet carpet shell
Important other	*Mya truncata*	Blunt gaper
Important other	*Littorina littorea*	Common periwinkle
Important other	*Arenicola marina*	Blow lug

Explanation

Venerupis senegalensis is the species which defines this biotope. It is dominant, highly faithful and frequent. Loss of the species would also result in loss of the biotope. However, loss of the species would be unlikely to have significant knock on effects for the rest of the community as there are other bivalve species in the biotope which fill similar niches. *Venerupis senegalensis* is therefore assessed as "important characterizing" and not "key".

Other species in the biotope which should be considered when assessing biotope sensitivity are *Littorina littorea*, *Arenicola marina* and *Mya truncata*. They are therefore categorized as 'important other'. In the absence of a complete Biology and Sensitivity Key Information Review for *Mya truncata* the review of *Mya arenaria* has been used for reference.

Species found especially in biotope

Venerupis senegalensis Pullet carpet shell

Additional information

No text entered

Biotope sensitivity

Physical Factors

	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Substratum Loss	High	High	Moderate	Major Decline	High
Smothering	Intermediate	High	Low	Decline	Low
Increase in suspended sediment	Low	Very high	Very Low	Minor Decline	Low
Decrease in suspended sediment	Low	Immediate	Not sensitive	No Change	Low
Desiccation	Low	Very high	Very Low	No Change	Low
Increase in emergence regime	Intermediate	High	Low	Decline	Low
Decrease in emergence regime	Tolerant*	Not Relevant	Not sensitive*	No Change	High
Increase in water flow rate	Intermediate	High	Low	Decline	Low

Decrease in water flow rate	Tolerant	Not Relevant	Tolerant	Minor Decline	Low
Increase in temperature	Low	Very high	Very Low	No Change	Moderate
Decrease in temperature	Intermediate	High	Low	Minor Decline	Moderate
Increase in turbidity	Low	Very high	Very Low	Minor Decline	Low
Decrease in turbidity	Tolerant	Not Relevant	Tolerant	No Change	Low
Increase in wave exposure	High	High	Moderate	Decline	Low
Decrease in wave exposure	Tolerant	Not Relevant	Tolerant	No Change	High
Noise	Tolerant	Not Relevant	Tolerant	No Change	Low
Visual Presence	Tolerant	Not Relevant	Tolerant	No Change	Low
Abrasion & physical disturbance	Intermediate	High	Low	Minor Decline	Low
Displacement	Intermediate	High	Low	No Change	Low
Chemical Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Synthetic compound contamination	High	High	Moderate	Decline	Very low
Heavy metal contamination	High	High	Moderate	Decline	High
Hydrocarbon contamination	Intermediate	Moderate	Moderate	Minor Decline	Moderate
Radionuclide contamination	Insufficient information	Not Relevant	Insufficient information	Insufficient Information	Not Relevant
Changes in nutrient levels	Intermediate	High	Low	No Change	Low
Increase in salinity	Tolerant	Not Relevant	Tolerant	No Change	High
Decrease in salinity	Intermediate	High	Low	Minor Decline	Low
Changes in oxygenation	Intermediate	High	Low	Minor Decline	Low
Biological Factors					
	Intolerance	Recoverability	Sensitivity	Species Richness	Evidence / Confidence
Introduction of microbial pathogens/parasites	Intermediate	High	Low	Minor Decline	High
Introduction of non-native species	Intermediate	Very low	High	Minor Decline	Very low
Extraction of key or important characterizing species	Intermediate	High	Low	Minor Decline	High
Extraction of important species	Not Relevant	Not Relevant	Not relevant	Not Relevant	Not Relevant

Explanation of sensitivity and recoverability

Physical Factors	
Substratum Loss (see benchmark)	Removal of the substratum would remove entire populations of infauna, epifauna and macroalgae. Intolerance is therefore assessed as high and there would be a major decline in species richness. Recoverability is assessed as high (see additional information below).
Smothering	*Venerupis senegalensis* typically burrows to a depth of 3-5 cm and is often attached to small stones or shell fragments by byssal threads. It is an active

(see benchmark)	suspension feeder and therefore requires its siphons to be above the sediment surface in order to maintain a feeding and respiration current. Kranz (1972; cited in Maurer *et al.*, 1986) reported that shallow burying siphonate suspension feeders are typically able to escape smothering with 10-50 cm of their native sediment and relocate to their preferred depth by burrowing. This is likely to apply to the proportion of the *Venerupis senegalensis* population which is not firmly attached by byssal threads. However, those individuals which are attached may be inhibited from relocating rapidly following smothering with 5 cm of sediment and some mortality is expected to occur. Emerson *et al.* (1990) examined smothering and burrowing of *Mya arenaria* after clam harvesting. Significant mortality (2 -60%) in small and large clams occurred only at burial depths of 50 cm or more in sandy substrates. However, they suggested that in mud, clams buried under 25 cm of sediment would almost certainly die. Dow & Wallace (1961) noted that large mortalities in clam beds resulted from smothering by blankets of algae (*Ulva* sp.) or mussels (*Mytilus edulis*). In addition, clam beds have been lost due to smothering by 6 cm of sawdust, thin layers of eroded clay material, and shifting sand (moved by water flow or storms) in the intertidal. The more mobile burrowing infauna, such as polychaetes, are likely to be able to relocate to their preferred depth following smothering with little or no loss of fitness. Due to their requirement for light for photosynthesis, macroalgae, and especially the encrusting and low growing species such as the Corallinaceae, are likely to be highly intolerant of smothering. Due to the intolerance of the important characterizing species, *Venerupis senegalensis*, intolerance for the biotope is assessed as intermediate. Populations of epifauna and macroalgae may be lost so species richness is expected to decline. Recoverability is recorded as high (see additional information below).
Increase in suspended sediment (see benchmark)	*Venerupis senegalensis* is an active suspension feeder, trapping food particles on the gill filaments (ctenidia). An increase in suspended sediment is therefore likely to affect both feeding and respiration by potentially clogging the ctenidia. In *Venerupis corrugatus*, increased particle concentrations between low and high tide resulted in increased clearance rates and pseudofaeces production with no significant increase in respiration rate (Stenton-Dozey & Brown, 1994). It seems likely therefore that *Venerupis senegalensis* would also be able to clear its feeding and respiration structures, although at high particle concentrations there may be some energetic cost. An energetic cost resulting from increased suspended sediment has also been suggested for other bivalves which occur in the biotope, for example *Mya arenaria* (Grant & Thorpe, 1991) and *Cerastoderma edule* (Navarro & Widows, 1997). According to the benchmark, the increase in suspended sediment persists for a month and no mortality of suspension feeders is expected in this time. Intolerance of the biotope is therefore assessed as low. When suspended sediment returns to original levels, metabolic activity should quickly return to normal and recoverability is assessed as very high. An increase in suspended sediment would probably result in an increased rate of siltation. The extent of substratum suitable for the epifauna in the biotope would decrease and encrusting macroalgae would become smothered. There is therefore likely to be a minor decline in species richness.
Decrease in suspended sediment (see benchmark)	The majority of species in the biotope are either suspension feeders or deposit feeders and therefore rely on a supply of nutrients in the water column and at the sediment surface. A decrease in the suspended sediment would result in decreased food availability for suspension feeders. It would also result in a decreased rate of deposition on the substratum surface and therefore a reduction in food availability for deposit feeders. This would be likely to impair growth and reproduction. The benchmark states that this change would occur for one month and therefore would be unlikely to cause mortality. An intolerance of low is therefore recorded. As soon as suspended sediment levels increased, feeding activity would return to

	normal and hence recovery is recorded as immediate.
Desiccation (see benchmark)	The majority of the species in the biotope, including *Venerupis senegalensis*, live infaunally in muddy sand and gravel, a substratum with a high water content, and are therefore protected from desiccation stress. Additionally, most bivalves, including *Venerupis senegalensis,* are able to respond to desiccation stress by valve adduction during periods of emersion. It is likely that these species would be able to retain enough water in the shell to prevent mortality during the benchmark exposure period of one hour. However, during the period of emersion, the species would not be able to feed and respiration would be compromised, so there is likely to be some energetic cost. Biotope intolerance is therefore recorded as low. On immersion, metabolic activity should quickly return to normal so recoverability is recorded as very high. Other bivalves, including *Mya arenaria* and *Ensis ensis*, have gaping shells and are therefore more intolerant of desiccation.
Increase in emergence regime (see benchmark)	The biotope occurs on the extreme lower shore (Connor *et al.*, 1997a) and so is vulnerable to an increase in emergence. The fact that the biotope does not occur further up the shore suggests that the characterizing species must be limited by one or more factors including desiccation, temperature and wave exposure. The benchmark for emergence is an increase in exposure for one hour every tidal cycle for a year. During this time, exposed marine species will not be able to feed and respiration will be compromised. Over the course of a year, it is expected that the resultant energetic cost to the individuals highest up the shore will lead to some mortality and therefore intolerance is recorded as intermediate. Some species will be more sensitive than others. *Littorina littorea*, for example, is relatively tolerant of increases in emergence as it is mobile and has behavioural adaptations to counter desiccation. Recoverability is recorded as high (see additional information below).
Decrease in emergence regime (see benchmark)	The majority of the biotope occurs in the shallow subtidal (Connor *et al.*, 1997a) and so is not likely to be intolerant of a decrease in emergence regime. It is possible that a decrease in emergence regime would allow the biotope to extend further up the shore.
Increase in water flow rate (see benchmark)	IMX.VsenMtru occurs in wave protected areas where water flow is typically "weak" (Connor *et al.*, 1997a). An increase in water flow of 2 categories would place the biotope in areas of "strong" flow. The increase would change the sediment characteristics in which the biotope occurs, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). The underlying sediment in the biotope has a high silt content; a substratum which would not occur in very strong tidal streams. Therefore, the infaunal species, such as *Venerupis senegalensis*, would be outside their habitat preferences and some mortality would be likely to occur, probably due to interference with feeding and respiration. Additionally, the consequent lack of deposition of particulate matter at the sediment surface would reduce food availability for the deposit feeders in the biotope. The resultant energetic cost over one year would also be likely to result in some mortality. A biotope intolerance of intermediate is therefore recorded and species richness is expected to decline. Recoverability is assessed as high (see additional information below). The expected change in sediment composition would favour the epifauna and macroalgae which would probably become more abundant.
Decrease in water flow rate (see benchmark)	IMX.VsenMtru occurs in low energy environments such as sheltered beaches where the water flow is typically "weak" (Connor *et al.*, 1997a). The majority of species in the biotope are infaunal and are capable of generating their own respiration and feeding currents. These species are unlikely to be intolerant of a decrease in water flow rate. However, decreased water flow rate is likely to lead to increased deposition of fine sediment (Hiscock, 1983) and therefore decreased

	availability of suitable substrata for the attachment of macroalgae and epifauna. There may, therefore, be a minor decline in species richness in the biotope.
Increase in temperature (see benchmark)	The temperature intolerance of the biotope is largely dependent on the intolerance of the important characterizing species. The geographic range of *Venerupis senegalensis* extends to northern Africa. Therefore, the species must be capable of surviving in higher temperatures than it experiences in Britain and Ireland and thus would be expected to tolerate temperature change over an extended period. A population of *Venerupis corrugatus* endured a temperature rise from 13 to 18 °C over 5 hours in a rockpool and then a drop to 14 °C following inundation by the tide, with no obvious ill effects (Stenton-Dozey & Brown, 1994). Albentosa *et al.* (1994) found that scope for growth of *Venerupis senegalensis* increases to an optimum at 20 °C and then declines. Hence, it is expected that *Venerupis senegalensis* would be able to tolerate a long term, chronic temperature increase and a short term acute change with no mortality. However, a rapid increase in temperature may result in sub-optimal conditions for growth and reproduction and therefore intolerance of the biotope is assessed as low. Metabolic activity should return to normal when temperatures decrease and so recoverability is assessed as very high. The intolerance of other species in the biotope is variable. Epifauna and macroalgae which occur in the intertidal tend to be quite tolerant of temperature change. *Littorina littorea*, for example, occurs in upper shore rockpools where temperatures may exceed 30 °C. The infauna may be less tolerant of temperature change *per se*, e.g. upper median lethal temperature for *Cerastoderma edule* is 29 °C after 96 hrs exposure (Ansell *et al.*, 1981), but are less likely to experience rapid changes in temperature due to being buried in sediment.
Decrease in temperature (see benchmark)	The temperature intolerance of the biotope is largely dependent on the intolerance of the important characterizing species. The geographic range of *Venerupis senegalensis* extends to northern Norway. Therefore, the species must be capable of survival at lower temperatures than it does in Britain and Ireland and would be expected to tolerate a chronic temperature decrease over an extended period. However, in the harsh British winter of 1962-63, when the south coast experienced temperatures 5-6 °C below average for a period of 2 months, *Venerupis senegalensis* (studied as *Venerupis pullastra*) suffered 50% mortality around the Isle of Wight and near 100% mortality in Poole Harbour (Waugh, 1964). The species is less tolerant therefore of acute decreases in temperature and a biotope intolerance of intermediate is recorded. Recoverability is recorded as high (see additional information below). Other species which suffered significant mortality during the winter of 1962-63 include *Cerastoderma edule*, *Ensis ensis* and *Gibbula cineraria* (Crisp, 1964). It is expected that there will be a minor decline in species richness in the biotope.
Increase in turbidity (see benchmark)	IMX.VsenMtru occurs in relatively turbid waters and therefore the species in the biotope are likely to be well adapted to turbid conditions. An increase in turbidity may affect primary production in the water column and therefore reduce the availability of diatom food, both for suspension feeders and deposit feeders. In addition, primary production by the microphytobenthos on the sediment surface may be reduced, further decreasing food availability for deposit feeders. However, primary production is probably not a major source of nutrient input into the system and, furthermore, phytoplankton will also immigrate from distant areas so the effect may be decreased. As the benchmark turbidity increase only persists for a year, decreased food availability would probably only affect growth and fecundity of the intolerant species so a biotope intolerance of low is recorded. As soon as light levels return to normal, primary production will increase and hence recoverability is recorded as very high. Macroalgae are likely to be most affected by an increase in turbidity. There may therefore be a minor decline in species richness.

Decrease in turbidity (see benchmark)	A decrease in turbidity will mean more light is available for photosynthesis by macroalgae, phytoplankton in the water column and microphytobenthos on the sediment surface. This would increase the primary production in the biotope and may mean greater food availability for grazers, suspension feeders and deposit feeders. There may be a consequent proliferation of epifauna and macroalgae at the expense the previously dominant infauna.
Increase in wave exposure (see benchmark)	IMX.VsenMtru occurs in sheltered inlets and sea lochs and is characterized by a mixed substratum (Connor *et al.*, 1997a). This suggests that the biotope would be intolerant of wave exposure to some degree. An increase in wave exposure by two categories for one year would be likely to affect the biotope in several ways. Fine sediments would be eroded (Hiscock, 1983) resulting in the likely reduction of the habitat of the infaunal species, e.g. *Venerupis senegalensis*, and a decrease in food availability for deposit feeders. Gravel and cobbles are likely to be moved by strong wave action resulting in damage and displacement of epifauna. Species may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action. For example, large macroalgae, such as *Fucus serratus*, are particularly vulnerable and are likely to suffer damaged fronds and dislodged plants. Furthermore, strong wave action is likely to cause damage or withdrawal of delicate feeding and respiration structures of species within the biotope resulting in loss of feeding opportunities and compromised growth. It is likely that high mortality would result and therefore an intolerance of high is recorded and species richness is expected to decline. Recoverability is recorded as high (see additional information below).
Decrease in wave exposure (see benchmark)	IMX.VsenMtru occurs in "extremely sheltered" environments (Connor *et al.*, 1997a). The biotope, therefore, is unlikely to be intolerant of a further decrease in wave exposure and species richness is unlikely to change. However, it should be noted that decreased wave exposure will lead to changes in oxygenation and increased risk of smothering due to siltation. These factors are discussed in their relevant sections.
Noise (see benchmark)	No information was found concerning the intolerance of the biotope or the characterizing species to noise. However, it is unlikely that the biotope will be affected by noise or vibrations caused by noise at the level of the benchmark.
Visual Presence (see benchmark)	The majority of the species in the biotope, including *Venerupis senegalensis*, have very little or no visual acuity, and are therefore unlikely to be intolerant of visual disturbance. Some species, however, respond to visual disturbance by withdrawal of feeding structures and are therefore likely to experience some energetic cost through loss of feeding opportunities. *Aphelochaeta marioni*, for example, feeds only at night, and responds to sudden light pollution by the retraction of palps and cirri and cessation of all activity for some minutes (Farke, 1979).
Abrasion & physical disturbance (see benchmark)	Many species in the biotope are vulnerable to physical abrasion. The infaunal annelids are predominantly soft bodied, live within a few centimetres of the sediment surface and may expose feeding or respiration structures where they could easily be damaged by a physical disturbance such as a scallop dredge. Despite their robust body form, bivalves are also vulnerable. For example, as a result of dredging activity, mortality and shell damage have been reported in *Mya arenaria* and *Cerastoderma edule* (Cotter *et al.*, 1997). Robust bodied or thick shelled species were less sensitive, while species with brittle, hard tests are regarded to be sensitive to impact with scallop dredges (Kaiser & Spencer, 1995; Bradshaw *et al.*, 2000). Epifauna and macroalgae risk being damaged and/or dislodged by physical abrasion. Some mortality is likely to result from physical abrasion so intolerance is recorded as intermediate and species richness may suffer a minor decline. Recoverability is assessed as high (see additional information below).

Displacement (see benchmark)	*Venerupis senegalensis* is the only important characterizing species in the biotope. When displaced and returned to the surface of the substratum, it is able to re-bury itself (e.g. Kaschl & Carballeira, 1999). This probably occurs naturally due to shifting sediments caused by storms. However, while exposed at the sediment surface, the species is more vulnerable to predation and some mortality may occur. Intolerance is therefore recorded as intermediate. Recoverability is recorded as high (see additional information below).
Chemical Factors	
Synthetic compound contamination (see benchmark)	Beaumont *et al.* (1989) concluded that bivalves are particularly intolerant of tri-butyl tin (TBT), the toxic component of many antifouling paints. For example, when exposed to 1-3 µg TBT/l, *Cerastoderma edule* and *Scrobicularia plana* suffered 100% mortality after 2 weeks and 10 weeks respectively. Furthermore, there is evidence that TBT causes recruitment failure in bivalves, either due to reproductive failure or larval mortality (Bryan & Gibbs, 1991). Beaumont *et al.* (1989) also concluded that TBT had a detrimental effect on the larval and/or juvenile stages of infaunal polychaetes. Collier & Pinn (1998) investigated the effect on the benthos of ivermectin, a feed additive treatment for infestations of sea-lice on farmed salmonids and a common contaminant in sea lochs. The polychaete *Hediste diversicolor* was particularly susceptible, exhibiting 100% mortality within 14 days when exposed to 8 mg/m² of ivermectin in a microcosm. *Arenicola marina* was also intolerant of ivermectin through the ingestion of contaminated sediment (Thain *et al.*, 1998; cited in Collier & Pinn, 1998) and it was suggested that deposit feeding was an important route for exposure to toxins. Given the intolerance of infaunal bivalves and polychaetes, overall biotope intolerance is assessed as high and there is likely to be a decline in species richness in the biotope. Recoverability is assessed as high (see additional information below).
Heavy metal contamination (see benchmark)	Kaschl & Carballeira (1999) investigated the effect of sediment contamination on *Venerupis senegalensis* (studied as *Venerupis pullastra*) by exposing the species to sediments spiked with copper sulphate. Following placement of clams on the sediment surface, slowing of burial was observed in proportion to the concentration of copper added to the sediment. The effect was detectable at a pore water concentration of 95 µg Cu/l. At the highest copper concentrations (spiking solution concentration >125 mg Cu/l), the majority of clams closed up and did not bury. Spiking of the sediments with copper also resulted in re-emergence between 24 and 120 hours after burial, a behaviour not observed in controls. The proportion of clams re-emerging increased with the copper concentration in the sediment, and was concluded to be an avoidance behaviour. Kaschl & Carballeira (1999) suggested that the delay in burial at low copper concentrations was due to physiological disruption as it did not avoid exposure to the toxin and further increased the risk of predation. At higher concentrations, there was a payoff between toxin avoidance (by valve closure or re-emergence) and predator avoidance. The copper 10 day LC_{50} for *Venerupis senegalensis* was found to be 88 µg/l in sandy sediments (Kaschl & Carballeira, 1999). For reference to polluted UK sediments, copper concentration in the interstitial water of Restronguet Creek sediments has been measured at 100 µg/l (Bryan & Langston, 1992). Eisler (1977) exposed *Mya arenaria* to a mixture of heavy metals in solution at concentrations equivalent to the highest recorded concentrations in interstitial waters in the study area. At 0 °C and 11 °C (winter temperatures) 100% mortality occurred after 4-10 weeks. At 16-22 °C (summer temperatures) 100% mortality occurred after 6-14 days, indicating greater intolerance at higher temperatures. Generally, polychaetes (e.g. Bryan, 1984), gastropods (e.g. Bryan, 1984) and macroalgae (e.g. Strömgren, 1979a,b) are regarded as being tolerant of heavy metal contamination. In light of the high intolerance of bivalves, including the

	important characterizing species, overall biotope intolerance is assessed as high and species richness is expected to decline. Recoverability is recorded as high (see additional information below).
Hydrocarbon contamination (see benchmark)	Oil spills resulting from tanker accidents can cause large-scale deterioration of communities in shallow subtidal sedimentary systems. The majority of benthic species often suffer high mortality, allowing a few tolerant opportunistic species to proliferate. For example, after the *Florida* spill of 1969 in Massachusetts, the entire benthic fauna was eradicated immediately following the spill and populations of the opportunistic polychaete *Capitella capitata* increased to abundances of over 200,000/m² (Sanders, 1978). Suchanek (1993) reviewed the effects of oil on bivalves. Sublethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates have increased at low concentrations and decreased at high concentrations. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates. Mortality following oil spills has been recorded in *Mya arenaria* (Dow, 1978; Johnston, 1984), *Ensis* sp. (SEEC, 1998) and *Cerastoderma edule* (SEEEC, 1998). Suchanek (1993) reported that infaunal polychaetes were also vulnerable to hydrocarbon contamination. For example, high mortality has been demonstrated in *Arenicola marina* (Levell, 1976). However, deposit feeders, such as *Aphelochaeta marioni*, are likely to be less vulnerable due to the feeding tentacles being covered with a heavy secretion of mucus (Suchanek, 1993). As the biotope occurs subtidally, it is likely to avoid the worst impact of an oil spill and therefore the intolerance is recorded as intermediate. Some of the more intolerant species are likely to be eradicated so there may be a minor decline in species richness. Oil has the capacity to persist for a long time in soft sediments and so recoverability is assessed as moderate.
Radionuclide contamination (see benchmark)	Stamouli & Papadapoulou (1990) investigated bioaccumulation of radioactive trivalent Chromium 51 (^{51}Cr) in a *Venerupis* species from Greece. ^{51}Cr is derived from nuclear tests, disposal of radioactive waste and is one of the principal corrosion products of nuclear powered ships. ^{51}Cr was found to rapidly accumulate in *Venerupis* sp., predominantly in the shell, and reached a stable level in 8 days. No mortality was reported after 20 days. Chassaud-Bouchard (1992) reported accumulation of Americium 241, Plutonium 239 and Uranium 238 in *Cerastoderma edule* associated with damage to the nucleus, increased activity of the golgi apparatus and decreased numbers of mitochondria in the cells. The ecological significance of these findings is unclear. No further information was found concerning the uptake of radionuclides by species in the biotope.
Changes in nutrient levels (see benchmark)	Nutrient enrichment can lead to significant shifts in community composition in sedimentary habitats. Typically the community moves towards one dominated by deposit feeders and detritivores, such as polychaete worms (see review by Pearson & Rosenberg, 1978). The biotope includes species tolerant of nutrient enrichment and typical of enriched habitats (e.g. *Tubificoides benedii*) (Pearson & Rosenberg, 1978). It is likely that such species would increase in abundance following nutrient enrichment, with an associated decline in suspension feeding species such as bivalves. No information regarding the specific effects of nutrients on *Venerupis senegalensis*, the important characterizing species, was found. However, increased nutrients are likely to enhance ephemeral algal and phytoplankton growth, increase organic material deposition and enhance bacterial growth. At low levels, an increase in phytoplankton and benthic diatoms may increase food

	availability for *Venerupis senegalensis*, thus enhancing growth and reproductive potential (e.g. Beiras *et al.*, 1993). However, increased levels of nutrient (beyond the carrying capacity of the environment) may result in eutrophication, algal blooms and reductions in oxygen concentrations (e.g. Rosenberg & Loo, 1988). Rosenberg & Loo (1988) reported mass mortalities of *Mya arenaria* and *Cerastoderma edule* following a eutrophication event in Sweden, although no direct causal link was established. It is likely therefore that a dramatic increase in nutrient levels would cause some mortality of *Venerupis senegalensis* and so a biotope intolerance of intermediate is recorded. Recoverability is recorded as high (see additional information below). As explained above, community composition may change but a decline in species richness is not expected.
Increase in salinity (see benchmark)	The biotope occurs in fully saline conditions (Connor *et al.*, 1997a) and therefore is not likely to be intolerant of increases in salinity. No information was found concerning the intolerance of the important characterizing species, *Venerupis senegalensis*, to hypersaline conditions. However, the intolerance to hypersalinity of some other species which occur in the biotope has been researched. For *Cerastoderma edule*, Russell & Peterson (1973) reported an upper median salinity limit of 38.5 psu. Rygg (1970) noted that a population of *Cerastoderma edule* did not survive 23 days exposure at 60 psu, although they did survive at 46 psu. When exposed to hyper-osmotic shock (47 psu), *Arenicola marina* lost weight, but were able to regulate and gain weight within 7-10 days (Zebe & Schiedek, 1996).
Decrease in salinity (see benchmark)	The biotope occurs in variable salinity conditions (Connor *et al.*, 1997a) and therefore the majority of species are unlikely to be intolerant of a reduction in salinity. In assessing biotope intolerance, the most important species to consider is *Venerupis senegalensis*. No information was found concerning the effects of decreasing salinity on the species specifically. However, Lange (1972) reported that the muscle volume of *Venerupis rhomboides*, a stenohaline species, increased as salinity decreased, and hence concluded that the species was unable to regulate its muscle volume. Euryhaline bivalve species, however, e.g. *Mya arenaria*, *Cerastoderma edule*, were able to regulate muscle volume with changing salinity. *Venerupis japonica* displayed a variety of behavioural reactions in response to reduced salinity in the Sea of Japan (Yaroslavtseva & Fedoseeva, 1978). Salinities typically encountered ranged from 11-30 psu over the course of a day. *Venerupis japonica* was active down to 20 psu, below which it reacted with siphon withdrawal and valve closure. Mortality occurred if salinity remained below 14 psu for an extended period. The benchmark includes a change of 2 categories on the salinity scale for a week (see glossary). This would place some of the biotope in a reduced salinity environment (*Venerupis senegalensis* would occur. A biotope intolerance of intermediate is therefore recorded. Recoverability is recorded as high (see additional information below). As mentioned above, some species in the biotope are more tolerant of reduced salinity than others: • *Mya arenaria*, for example, is a euryhaline osmoconformer and has been reported from the west Atlantic coast in salinities of 4 psu (Strasser, 1999). • *Arenicola marina* is unable to tolerate salinities below 24 psu and is excluded from areas influenced by freshwater runoff or input (e.g. the head end of estuaries) (Hayward, 1994). The more intolerant species are unlikely to be able to tolerate salinities below 18 psu so there is expected to be a minor decline in species richness.
Changes in oxygenation (see benchmark)	The fauna in the biotope are all aerobic organisms and are therefore likely to be intolerant in some degree to lack of oxygen. Jorgensen (1980) recorded the effects of low oxygen levels on benthic fauna in a Danish fjord. At dissolved oxygen concentrations of 0.2-1.0 mg/l the bivalves, *Cerastoderma edule* and *Mya*

	arenaria, suffered mortality between 2 and 7 days. Rosenberg *et al.* (1991) reported 100% mortality of *Cerastoderma edule* exposed to 0.5 - 1.0 ml/l oxygen for 43 days and 98% mortality after 32 days. Intertidal and infaunal organisms tend to be more tolerant of anoxia. Zebe & Schiedek (1996) reported that *Arenicola marina* is able to respire anaerobically and survived 72 hrs of anoxia at 16 °C. *Littorina littorea* can endure long periods of oxygen deprivation. The snails can tolerate anoxia by drastically reducing their metabolic rate (down to 20% of normal) (MacDonald & Storey, 1999). At the bench mark level of hypoxia (2 mg/l for 1 week) it is expected that some mortality of the more intolerant species, such as bivalves, would occur and therefore biotope intolerance is assessed as intermediate, with a minor decline in species richness. Recoverability is recorded as high (see additional information below).
Biological Factors	
Introduction of microbial pathogens/parasites (see benchmark)	Navas *et al.* (1992) investigated the parasites of *Venerupis senegalensis* (studied as *Venerupis pullastra*), from a population in south west Spain. The following were recorded: • 36.6% prevalence of *Perkinsus atlanticus*; trophozoites found in the connective tissue of different organs with a very intensive hemocytic response, encysting the parasite and destroying tissue structure. • 96.6% prevalence of ciliates in gills, including *Trichodina* sp. • 11.8% prevalence of turbellarians. • 11.1% prevalence of trematodes. *Perkinsus atlanticus* was also recorded as causing mortality in *Venerupis decussata* and *Venerupis aureus*. Freire-Santos *et al.* (2000) recorded the presence of oocysts of *Cryptosporidium* sp. in *Venerupis senegalensis* (studied as *Venerupis pullastra*) collected from north west Spain and destined for human consumption. Several parasites occur in *Mya arenaria*, e.g. cercaria of *Himasthla leptosoma*, the nemertean parasite *Malacobdella* sp. and the copepod *Myicola metisciensis* may be commensal (Clay, 1966). The protozoan, *Perkinsus* sp. has recently been isolated from *Mya arenaria* in Chesapeake Bay, USA (McLaughlin & Faisal, 2000). *Mya arenaria* is also known to suffer from cancers, disseminated neoplasia and gonadal tumours. Disseminated neoplasia, for example, has been reported to occur in 20% of the population in north eastern United States and Canada, and caused up to 78% mortalities in New England (Brousseau & Baglivo, 1991; Landsberg, 1996). Little information was found regarding microbial infection of polychaetes, although Gibbs (1971) recorded that nearly all of the population of *Aphelochaeta marioni* in Stonehouse Pool, Plymouth Sound, was infected with a sporozoan parasite belonging to the acephaline gregarine genus *Gonospora*, which inhabits the coelom of the host. No evidence was found to suggest that gametogenesis was affected by *Gonospora* infection and there was no apparent reduction in fecundity. The parasite loads of the bivalves discussed above have been proven to cause mortality and therefore a biotope intolerance of intermediate is recorded and there may be a minor decline in species richness in the biotope. Recoverability is recorded as high (see additional information below).
Introduction of non-native species (see benchmark)	No information was found concerning the susceptibility of *Venerupis senegalensis* to invasive species. However, the American hard-shelled clam, *Mercenaria mercenaria*, colonized the niche left by *Mya arenaria* killed after the cold winters of 1947 and 1962/63 in Southampton Water (Eno *et al.*, 1997). The *Mya arenaria* populations had not recovered in this area by 1997 (Eno *et al.*, 1997; Eno *et al.*, 2000). *Mya arenaria* often occurs in the IMX.VsenMtru biotope and therefore *Mercenaria mercenaria* may pose a threat of invasion. Biotope intolerance is therefore recorded as intermediate with a minor decline in species richness. Once

	Mercenaria mercenaria has invaded, displaced bivalve populations may never re-establish and hence recoverability is recorded as very low.
Extraction of key or important characterizing species (see benchmark)	*Venerupis senegalensis* is a very important commercial shellfish in Spain. It is harvested from the wild and raised in aquaculture (Jara-Jara *et al.*, 2000). No information was found concerning the effect of harvesting on wild populations but it can be assumed that high mortality would occur in the intertidal where populations are more accessible to harvesters. The majority of the biotope occurs subtidally where it is less likely to be exploited. An intolerance of intermediate is therefore recorded. Recoverability is recorded as high (see additional information below).
Extraction of important species (see benchmark)	Not relevant

Additional information

Recoverability
The recoverability of the important characterizing species in this biotope, *Venerupis senegalensis*, is the principal factor in assessing the recoverability of the biotope.

- *Venerupis senegalensis* is a long lived, fast growing species that reaches maturity within one year and spawns several times in one season (Johannessen, 1973; Perez Camacho, 1980). No information was found concerning number of gametes produced, but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). The larvae remain in the plankton for up to 30 days (Fish & Fish, 1996) and hence have a high potential for dispersal. Given these life history features, it is expected that *Venerupis senegalensis* would have strong powers of recoverability. However, recoverability will be influenced by pre and post recruitment processes. The species exhibits pronounced year class variability in abundance (Johannessen, 1973b; Perez Camacho, 1980) which suggests that recruitment is patchy and/or post settlement processes are highly variable. Olafsson *et al.* (1994) reviewed the potential effects of pre and post recruitment processes. Recruitment may be limited by predation of the larval stage or inhibition of settlement due to intraspecific density dependent competition. Post settlement processes affecting survivability include predation by epibenthic consumers, physical disturbance of the substratum and density dependent starvation of recent recruits. Hence, for *Venerupis senegalensis*, an annual predictable population recovery is not certain. However, given the life history characteristics discussed above it is expected that recovery would occur within 5 years and therefore recoverability for *Venerupis senegalensis* is assessed as high.
- The infaunal deposit feeding polychaetes, such as *Arenicola marina* and *Aphelochaeta marioni*, have similar recoverability characteristics. Neither species has a pelagic phase in its lifecycle, and dispersal is limited to the slow burrowing of the adults and juveniles. The dispersal and recoverability of *Arenicola marina* have been well studied. Heavy commercial exploitation in Budle Bay in winter 1984 removed 4 million worms in 6 weeks, reducing the population from 40 to <1 per m^2. Recovery occurred within a few months by recolonization from surrounding sediment (Fowler, 1999). However, Cryer *et al*. (1987) reported no recovery for 6 months over summer after mortalities due to bait digging. Beukema (1995) noted that the lugworm stock recovered slowly after mechanical dredging, reaching its original level in at least three years. Fowler (1999) pointed out that recovery may take a long time on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if adjacent populations are available recovery will be rapid. However where the affected population is isolated or severely reduced, recovery may be extended.
- For all the shallow burrowing infauna, an important factor contributing to recoverability may be bedload sediment transport (Emerson & Grant, 1991). It has been demonstrated to account for changes in densities of the clam, *Mya arenaria*, and suggested that it may affect recruitment in other infaunal bivalves and polychaetes (Emerson & Grant, 1991).
- The grazing gastropods in the biotope are likely to have strong powers of recoverability. *Littorina littorea*, for example, is an iteroparous breeder with high fecundity that lives for up to 4 years. Breeding can occur throughout the year. The planktonic larval stage lasts for up to 6 weeks although larvae do tend to remain in waters close to the shore. Recolonization, recruitment and recovery rates

are therefore likely to be high.

- Among the macroalgae in the biotope, recovery rates are likely to vary according to life history characteristics. Fast growing species, such as *Fucus serratus*, are iteroparous, highly fecund and survive and breed for protracted periods over 3-4 years. The eggs are broadcast into the water column allowing a potentially large dispersal distance.

The majority of guilds in the biotope are likely to have high recoverability. In light of this, and particularly the recoverability of the important characterizing species, *Venerupis senegalensis*, recoverability of the biotope as a whole is assessed as high.

Species used to indicate biotope intolerance

To assess the sensitivity of the biotope, the sensitivity of component species is reviewed. Those species that are considered to be particularly indicative of the sensitivity of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors			
	Venerupis senegalensis	***Littorina littorea***	***Arenicola marina***
Community Importance	Important characterizing	Important other	Important other
Substratum Loss	High	High	High
Smothering	Intermediate	High	Not Sensitive
Increase in suspended sediment	Low	Intermediate	Low
Decrease in suspended sediment	Low	See explanation	See explanation
Desiccation	Low	Low	Not Relevant
Increase in emergence regime	Intermediate	Low	Intermediate
Decrease in emergence regime	Not Sensitive	See explanation	See explanation
Increase in water flow rate	Intermediate	Intermediate	Intermediate
Decrease in water flow rate	Not Sensitive	See explanation	See explanation
Increase in temperature	Low	Low	Intermediate
Decrease in temperature	Intermediate	See explanation	See explanation
Increase in turbidity	Low	Low	Low
Decrease in turbidity	Not Sensitive	See explanation	See explanation
Increase in wave exposure	Intermediate	Intermediate	Intermediate
Decrease in wave exposure	Not Sensitive	See explanation	See explanation
Noise	Not Sensitive	Not Sensitive	Not Sensitive
Visual Presence	Not Sensitive	Not Sensitive	Not Sensitive
Abrasion & physical disturbance	Intermediate	Intermediate	Intermediate
Displacement	Intermediate	Not Sensitive	Low
Chemical factors			
	Venerupis senegalensis	***Littorina littorea***	***Arenicola marina***
Community Importance	Important characterizing	Important other	Important other
Synthetic compound contamination	High	Low	High
Heavy metal contamination	High	Intermediate	Low
Hydrocarbon contamination	Intermediate	High	Intermediate
Radionuclide contamination	Insufficient information	Insufficient information	Insufficient information
Changes in nutrient levels	Intermediate	Not Sensitive	Intermediate
Increase in salinity	Not Sensitive	Not Sensitive	Low
Decrease in salinity	Intermediate	See explanation	See explanation
Changes in oxygenation	Intermediate	Low	Low

Biological factors			
	Venerupis senegalensis	*Littorina littorea*	*Arenicola marina*
Community Importance	Important characterizing	Important other	Important other
Introduction of microbial pathogens/parasites	Intermediate	Insufficient information	Insufficient information
Introduction of non-native species	Insufficient information	Insufficient information	Insufficient information
Extraction of this species	Intermediate	Intermediate	Intermediate
Extraction of other species	Intermediate	Not Sensitive	Intermediate

Species used to indicate biotope recoverability

To assess the recoverability of the biotope, the recoverability of component species is reviewed. Those species that are considered to be particularly indicative of the recoverability of the biotope, and for which research has been undertaken in detail are shown below (See Appendix 3).

Physical factors			
	Venerupis senegalensis	*Littorina littorea*	*Arenicola marina*
Community Importance	Important characterizing	Important other	Important other
Substratum Loss	High	High	High
Smothering	High	High	Not Relevant
Increase in suspended sediment	Very high	High	Immediate
Decrease in suspended sediment	Very high	See explanation	See explanation
Desiccation	Very high	Immediate	Not Relevant
Increase in emergence regime	High	Immediate	Very high
Decrease in emergence regime	Not Relevant	See explanation	See explanation
Increase in water flow rate	High	High	Very high
Decrease in water flow rate	Not Relevant	See explanation	See explanation
Increase in temperature	Very high	Immediate	Very high
Decrease in temperature	High	See explanation	See explanation
Increase in turbidity	Very high	Very high	Immediate
Decrease in turbidity	Not Relevant	See explanation	See explanation
Increase in wave exposure	High	High	Very high
Decrease in wave exposure	Not Relevant	See explanation	See explanation
Noise	Not Relevant	Not Relevant	Not Relevant
Visual Presence	Not Relevant	Not Relevant	Not Relevant
Abrasion & physical disturbance	High	High	Very high
Displacement	High	Not Relevant	Immediate
Chemical factors			
	Venerupis senegalensis	*Littorina littorea*	*Arenicola marina*
Community Importance	Important characterizing	Important other	Important other
Synthetic compound contamination	High	Very high	High
Heavy metal contamination	High	High	Very high
Hydrocarbon contamination	High	High	High
Radionuclide contamination	Not Relevant	Insufficient information	Not Relevant
Changes in nutrient levels	High	Not Relevant	High
Increase in salinity	Not Relevant	Not Relevant	Immediate
Decrease in salinity	High	See explanation	See explanation
Changes in oxygenation	High	Very high	Immediate
Biological factors			
	Venerupis senegalensis	*Littorina littorea*	*Arenicola marina*
Community Importance	Important characterizing	Important other	Important other
Introduction of microbial pathogens/parasites	High	Insufficient information	Not Relevant
Introduction of non-native species	Not Relevant	Insufficient information	Not Relevant

Extraction of this species	High	High	Very high
Extraction of other species	High	Not Relevant	Very high

Importance

Marine natural heritage importance

Listed under: **UK Biodiversity Action Plan**
EC Habitats Directive

National importance Scarce

Habitat Directive feature (Annex 1) Large shallow inlets and bays
Estuaries
Lagoons

UK Biodiversity Action Plan habitat Inshore sublittoral sediment (broad habitat statement)
Sheltered muddy gravels
Saline lagoons

Biotope importance

Intertidal and shallow subtidal mud and sand flats are important nursery areas for fish such as plaice, *Pleuronectes platessa*, as well as feeding areas for bass, *Dicentrarchus labrax*, dab, *Limanda limanda*, sole, *Solea solea*, and flounder, *Platichthys flesus*. They feed predominantly on polychaetes, immature bivalves and bivalve siphons (see review by Elliott *et al.*, 1998). The biotope is probably an important feeding area for mobile epifauna, such as shore crabs, *Carcinus maenas* (Feder & Pearson, 1988). Shorebirds predate bivalves (Meire, 1993) but the biotope is probably not accessible for long enough for it to be a very important food source.

Exploitation

Venerupis senegalensis is a very important commercial shellfish in Spain. It is harvested from the wild and raised in aquaculture (Jara-Jara *et al.*, 2000). There is no literature concerning its harvest in the UK. Other species in the biotope which are exploited commercially include *Arenicola marina* (Fowler, 1999), *Cerastoderma edule* (Hall & Harding, 1997), *Ensis ensis* (Fowler, 1999) and *Mya arenaria* (Emerson *et al.*, 1990).

Additional information

No text entered

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