CIRCALITTORAL FAUNAL TURF BIOTOPES

An overview of dynamics and sensitivity characteristics for conservation management of marine SACs

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PREFACE

The 1990s are witnessing a “call to action” for marine biodiversity conservation through wide ranging legislative fora, such as the global Convention on Biodiversity, the European Union’s “Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora” (the Habitats Directive) and more recently in developments to the Oslo and Paris Convention (OSPAR). These landmark legal instruments have in turn provided sufficient scientific rationale, legal mandate and social synergy to rally governments, NGOs, private industry and local communities into a new era of unprecedented conservation action.

Each of these initiatives identifies marine protected areas as having a key role in sustaining marine biodiversity. To manage specific habitats and species effectively there needs to be a relatively clear understanding of their present known distribution, the underpinning biology and ecology and their sensitivity to natural and anthropogenic change. From such a foundation, realistic guidance on management and monitoring can be derived and applied.

The Habitats Directive requires the maintenance and/or restoration of natural habitats and species of European interest at favourable conservation status across their biogeographical range. The designation and management of a network of Special Areas of Conservation (SACs) have a key role to play in this. The specific 'marine' habitats defined in Annex I of the Habitats Directive include:

- Sandbanks which are slightly covered by sea water all the time,
- Estuaries
- Mudflats and sandflats not covered by seawater at low-tide,
- Large shallow inlets and bays
- Lagoons
- Reefs
- Submerged or partly submerged sea caves

These habitats are vast in scope and challenging to quantify in terms of favourable conservation status, so there has been increased attention to 'sub-features' of these habitats which are in effect constituent components and/or key elements of the habitats from a range of biodiversity perspectives.

One initiative now underway to help implement the Habitats Directive is the UK Marine SACs LIFE Project, involving a four year partnership (1996-2001) between English Nature (EN), Scottish Natural Heritage (SNH), the Countryside Council for Wales (CCW), Environment and Heritage Service of the Department of the Environment for Northern Ireland (DOENI), the Joint Nature Conservation Committee (JNCC), and the Scottish Association of Marine Science (SAMS). While the overall project goal is to facilitate the establishment of management schemes for 12 of the candidate SAC sites, a key component of the project assesses the sensitivity characteristics and related conservation requirements of selected sub-features of the Annex I habitats noted above. This understanding will contribute to more effective management of these habitats by guiding the detailed definition of the conservation objectives and monitoring programmes and by identifying those activities that may lead to deterioration or disturbance.

A diverse series of sub-features of the Annex I marine habitats were identified as requiring a scientific review, based on the following criteria:

- key constituent of several candidate SACs;

- important components of Annex I habitats in defining their quality and extent;
- extensive information exists requiring collating and targeting, or there is minimal knowledge needing verification and extended study.

This resulted in the compilation a nine-volume review series, each providing an "Overview of Dynamics and Sensitivity Characteristics for Conservation Management of Marine SACs" for the following sub-features:

Vol.I	Zostera Biotopes
Vol II	Intertidal Sand and Mudflats & Subtidal Mobile Sandbanks
Vol III	Sea Pens and Burrowing Megafauna
Vol.IV	Subtidal Brittlestar Beds
Vol.V	Maerl
Vol.VI	Intertidal Reef Biotopes
Vol.VII	Infralittoral Reef Biotopes with Kelp Species
Vol.VII	ICircalittoral Faunal Turfs
Vol.IX	Biogenic Reefs.

Each report was produced initially by appropriate specialists from the wider scientific community in the respective subject. These reports have been reviewed through an extensive process involving experts from academic and research institutions and the statutory nature conservation bodies.

The results of these reviews are aimed primarily at staff in the statutory nature conservation bodies who are engaged in providing conservation objectives and monitoring advice to the marine SAC management schemes. However these reports will be a valuable resource to other relevant authorities and those involved in the broader network of coastal-marine protected areas. In order to reach out to a wider audience in the UK and Europe, a succinct 'synthesis' document will be prepared as a complement to the detailed 9-volume series. This document will summarise the main points from the individual reviews and expand on linkages between biotopes, habitats and sites and related conservation initiatives.

These reports provide a sound basis on which to make management decisions on marine SACs and also on other related initiatives through the Biodiversity Action Plans and Oslo and Paris Convention and, as a result, they will make a substantial contribution to the conservation of our important marine wildlife. Marine conservation is still in its infancy but, through the practical application of this knowledge in the management and monitoring of features, this understanding will be refined and deepened.

We commend these reports to all concerned with the sustainable use and conservation of our marine and coastal heritage.

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EXECUTIVE SUMMARY

Project context and aims

Some forty marine sites around the UK have been identified as candidate or possible Special Areas of Conservation (SACs) under the terms of the EU Habitats and Species Directive. The regulations require that these sites are managed so as to maintain the favourable conservation status of their natural habitats and species. Twelve of the sites have been selected as demonstration SACs in order to develop and test appropriate management schemes, and to facilitate this the SACs Project has commissioned reviews of selected biotopes. Each review is expected to summarise information relevant to management of the biotope, covering basic ecology, sensitivity to natural and anthropogenic changes, and suitable monitoring programmes for use in the SACs. This report covers ‘Circalittoral Faunal Turfs’ (CFTs), which make up important biotope complexes within two Annex I habitats - ‘Reefs’ and ‘Submerged or partly submerged sea caves’.

Nature and importance of CFT biotopes

Faunal turfs are animal-dominated communities of hard substrata, where most of the prominent species live attached to the substratum. Constituent species range in form from tall erect sea fans and soft corals to low encrusting sponges and bryozoans. The circalittoral region is that area of the sublittoral zone lying beneath the depth where there is enough light to support profuse and usually dominating macroalgal growth - typically below 10 to 20 m. CFT communities are both diverse and species-rich - the MNCR biotope classification lists over 50 biotopes which are regarded as CFTs within the broad definition used for this review.

CFTs are important within the context of the SACs project. They are very diverse, are of considerable aesthetic appeal, and occur abundantly within two of the EC Habitats Directive Annex I habitats - ‘Reefs’ and ‘Submerged or partly submerged sea caves’. CFTs are important within seven of the twelve demonstration SACs. In three of the seven selection was in part based on the importance of reefs as an Annex I feature - Papa Stour, Berwickshire and North Northumberland Coast, and Lleyn Peninsula and the Sarnau. In four others CFTs make up a significant component - Loch Maddy, Sound of Arisaig, Strangford Lough, and Plymouth Sound and Estuaries.

Environmental factors and the distribution of CFTs

A number of environmental factors influence the distribution of CFT biotopes, often interacting so that individual effects are difficult to discriminate. Seawater temperature is the major factor controlling geographical distribution: there are cold water and warm water CFT species and biotopes with restricted distributions to the north and south of Britain respectively. Limited geographical distribution is an important index of conservation interest.

The depth range of CFTs is determined by the interaction of light availability, water turbidity and substratum slope. The upper limit of CFTs occurs where the available light becomes insufficient for macroalgae to dominate the community, and light becomes less with greater depth, higher turbidity, and increasing slope. In caves or under overhangs, or in very turbid waters, CFTs may occur at depths of only a few metres. In contrast, on gently sloping substrata in clear oceanic water the upper limit may be at 20 m or greater. The lower limit is set only by the availability of hard substratum.

The factors exerting the main influence on the type of CFT community found locally are amount of water movement, prevalence of scour, amount of suspended material, and reduction or variation of salinity - in that order of importance.

Biology and ecological functioning

Most of the prominent CFT species are sessile filter feeders, either fixed permanently in one place like barnacles or corals, or like anemones capable of only very limited movement. This sessile habit prevents dislodgement by strong water movement, but makes them dependent upon currents to bring a supply of suspended food. The main sessile taxa are sponges, coelenterates, serpulids, bryozoans and tunicates. There are also large mobile species - echinoderms, decapod crustaceans and fish - which feed as grazers, scavengers and carnivores. Finally there is a diverse mobile cryptofauna which does not feature in standard visual surveys.

Biological interactions are little studied in British CFT biotopes, but may play important structuring roles. Sessile species compete for space, and 'disturbance' is a necessary process to maintain diversity in the face of potential dominance. The role of 'keystone' grazers and carnivores in this respect needs further study. Many CFT species are slow growing and long lived, which contributes to community stability, but makes recovery from severe impact a slow process. Other species are short lived, causing some biotopes to show marked annual and year to year fluctuations. Levels of natural community change need to be evaluated further as a matter of urgency. Most CFT species have pelagic larvae, facilitating dispersal and recolonisation: species lacking such dispersal ability are at greater risk.

CFT biotopes are generally abundant, but there are those which are less prevalent and thus of considerable conservation importance. There are some with limited geographic spread within the UK, either restricted to the far north or to the south-west. Biotopes in extreme shelter, and subject to variable or reduced salinity, are both scarce in UK Management plans for SACs should cover species of 'special interest', which should include those on the Biodiversity Action Plan list, and those selected using a list of interest criteria.

Sensitivity to natural events

Global warming may affect species with limited distributions, particularly those limited to the far north. Associated sea level changes are unlikely to have much impact. There is no evidence of storm damage to CFT communities, which are protected by their depth. Natural fluctuations in abundance of grazers and predators could affect community balance, and need more study.

Sensitivity to human activities

Oil pollution is largely a surface phenomenon, and is not considered a serious risk to CFT biotopes. Organic based effluents such as sewage, or intensive fish farming, could certainly be a threat in more enclosed situations, and any new or changed inputs of such type would need careful evaluation. The same considerations would apply to any other effluents originating from a point source which might contain heavy metals, pesticides, PCBs, or other potential toxins.

The increasing eutrophication of British waters poses a real threat, and Scandinavian experience has shown that neither depth nor wave exposure necessarily protects CFT biotopes. Effects of eutrophication will include reduced water transparency, affecting light transmission and algal growth, and the toxic effects and deoxygenation induced by algal blooms.

The indirect effects of fishing can be damaging. Towed gear is a major threat, both by direct impact, and by re-suspending sediment. Potting is thought to be a lesser risk on the basis of current experience, but long term risks need to be assessed. However, it will damage brittle species which may be important keystone habitat providers. The direct effect of potting is to reduce numbers of the target species - crayfish, crabs and lobsters. These are of high aesthetic 'interest' value, and have a suspected role in maintaining diversity.

Commercial diving, which normally targets sensitive species, has no place in CFTs. Recreational diving, when carried out at current levels following present codes of practice, poses little risk. The same applies to recreational angling. However, in both cases the incidental damage from anchoring, and excessive concentrations of activity, are matters of possible concern.

Monitoring and surveillance options

The aims of monitoring are to detect real change in CFT communities, to determine whether this is natural or the result of human activities (surveillance monitoring), and if the latter to provide feedback to the management process (compliance monitoring). The limitations on achieving these aims for CFTs are the dearth of information on natural change, and the limitations of the methods suitable for their monitoring.

Remote techniques for CFT monitoring are largely unsuitable, untried or unrealistically expensive, though there is potential in the use of ROVs. However, for the immediate future monitoring will be conducted predominantly by divers operating *in situ*. This imposes constraints in terms of operating depth and bottom time, which will become more limiting when sites are more exposed, more remote, or as is often the case, both. The effective depth limit is 40 m in favourable situations, and work time will be limited. The logistics of diving must be considered at the earliest stages of planning monitoring programmes.

Two monitoring procedures are recommended for CFT biotopes. The first is visual recording of prominent species using check lists and abundance scales (ACE surveys). This is subject to operator error, and is not capable of statistic analysis. However, with training it is reliable, can assess rare as well as common species, and a change of more than one abundance grade can be accepted as 'real'. The second method is photographic recording of fixed quadrats. This can reliably discriminate smaller changes in abundance, though interpretation presents problems. It also generates data on growth rates, longevity, mortality and recruitment.

Initially these programmes will serve primarily to provide needed research data. Their surveillance and compliance roles will be refined with the feedback of these data. There will be substantial benefits is comparable programmes are carried out in different SACs, particularly those within a geographical region.

Gaps in knowledge

Although we acknowledge the importance of environmental factors in determining the distribution of CFT communities, there is limited quantitative information on any variables other than light intensity. Self-contained instrumentation for the logging of variable is now becoming available at reasonable cost. Perhaps the greatest need is for better understanding of natural variation in CFT communities: this is central to detecting anthropogenic changes, and to setting compliance standards.

Much of the evidence for levels of anthropogenic damage is anecdotal. or based on limited experimental or observational work. The following risks need to be evaluated more fully: the long term effects of potting activity, in terms of direct damage, and the impact of removing target species; impacts resulting from recreational diving; risks of siltation due to dredging and trawling, spoil dumping or coastal development; effects of eutrophication.

Improved methods for working on CFTs are needed. Improvements in diving technology, and the potential transfer of methods from the commercial to the scientific field, need to be kept under review. Diver time can be maximised by better ‘tools’ for location, manipulation and recording. Finally the use of non-diving technologies, notably ROVs, must be investigated further.

Application to SAC management

The information in this review contributes particularly to two aspects of site management. Firstly procedures to monitor status, and to reveal changes outside natural variation. Secondly control measures which can influence the impact of human activities within SACs.

Recommended monitoring procedures are outlined above, emphasising the limitations imposed by the need to use diving as the primary method. Problems arise from the lack of information on natural change, and consequently use in the compliance mode will be initially restricted.

There are some human impacts which can not be controlled by any SAC management plan - global warming and eutrophication are the prime examples. Nevertheless such impacts need to be identified to exclude other causes. Other human impacts can, where necessary, be limited by appropriate regulation. Effluent release, and the use of towed gear, must be tightly controlled within or near SACs. Potting should be held to current levels, and experimental exclusion zones established. Levels of sports diving and angling should be monitored, limited if necessary, and codes of practice initiated.

I
INTRODUCTION

A. PROJECT CONTENT AND STUDY AIMS

Subtidal hard substrata in temperate waters resemble coral reefs in the tropical marine realm in that they support the highest diversity of marine organisms for these regions - organisms which for the most part require attachment to a hard surface. Algal dominated communities typify the shallower infralittoral zone, typically down to ten or twenty metres, whilst the deeper circalittoral zone is largely animal dominated. It is the latter group of organisms - 'circalittoral faunal turfs' (CFTs) - which provides the focus of this particular volume of the UK Marine SAC Project's activity on reviewing sensitivity for selected biotope complexes.

CFTs were chosen as a target group for Task 1.1 study because they:

- have high biodiversity;
- comprise a major portion of the UK nearshore hard-substratum habitat;
- are vulnerable to some natural and anthropogenic impacts; and
- have been poorly studied until recently, and though recent developments in diving and submersible technology have widened understanding, there is still an urgent need to bring existing information to the forefront of applied science and the marine conservation arena.

The audience for this report is typically marine resource managers working at a site level. Therefore, this report summarises existing knowledge on CFTs with particular emphasis on achieving a greater understanding of the ecological dynamics and sensitivity of this biotope complex, through the following:
a) examining the fundamental environmental, physical, biological and ecological features of CFTs;
b) assessing CFT sensitivity to natural phenomena and anthropogenic impacts; and
c) exploring options for monitoring and information-research gaps that are relevant to the management of CFT communities in marine SAC areas.

B. NATURE AND IMPORTANCE OF CIRCALITTORAL FAUNAL TURFS (CFTs)

1. What are CFTs?

'Faunal turfs' are basically assemblages of attached animals growing on hard substrata. These organisms can vary substantially in growth form, 'turf' being used in a highly generic sense. So they will range from low encrusting forms less than a centimetre high, such as many ectoprocts (sea mats) and sponges, to tall erect forms such as alcyonarians (soft corals) and gorgonians (sea fans) which may exceed 25 cm in height. The CFT community will also include prominent mobile organisms associated with the attached fauna such as decapod crustaceans, echinoderms, molluscs and fish, which may play important structuring roles in the community. Also included are a diverse but cryptic assemblage of small mobile organisms such as isopods, amphipods, nemerteans and polychaetes. Although by definition CFT communities are animal dominated, there will be algae present. In the upper regions of the circalittoral there will be foliose red algae. Deeper these will disappear, but crustose reds such as the calcified lithothamnia and non-calcified *Cruoria* will persist for some distance. Some general features of circalittoral communities have been pointed out by Sebens (1985a) which contrast them with intertidal ones. Zonation is very much broadened, with 'zones' extending for ten metres or more in depth. Space is less frequently monopolised by single dominant species. Physical disturbance, creating large areas of 'bare' space, is much less common, but nevertheless species diversity is generally high.

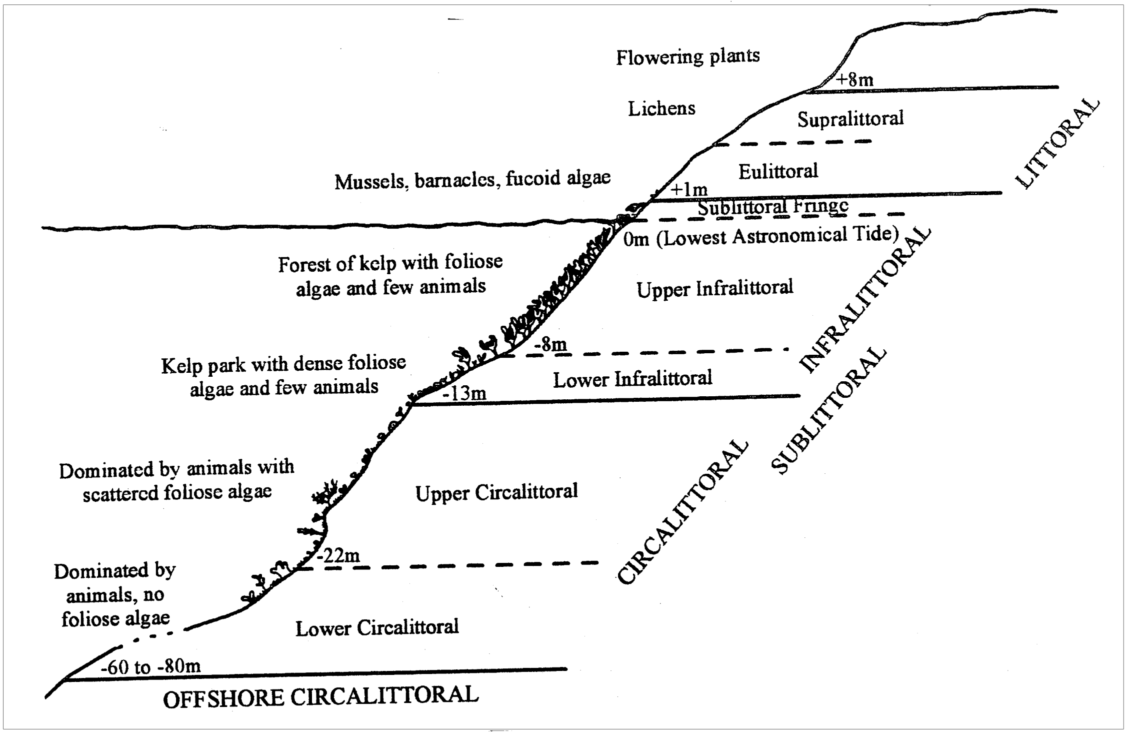

Figure 1. Profile of rocky shore and seabed to show the biological zones; depths are typical values for south-west Britain (after Connor et al., 1997, modified from Hiscock *ed.* 1996).

'Circalittoral' is generally taken as those depths where the light intensity is reduced to a level where it will no longer support substantial algal growth. Thus the normal sublittoral progression with increasing depth will be from the algal-dominated infralittoral biotopes to the animal-dominated circalittoral biotopes, and there will be a zone where the two merge (Figure 1). However, as will be elaborated in section II, depth is not the sole factor determining light availability - the slope of the substratum is also important. So on overhangs, and especially in caves, 'circalittoral' communities occur in depths where algae would normally be expected to dominate. Grazing activities can also mediate the outcome of animal-plant interactions and limit plant dominance. There is no formal lower limit to the circalittoral, and it will extend well below the depths encountered in any of the candidate SACs.

2. The importance of CFTs

The brief outline above may leave the impression that CFTs are a complex of biotopes, not easily accessible, and of limited interest other than in a scientific context. Fifty years ago this impression might have been true, but not any longer. The major factor in changing our perception of CFT communities has been the development of scientific and sports diving over the intervening period. Amateur diving is still growing in popularity, and its capabilities are being continually extended by technological developments. The proliferation of RIBs (rigid inflatable boats) has provided greater mobility and seagoing capability, bringing more inaccessible areas within easier reach. Advances in suit technology, the introduction of nitrox and mixed gas diving to the amateur and scientific field, and the development of rebreathing systems, have all enabled longer and deeper dives to be safely accomplished. The circalittoral is increasingly being brought to the divers' doorstep.

Consequently increasing numbers of divers are attracted to the CFT biotopes, because this is **the** most scenic and spectacular of the underwater environments. The rock faces covered with a diversity of multicoloured animal life are in sharp contrast to the relatively drab algal cover of the infralittoral, and the temperate circalittoral can indeed rival the tropical reefs in spectacle, if not in diversity. So concern for CFTs is an important component of the SAC project, because although CFTs are quite widespread, high quality accessible CFT areas are not. Such areas will be subject to very heavy diving (and other) pressure, and can degrade under such pressure. Management strategies will be required. In addition to this aesthetic appeal, CFTs have a high scientific interest because of their biodiversity, and the complex biological interactions within their communities (currently far from fully understood). They also support shellfisheries of considerable economic importance.

3. Classification strategies for CFTs

The highly diverse nature of CFTs has made definitive classification of CFTs into various schemes a challenge - there are two approaches to the classification of CFT communities. The commonest approach is based upon a heirarchical division according to environmental variables, the approach which has culminated in the MNCR biotope classification. The highest ranked variable under this scheme is degree of exposure to water movement, and lower rank variables include slope and scour. This approach will of necessity be somewhat subjective, though in compiling the classification the MNCR did include multivariate techniques. However, the outcome is readily understood, and is usable in the field.

An alternative approach is to be strictly objective, and to analyse a range of populations by multivariate methods, without preconceptions, to see what groupings emerge. This approach has been adopted for Scottish hard-substratum communities (Kluiver, 1993). This resulted in a clear separation of communities between the photic and aphotic zones - as might be expected. The communities of the aphotic (circalittoral) zone grouped into eight clusters, which generally correlated with different depths and angles of slope. This analysis used a quite restricted dataset of 60 stations.

It must be remembered that any attempt to classify communities within the circalittoral (or indeed any other such environmental division) means attempting to divide up what is essentially a continuum. For convenience and descriptive purposes it must be done, but it involves describing rather arbitrary 'typical' communities. Intermediate stages between all of the described communities will invariably be found as well. There are three ‘classification schemes’ which relate to CFT biotopes.

a. EU Habitats directive

The UK Marine SACs project has been developed largely in response to the EC Habitats Directive, so how relevant are CFT biotopes to the Annex I Features (Habitats) of the Directive? Two of the listed habitat features are 'reefs' and 'sea caves', and both of these are potential habitats for CFTs..

b. UK Biodiversity Action Plan

CFTs additionally have importance in relation to the UK Biodiversity Action Plan. In the 'Broad Habitat' listing they fall within the very broad category of 'Offshore Sea Beds'. A number of the species listed under the Biodiversity Action Plan are prominent members of the CFT community - e.g. *Strongylocentrotus droebachiensis,* the northern sea urchin; *Alcyonium glomeratum,* the red sea finger; *Leptosammia pruvoti,* the sunset star coral; *Eunicella verrucosa* -the pink sea fan. These, and other species on the Biodiversity Action Plan list will be discussed in detail in section III.E.

c. MNCR biotope classification

The MNCR biotopes classification provides a framework within which CFT communities can be placed. Circalittoral Faunal Turfs can be directly equated with the majority of the 'circalittoral rock' biotopes listed in the MNCR biotopes classification (Connor et al., 1997). This classification divides the biotopes into those characteristic of exposed, moderately exposed and sheltered circalittoral rock, which comprise 12, 26 and 13 biotopes respectively. These are listed in Appendix 1. 'Faunal turf' is interpreted broadly in the present context, and both faunal turf and faunal crust biotopes in the MNCR classification are considered to fall within the remit - they share the same environments, and it would be pointless to separate them. The only MNCR circalittoral rock biotopes which are not discussed here as CFT biotopes are those which are dealt with elsewhere under the SAC Project. These are biogenic reefs, such as dense *Modiolus* (horse mussels) growing on mixed substrata, and brittlestar beds. For management purposes the reviews on Biogenic Reefs and Brittlestar Beds must be considered in conjunction with this review for any SACs containing circalittoral rock, since they may occur in a mosaic pattern with the typical CFT communities. Following major perturbations, such as toxic algal blooms, CFT communities may be temporarily replaced by mussel-dominated communities (Lundälv, 1990). Excluded Circalittoral Rock biotopes (8 in all) are indicated by asterisks in Appendix 1. Within the biotope classification there is a Circalittoral Offshore Rock division which contains only one biotope - *Lophelia* reefs. These deep sea corals will not be found within the limits of any proposed Marine SACs, and in any case are biogenic reefs rather than faunal turfs. Figure 2 provides a quick reference as to which CFT biotopes are most likely to be found under various environmental conditions.

This classification into biotopes is temptingly definitive, but the following cautionary comment in Connor et al. (1997) should be kept in mind. "It is typical for the community not to be dominated by single species, as is common in shore and infralittoral habitats, but rather comprise a mosaic of species. This, coupled with the range of influencing factors, makes circalittoral rock a difficult area to satisfactorily classify; particular care should therefore be taken in matching species and habitat data to the classification." However, since most survey data have been collected by reference to the MNCR biotope scheme, and the JNCC MNCR database hold records in this form, the scheme must constitute an essential component of SAC management protocols.

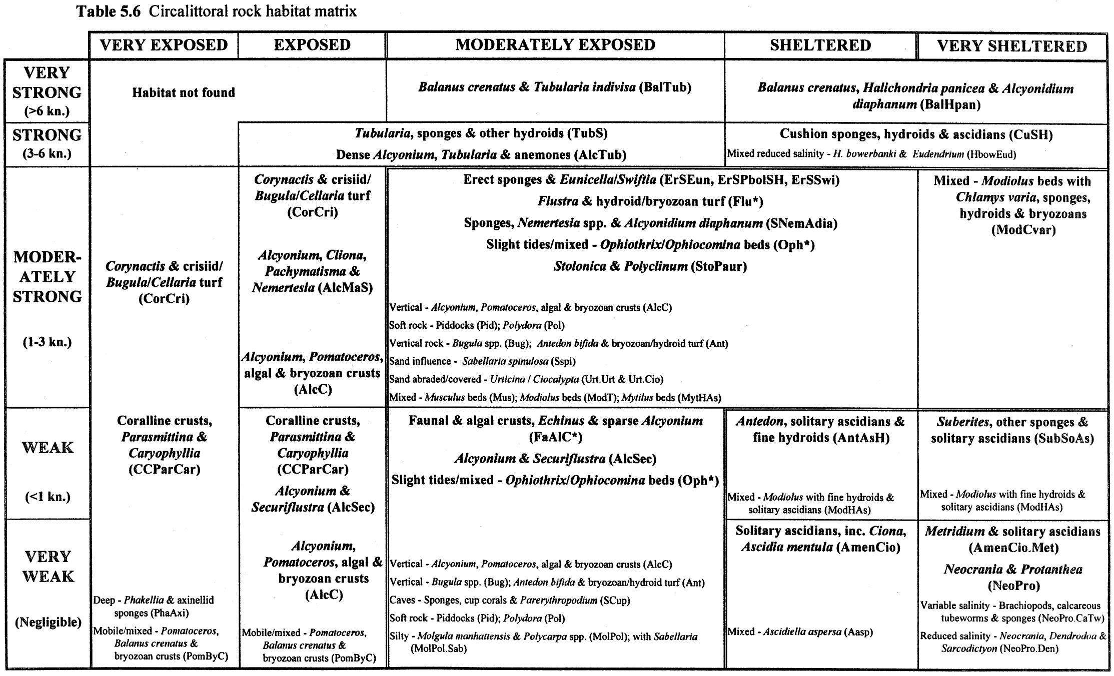

Table 5.6 Circalittoral rock habitat matrix

	VERY EXPOSED	EXPOSED	MODERATELY EXPOSED	SHELTERED	VERY SHELTERED
VERY STRONG (>6 kn.)	Habitat not found		*Balanus crenatus* & *Tubularia indivisa* (BalTub)	*Balanus crenatus*, *Halichondria panicea* & *Alcyonidium diaphanum* (BalHpan)	
STRONG (3-6 kn.)		*Tubularia*, sponges & other hydroids (TubS) Dense *Alcyonium*, *Tubularia* & anemones (AlcTub)		Cushion sponges, hydroids & ascidians (CuSH) Mixed reduced salinity - *H. bowerbanki* & *Eudendrium* (HbowEud)	
MODER-ATELY STRONG (1-3 kn.)	*Corynactis* & crisiid/ *Bugula*/*Cellaria* turf (CorCri)	*Corynactis* & crisiid/ *Bugula*/*Cellaria* turf (CorCri) *Alcyonium*, *Cliona*, *Pachymatisma* & *Nemertesia* (AlcMaS) *Alcyonium*, *Pomatoceros*, algal & bryozoan crusts (AlcC)	Erect sponges & *Eunicella*/*Swiftia* (ErSEun, ErSPbolSH, ErSSwi) *Flustra* & hydroid/bryozoan turf (Flu*) Sponges, *Nemertesia* spp. & *Alcyonidium diaphanum* (SNemAdia) Slight tides/mixed - *Ophiothrix*/*Ophiocomina* beds (Oph*) *Stolonica* & *Polyclinum* (StoPaur) Vertical - *Alcyonium*, *Pomatoceros*, algal & bryozoan crusts (AlcC) Soft rock - Piddocks (Pid); *Polydora* (Pol) Vertical rock - *Bugula* spp. (Bug); *Antedon bifida* & bryozoan/hydroid turf (Ant) Sand influence - *Sabellaria spinulosa* (Sspi) Sand abraded/covered - *Urticina* / *Ciocalypta* (Urt.Urt & Urt.Cio) Mixed - *Musculus* beds (Mus); *Modiolus* beds (ModT); *Mytilus* beds (MytHAs)		Mixed - *Modiolus* beds with *Chlamys varia*, sponges, hydroids & bryozoans (ModCvar)
WEAK (<1 kn.)	Coralline crusts, *Parasmittina* & *Caryophyllia* (CCParCar)	Coralline crusts, *Parasmittina* & *Caryophyllia* (CCParCar) *Alcyonium* & *Securiflustra* (AlcSec)	Faunal & algal crusts, *Echinus* & sparse *Alcyonium* (FaAlC*) *Alcyonium* & *Securiflustra* (AlcSec) Slight tides/mixed - *Ophiothrix*/*Ophiocomina* beds (Oph*)	*Antedon*, solitary ascidians & fine hydroids (AntAsH) Mixed - *Modiolus* with fine hydroids & solitary ascidians (ModHAs)	*Suberites*, other sponges & solitary ascidians (SubSoAs) Mixed - *Modiolus* with fine hydroids & solitary ascidians (ModHAs)
VERY WEAK (Negligible)	Deep - *Phakellia* & axinellid sponges (PhaAxi) Mobile/mixed - *Pomatoceros*, *Balanus crenatus* & bryozoan crusts (PomByC)	*Alcyonium*, *Pomatoceros*, algal & bryozoan crusts (AlcC) Mobile/mixed - *Pomatoceros*, *Balanus crenatus* & bryozoan crusts (PomByC)	Vertical - *Alcyonium*, *Pomatoceros*, algal & bryozoan crusts (AlcC) Vertical - *Bugula* spp. (Bug); *Antedon bifida* & bryozoan/hydroid turf (Ant) Caves - Sponges, cup corals & *Parerythropodium* (SCup) Soft rock - Piddocks (Pid); *Polydora* (Pol) Silty - *Molgula manhattensis* & *Polycarpa* spp. (MolPol); with *Sabellaria* (MolPol.Sab)	Solitary ascidians, inc. *Ciona*, *Ascidia mentula* (AmenCio) Mixed - *Ascidiella aspersa* (Aasp)	*Metridium* & solitary ascidians (AmenCio.Met) *Neocrania* & *Protanthea* (NeoPro) Variable salinity - Brachiopods, calcareous tubeworms & sponges (NeoPro.CaTw) Reduced salinity - *Neocrania*, *Dendrodoa* & *Sarcodictyon* (NeoPro.Den)

Figure 2. Matrix of circalittoral rock biotopes, ordered according to current speed on the vertical axis and wave exposure on the horizontal axis (from Connor et al., 1997).

There are also a number of faunal-dominated communities in shallower water described under the Infralittoral Rock category, generally on verticals, in gullies, or in conditions of strong exposure. These have a basic affinity with CFTs, and are also listed in Appendix 1.

C. DISTRIBUTION OF CFTs

1. Global and European perspectives

CFT communities occur world-wide, and have much in common in that a major component of the fauna is comprised of coelenterates. In the tropics CFTs on rock substrata are uncommon, because the original rock surface, at least down to a depth of over 60 metres, is generally covered with stony scleractinian corals. Nevertheless the other components of the community - sponges, hydroids, anemones, soft coral, fan corals, serpulids, bryozoans and tunicates - are similar to those found in temperate CFTs.

In temperate regions the hard scleractinian corals are reduced to a very minor role, consisting mainly of small solitary polyps (nevertheless still of considerable conservation and biodiversity interest). The rest of the fauna, with the abundance of soft corals, makes it an analogy of a tropical reef community. The deep sea *Lophelia* reefs provide the only real temperate equivalent of a coral reef. CFTs occur throughout Europe in abundance. They are important in the Mediterranean, and equally so in Scandinavia where there are very well developed deep sheltered reefs in the fjords.

2. Distribution within SAC sites

CFT communities will be found in those SAC sites wherever rock substratum extends substantially below ELWS, and will be best developed where the rock extends to well below the depths supporting profuse algal growth (10 m or more). The more striking CFT communities typically occur where wave action and/or tidal currents generate substantial (though not excessively vigorous) water movement (see section II.D). Nevertheless there are very sheltered situations where rich and diverse CFT communities can occur, given the absence of sedimentation, and these less-typical communities are often of considerable conservation interest. Thus a general knowledge of the marine topography will indicate where CFTs are likely to occur. The rocky coastlines of Papa Stour or the Llyn Peninsula will provide widespread opportunities, whilst the Solway Firth or Morecambe Bay have limited potential as CFT sites. However, where candidate SAC sites contain small areas of CFT communities amongst predominantly different biotopes, then these small areas can, if of adequate quality, provide particularly valuable resources which may well come under substantial pressure. Where appropriate they should be highlighted, and managed suitably.

Figure 3 shows the locations of the ‘candidate’ and ‘possible’ marine SAC sites - those with important CFT biotopes are shown in Figure 5. The twelve demonstration Marine SAC sites are shown in Figure 4, where they are divided into three categories according to the status of their CFT biotopes.
‘Reefs’ listed as an Annex I habitat feature for site selection, CFTs a major feature.
CFTs present in quantity, but not a selection feature.
CFTs absent, or present to only a minor extent.
The occurrence of CFTs in each of the demonstration SACs, grouped according to these three categories, is outlined below.

a. SACs in which CFTs are a feature for site selection

<u>i. Papa Stour</u>

This was selected for candidate SAC status because of the excellence of two Annex I habitats within the area, reefs and sea caves.

To quote from the supporting SNH documentation: "The coast and inshore waters of Papa Stour comprise a rugged stretch of some of the most exposed rocky reefs and some of the finest examples of sea caves to be found in the U.K......The numerous and extensive caves, which have rich faunal turfs on their walls, are the best examples of their type in Shetland and **are among the most extensive of such systems in the British**.....The rocky coastline of
Papa Stour is amongst the most exposed in Britain and both Papa Stour and the adjacent mainland are fringed entirely by bedrock and boulder reefs which reach depths beyond 30 m. This rocky underwater terrain is rugged, with rock walls, slopes, gullies, ledges, ridges and boulder slopes which provide a range of reef habitats for a variety of plant and animal communities....... Communities on circalittoral rock are characteristic of this area, with the dominant species including the soft coral *Alcyonium digitatum*, the feather star *Antedon bifida*, encrusting coralline algae and the serpulid *Pomatoceros triqueter*. Wave exposed gullies have rich, surge-tolerant communities with turfs of the jewel anemone *Corynactis viridis*, ascidians and bryozoans. In the strong tidal streams of the Sound of Papa, boulder reefs and bedrock ridges are dominated by scour-tolerant organisms such as the hydroid *Abietinaria abietina* and the brittlestar *Ophiocomina nigra*."

Accounts of the subtidal biotopes of Papa Stour are contained in Hiscock (1986), Howson (1988) and Moss & Ackers (1987). In terms of the density and variety of CFT biotopes Papa Stour is clearly a site of importance.

ii. Berwickshire and North Northumberland Coast

The SNH recommendation states : "The shore and inshore waters from St Abbs Head to Alnmouth, including the Farne Islands, comprise a site of unusually high marine habitat diversity which is of international importance under Annex I. It is recommended for its complex of extensive and diverse reef habitats, littoral and submerged sea caves and range of littoral mudflats and sandflats with rich infaunal communities."

The area is also biogeographically interesting. "A sizeable proportion of the marine species recorded in the area are characteristic of cold water influences from the sub-arctic, or are Atlantic species which are only rarely found on the North Sea coast. Several reach their southern or eastern limits of distribution within the area. There are also good examples present of representative North Sea marine communities characteristic of the wide range of habitats found."

Reefs are a major element of the recommendation, as is clear from the following. "The diversity of the reef habitats in this site is particularly high for the North Sea. These habitats include areas of limestone, an unusual marine habitat in Britain, sandstone, millstone grit and volcanic outcrops which descend steeply into deep water around the Farnes and St. Abbs Head. Sublittoral bedrock extends upwards into the littoral, providing a variety of terraces, overhangs, ridges and gullies, ideal habitats for diverse reef communities including populations of commercially-important crustaceans, some rock-boring fauna and extensive kelp forests. Reef habitats extend to the seaward boundary in many areas including the entire length of the Scottish sector. Along this stretch of coast, from Fast Castle to the border north of Berwick, inshore bedrock reefs are the dominant habitat type grading to boulder and cobble and then cobble towards the seaward boundary. Sublittoral sediments are restricted to small patches in this area whilst the entire coastline is rocky apart from sandy beaches at Coldingham and Eyemouth. From Burnmouth south to the border, these inshore sublittoral reefs are primarily rock platforms whilst north of here the seabed is more broken. The sublittoral cobble, pebble and gravel reefs swept by tidal currents support communities of high nature conservation importance, including many northern species.”

“St. Abbs Head is a major headland on the North Sea coast and has a variety of rock types surrounded by deep clear water. Habitats are predominantly rocky and include sublittoral reefs with gullies, cliffs, platforms, boulders and caves which extend upwards into the littoral zone as platforms, ridges and gullies. These habitats have a marked northern component to their fauna and flora apparent in the presence of species such as the hydroid *Thuiaria thuja*, the anemone *Bolocera tuediae* and the wolf fish *Anarichas lupus*, all of which are uncommon on the west coast of Scotland but frequent in the Shetland Islands. The headland supports one of the most important seabird colonies on the east coast of Scotland.”

“The Farne Islands (over 20 small islands and rocky outcrops) are the only rocky island complex in the North Sea south of Orkney and Norway. As well as a wide range of littoral and sublittoral reefs with surge gullies, cliffs, tunnels and dense kelp forests, they have large grey seal and seabird breeding populations."

"Within the Scottish sector of this site, the extensive reef habitats around the major headland of St. Abbs Head southwards to Eyemouth are considered to be of particular interest. The relatively deep clear water and strong tidal streams produce a diverse range of habitats and associated communities **which are the best examples of their kind in the North Sea**."

Its importance in terms of density and range of CFT biotopes is very clear, as is biogeographical importance. There is extensive information available on the sublittoral environment (Earll, 1981,1982; Edwards, 1983; Kluijver, 1993; Mathers et al., 1978; Pagett, 1983).

iii. Llyn Peninsula and the Sarnau

This was selected for SAC status partly on the basis of its reefs, "for which this is considered to be **one of the best areas in the United Kingdom**" (CCW recommendation documentation). The following account presents the relevant parts of the CCW 'Description of marine interest'.

"The diversity of reefs around and offshore of the LLyn Peninsula and Bardsey Island provide a wide range of habitats that reflect the varied aspects and exposure to water movement, substratum and topographical features of the coastline. The varied habitats in areas of bedrock, boulders, cobble, sandy rock, surge gullies and the tideswept areas of Bardsey Sound support a diverse array of plant and animal communities. There are distinctive communities on bedrock and boulders from sites exposed to very strong wave action and/or tidal streams, to sites sheltered from strong water movement."

"The Sarnau (Sarn Badrig, Sarn-y-Bwlch and Cynfelyn Patches) are very unusual shallow subtidal reefs which extend into Cardigan Bay from the coast. .... Fast tidal currents and strong wave action have a profound influence on the marine communities occurring on the Sarnau, and the reefs as a whole are characterised by a large number of species resistant to scour and sand cover. Algal communities are dominant over much of the reef........ Rich animal populations are found in the slightly deeper parts of the reefs, with a wide variety of animal species present in some locations including crustaceans, coelenterates, sponges, hydroids, and encrusting bryozoans."

"There is an extremely well developed cave system around the St Tudwal's Islands that includes both littoral and sublittoral components and contains habitats of high conservation interest and unusual species communities. There is also a completely submerged cave at Pen-y-cil which penetrates from west to east through the headland."

A site of importance for CFT biotopes which clearly provides a wide diversity of environments. Accounts of the sublittoral environment are given by Hiscock (1984, 1986).

b. SACs in which CFTs are present in quantity

i. Loch Maddy

Loch Maddy is recommended as a candidate SAC by reason of the very well developed system of saline lagoons. These are predominantly shallow and mostly soft bottomed, though limited CFTs are present. However there are more extensive circalittoral rock environments in the entrance to the Loch.

To quote from the SNH recommendation: "Reefs are restricted to the littoral zone and shallow water in the shelter of the lochs, although bedrock and boulders extend to depths of around 30 m in the more exposed entrance areas."

"There is little circalittoral rock other than in the entrance areas where there are rich animal communities with species such as the sea fan *Swiftia pallida* and the colonial ascidian *Diazona violacea* present, a few sheltered boulder slopes further into the lochs with solitary ascidians such as *Ascidia mentula* and very sheltered shallow bedrock outcrops and boulders on soft mud in the inner basins with unusual combinations of anemones including *Sagartiogeton laceratus* and *Cereus pedunculatus* and algae. Particularly unusual are communities of very tall laminarians with diverse epiphytes, including large colonies of the sponges *Grantia compressa* and *Halichondria panicea*, and an abundance of ascidians, particularly *Ascidiella scabra*, and the feather star *Antedon bifida* on scoured shallow bedrock in inner Loch Maddy. These are the most extensive and best developed examples of such communities known in Scotland."

"The boundary encloses the entire marine part of the Loch Maddy system, with the eastern boundary running from Weaver's Point on the northern side of the entrance to Rubha nam Pl`eac on the southern side. This includes examples of the moderately exposed bedrock communities of the entrance area which are a feature of sealoch entrances on the east of the Hebrides."

Thus Loch Maddy does contain a variety of CFT biotopes in the entrance to the Loch, including some which are regionally rare, though they are not a criterion for its selection. Descriptions of the subtidal communities are found in Dipper & Mitchell (1980), Howson (1991) and Howson et al. (1994).

ii. Sound of Arisaig

To quote the SNH recommendation: "Sound of Arisaig has an unusually high diversity of sublittoral sediment habitats within a relatively small area. The extensive sublittoral maerl beds are the richest known in Scotland whilst the site also has a range of representative marine and brackish sediment habitats and associated communities".

Hence the justification for candidate status is based entirely on the interest of the soft sediments within Lochs Ailort, Ceann Traigh and Moidart. However the proposed boundaries of the SAC include a considerable area of the Sound of Arisaig, and the predominantly rocky coastline from Rubha Aird Druimnich northwards to Rubha Chaoliai.

"The region is characterised by a broken rocky coastline and clear high salinity water and has a boreal fauna and flora. The recommended site has an excellent combination of very sheltered inlets and exposed open coastline with considerable diversity of sediment habitats, high species richness and communities which reflect the major features of the region. The species complement illustrates the transition from southern to northern influences along this coastline with species with both predominantly southern and predominantly northern distributions found."

So whilst not selected on their account, CFT biotopes occur within the boundaries of the SAC, and may be of interest because of their biogeographic position. Descriptions occur in Howson (1990), and Howson et al. (1994).

iii. Strangford Lough

Strangford Lough has been selected as a SAC site because of its Annex I feature of shallow inlets and bays. However, the Lough is an extremely diverse ecosystem (Brown, 1990). Large areas are indeed shallow soft bottom environments, but there are also substantial areas of mussel (*Modiolus*) beds of considerable conservation interest. In the narrow entrance to the Lough tidal currents reach an excess of 8 knots, there are depths in excess of 50m, and the substratum is predominantly rock. This area supports a range of extremely interesting CFT biotopes which are not elsewhere available in this biogeographical area. They should be regarded as an important constituent of the SAC.

A detailed report of the subtidal environment in Strangford Lough is contained in Erwin et al. (1986). The 'narrows' leading into the Lough are indicated as sites of both upper and lower circalittoral areas with >20% bedrock (loc. cit. Maps 23 & 24), and of 50-100% bedrock at 20-50 metres (Map 39). The report contains considerable detail regarding sites surveyed and species found.

iv. Plymouth Sound and Estuaries

The reasons for selecting this area as a candidate SAC were the Annex I habitats - sandbanks, estuaries, and inlets and bays. However, the proposed seaward boundary from Rame Head to Yealm Head includes a region of open exposed rocky coastline, together with an expanse of deeper open water. As Moore (1995) summarises the area: "a very large inlet with extensive areas of fully marine and species rich hard substrata and sediments in the Sound....... Littoral and sublittoral bedrock biotopes in the Sound are particularly well developed and extend from the open coast extremely sheltered limestone with rock-boring fauna...".

Smith & Moore (1996) provide a detailed account of the area, though their seaward limit, from Penlee Point to Renney Rocks, was somewhat inshore of the proposed boundary of the SAC. Hiscock & Moore (1986) also covered the area. Moore (1995) lists in his Appendix 4 the very wide range of sublittoral rock biotopes occurring in the area. These include circalittoral rock biotopes characteristic of variable and reduced salinities (SRK.SUB, SRK.DEN, SRK.DYS, SRK.LOW), and also those characteristic of very sheltered conditions (SRK.SUB, SRK.LIME, SRK.COD).

There is clearly a diversity and fair abundance of CFT biotopes within this demonstration CFT site, with those in extreme shelter and subject to variable salinity of particular interest. It has been shown earlier that a number of CFT biotopes and important species have limited distributions in the south-west, and Plymouth Sound and Estuaries is the only demonstration SAC within that area. Consequently the CFT biotopes merit serious consideration.

c. SACs where CFTs are absent or unimportant

i. Solway Firth

The selection of this area was based on its estuarine and sedimentary habitats. "The Solway Firth is of international importance under Annex I as an estuarine habitat with extensive littoral and sublittoral sedimentary habitats. It is one of the least industrialised and most natural large estuaries in Europe, has the third largest area of littoral flats in Britain, and is the fourth largest estuary in the country."

However, there are some sublittoral hard substrata. "Reefs are a relatively minor component of the recommended area. They are mainly made up of scar grounds of glacial boulder deposits, and the most diverse littoral and sublittoral reef communities occur in the more stable outer reaches of the estuary." There are a few small areas of rocky coastline on the northern shore of the estuary, but given the shallow depths, the potential for CFT biotopes within the SAC is very poor. "Twelve MNCR surveys have been completed for the Irish Sea region, collecting data from some

213 sites. Twenty-four sites were surveyed in the inner Solway Firth, describing the biota from 75 geographically different stations. Analysis of these records has shown there to be 12 MNCR biotope types present in the inner Solway Firth, consisting of soft sediment types over the largest part of the area, with wave-sheltered rocky littoral communities present towards the outer limits of the site."

ii. Morecambe Bay

Morecambe Bay was selected because of its extensive mud and sand flats, and large areas of shallow water. There are virtually no hard substrata within the Bay, and very few CFT biotopes. The region has been surveyed sublittorally (Emblow, 1992), and the only CFT biotopes are in the Lune Deep at the entrance to Morecambe Bay. The proposed seaward boundary of the SAC (from Rossall Point to Hipsford Point) crosses the Lune Deep, and so some small area of rather limited CFT biotopes will lie within the SAC.

iii. The Wash and North Norfolk Coast

The Annex 1 features supporting the selection of this SAC are the abundance of sandbanks, mud and sand flats, and shallow inlets and bays. The coastline consists of sand and mud, largely backed by dunes and saltmarsh. The subtidal areas are all sediment bottoms. There are no CFT biotopes within the limits of the SAC.

iv. Cardigan Bay

This was selected as a candidate SAC because of its importance as a habitat for a resident population of the bottlenose dolphin, *Tursiops truncatus*. The coastline of the proposed SAC extends from just north of Aberayron to south of Cemaes Head (CCW documentation), and is largely rocky. The subtidal rock may provide some CFT biotopes, but none of particular note (FSCRC, 1992).

v. Chesil and the Fleet

There are no CFT biotopes within the limits of this SAC (Victoria Copley - personal communication). It is selected as a candidate SAC because of its lagoons (Annex I feature).

D. KEY POINTS FROM CHAPTER I

- Circalittoral Faunal Turfs are communities of predominantly attached animals living on hard sublittoral substrata. They occur below the depths where there is sufficient light for macroalgae to dominate the communities.

- CFTs are a complex mixture of biotopes. The MNCR biotopes classification includes 51 'circalittoral rock' biotopes, most of which can be classed as CFTs.

- CFTs have become increasingly accessible with the development of SCUBA diving. They represent a rich resource because of their biodiversity and aesthetic interest.

- Of the 12 demonstration SACs, 3 were selected partly because of the importance of their 'reef', and hence CFT, biotopes - Papa Stour, Berwickshire and the North Northumberland Coast, and Llyn Peninsula and the Sarnau. CFTs are an important feature in four others - Loch Maddy, Sound of Arisaig, Strangford Lough, and Plymouth Sound and Estuaries.

II
ENVIRONMENTAL FACTORS INFLUENCING THE DISTRIBUTION OF CFTs

It is fairly straightforward to analyse the effects of individual environmental factors on the CFT species so far as information is available. However, in determining the composition of a community in a specific location the complex interaction of physico-chemical variables must be considered - a simple presentation of this in relation to hard substrata is given in Figure 6. The interactions between depth, slope and suspended matter in determining light availability are particularly important.

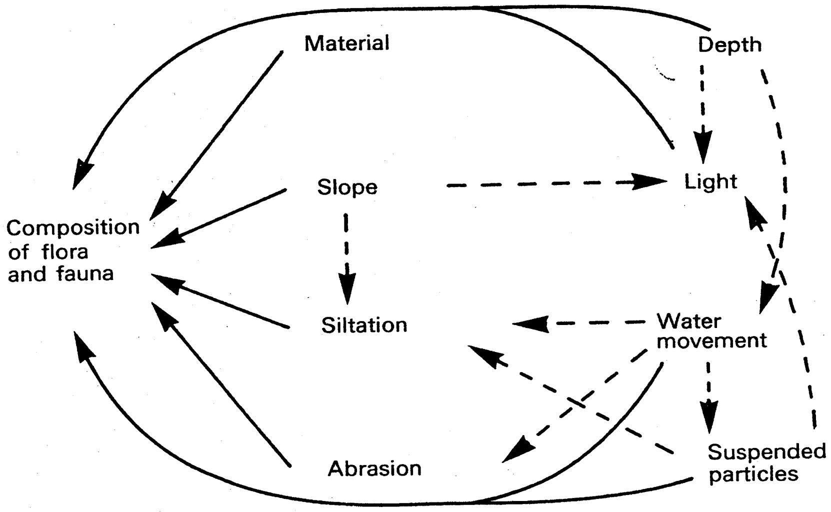

Figure 6. Environmental variables, and their interactions, important in determining community structure on hard sublittoral substrata (from Hartnoll, 1983).

Various factors are considered. Temperature is of most important on a geographical scale, whilst the others may vary widely on local scales to have major influences the distribution of CFT species and biotopes. In the previous section the significance of water movement as a determining factor was highlighted.

A. TEMPERATURE

Localised short term fluctuations in seawater temperature, resulting from heat loss or gain to the air or the substratum, can occur in the shallow surface layer in inshore water. CFT communities are largely insulated from such transient influences by their depth, and in many cases also by their prevalence in high energy systems which ensure vertical mixing of these variable surface waters with the more stable deeper layers. Seasonal shallow thermoclines may form, particularly in sheltered areas such as sea lochs, and extend down to 15m. Some animals such as the brachiopods *Crania* and *Terebratulina* seem restricted to below this thermocline (Hiscock, 1985).

The permanent thermocline represents a more substantial effect of depth on temperature. However, typical CFT communities within SACs will be located well above this, which is generally at around 200 m, and rarely above 80 m. Hence they will experience the annual temperature fluctuation of about 8°C characteristic of British coastal waters. There are deeper water circalittoral rock biotopes which occur beneath the thermocline and which are temperature sensitive - such as the *Lophelia* reefs. However, these will not occur within the limits of the proposed SACs. There have been suggestions that deeper water temperature-sensitive communities can be discriminated below 40 m off the Glénan Archipelago (Castric-Fey et al., 1973) and off Galway (Könneker, 1977).

The most obvious effects of temperature result from the geographical variation of seawater temperature, which generally decreases from the south-west to the north-east across the British Isles. Summer surface temperatures range from around 16-18°C in the south to 12-13°C in the north, with corresponding winter ranges of 9-10°C and 4-5°C respectively. These geographical variations of temperature are reflected in the distribution of important CFT species, such as the soft coral *Alcyonium glomeratum,* and the sea fan *Eunicella verrucosa* (Appendix 4, Figure 14b). These are both southern species, and limited tolerance of cold determines the northern limits of their distribution. On the other hand the northern sea fan *Swiftia pallida* (Appendix 4, Figure 14c) has a more northerly distribution. Similarly some JNCC biotopes can be geographically restricted because they are characterised by temperature sensitive species. Thus the 'erect sponges, *Eunicella verrucosa* and *Pentapora foliacea* on slightly tide-swept moderately exposed circalittoral rock' biotope is confined to the south west. Geographical distribution patterns for biotopes and species are both discussed in detail in section III.E.

Anything affecting the annual temperature regime can affect the abundance and distribution of temperature-sensitive species. The possible, but currently unquantifiable, effects of long-term global warming are touched on in section IV.A. There are however shorter term cyclical temperature fluctuations operating in the north Atlantic, such as those associated with the so called North Atlantic Oscillation (NAO), with a period of 7-8 years (Maximov et al., 1972). A variety of benthic populations have been demonstrated to co-fluctuate in abundance accordingly (Gray & Christie, 1983), and such cyclic fluctuations are recorded from typical rocky circalittoral species such as *Ciona intestinalis* (Lundälv, 1985) and *Echinus esculentus, Asterias rubens* and *Ascidia mentula* (Lundälv & Christie, 1986). The management implication is that such cycles must be discriminated from anthropogenic changes, and that areas may need to be compared and only "departures from a common pattern may indicate local effects of pollutants" (Gray & Christie, 1983). This may be facilitated if similar formats of monitoring are undertaken in adjacent SACs.

B. DEPTH

Initially depth would appear to be the paramount environmental factor determining the distribution of CFT communities. However, this is illusory in that depth *per se* is probably of little consequence. The organisms appear to be unaffected by pressure (the direct result of depth) within the depth range involved. If brought to the surface they live perfectly well at surface pressures - though this is not true of very deep sea organisms. Within the circalittoral zone depth exerts its effect only via its influence on other environmental factors. Light availability and the amount and type of water movement both vary greatly with depth. Temperature and salinity vary less, but the short term and annual fluctuations are both damped with increasing depth. These variables are all considered separately. The overall effect of increasing depth tends to be a reduction in fluctuations of most environmental factors, and it is now appreciated that in the deep sea this results in high biodiversity. This trend is apparent in circalittoral rock biotopes, with very high biodiversity evident in the deep circalittoral *Lophelia*-reef biotopes (Jensen & Fredriksen, 1992), where 298 species were recorded from a small area. With increasing depth hard substrata become scarcer, and as they appear to support diverse communities, they should be considered important in the context of SACs. The existing SACs include only limited areas of deep water, and this is perhaps a matter which needs consideration.

However relatively deep CFT biotopes (>50 m) occur within the recommended boundaries of several of the candidate/possible SACs, including the following - Papa Stour; St Kilda; Lochs Duich, Long and Alsh reefs; Isles of Scilly.

C. LIGHT

Light is the environmental factor which basically determines the depth distribution of the circalittoral - the decrease of light with depth defines the upper limit of the zone. In areas where enough incident light reaches the sea bed the rock substratum community tends to be dominated by large macroalgae (the kelps) creating the infralittoral zone. When the light levels decline there is a progressive shift to faunal dominated communities. The reduction of animals in shallower depths is mainly due to competition for space with algae, though a few animals have symbiotic algae in their tissues and thus require light. These include the anemone *Anemonia* viridis and the hydroid *Aglaophenia pluma* (Hiscock, 1985). Areas of the infralittoral dominated by animal biotopes occur as a result of steep slopes, heavy grazing, and sometimes extreme physical conditions, however they are very much the exception.

The depth of the infralittoral-circalittoral transition depends on the penetration of light, which is influenced by a number of factors (Drew,1983). The main factors influencing water column light attenuation are the concentration of dissolved organic pigments and suspended matter, and these are both more abundant in coastal than in oceanic waters. Approximately 50% of the surface light reaches a depth of 10 m in the clearest oceanic water, but only 0.1% in very turbid coastal waters (Jerlov, 1976; Drew, 1983). The critical depth for the growth of kelp plants is at about 1% of surface illumination, and for foliose red algae about 0.1% (Luning & Dring, 1979). Consequently in turbid coastal waters the lower limit of abundant algal growth, and hence the upper limit of the circalittoral zone, will be shallower. Thus the main infralittoral canopy alga, the kelp *Laminaria hyperborea*, reaches its lower limit at 8 m in the relatively turbid waters of Helgoland, whilst it extends to about 20 m in the clearer waters of the Isle of Man (Kain, 1971), and in very clear water will grow down to over 30 m (Drew, 1983). In St Kilda kelps grow down to 47 m (Alistair Davison, pers. comm.). Water clarity, and its response to suspended matter, must be a major consideration in relation to the management of SACs.

D. EXPOSURE TO WATER MOVEMENT

We have seen that light basically determines the depth distribution of the circalittoral communities. Within that depth range, however, water movement is the prime factor influencing community composition. This is recognised within the JNCC biotope classification, where the first division of Circalittoral Rock Biotopes is into the three categories of 'exposed', 'moderately exposed', and ‘sheltered’ rock.

In the coastal waters, water movement arises predominantly from two sources - the action of waves, and currents generated by tides, and 'exposure' in the JNCC classification refers to either or both. In general the two often go hand in hand, with wave-swept headlands at the same time being in the path of the strongest tidal currents. But this is not always so, and there are areas sheltered from waves but receiving very fast tidal currents, as in the entrances of sea lochs and of rias in south west Britain. There are also areas of strong wave action but little current flow. This diversity is reflected in the number of biotopes listed.

Wave action: this generates extreme forces, and is basically a result of wind blowing across the sea and transferring energy to the sea surface. It depends on three factors - the force of the wind, the duration it blows for, and the distance over which it blows (the fetch) - as any or all of these increase, so does the wave severity. Wave action will also be modified by local topography. A very comprehensive account of the theory of waves is given in Denny (1988), and only a few points need to be made here. The water movement generated by wave action is turbulent, and very difficult to measure underwater in the field. The severity of wave effects decrease with depth: under gale conditions the bottom water velocity may be >200 cm.sec^{-1} at 20 m, but reduced to about 60 cm.sec^{-1} at 40 m and 9 cm.sec^{-1} at 80 m (Hiscock, 1983). With increasing depth the water movement at the bottom tends to become oscillatory rather than multi-directional (Hiscock, 1983).

Tidal currents: these are easier to predict and measure than wave action. They normally flow to and fro with the tidal cycle, and they do not attenuate with depth as rapidly as does wave action. They may reach velocities up to 8 knots in straits between land masses (e.g. the Corryvreckan between Jura and Scarba in the Hebrides), or in the entrances to sea loughs (e.g. Strangford Lough in Northern Ireland). These extreme currents generate severe overfalls and whirlpools. A short general account is found in Hiscock (1983).

Water movement will affect species (and communities) in various ways, some beneficial, others detrimental. Beneficial effects include:
- Provision of suspended food supply for filter feeders.
- Prevents clogging of gills or other organs by settlement of silt.
- Ensures a high dissolved oxygen content.

Detrimental effects include:
- Physical damage or dislodgement of organisms.
- Restriction of effective feeding time.

The presence or absence of water movement will alter the balance of competition between species which might be otherwise able to survive across a wide range of exposure. This effect is very obvious intertidally on rocky shores, where the balance between macroalgae and grazing limpets changes completely with the degree of wave action, and limpets exclude fucoids from exposed areas where they can otherwise survive successfully (Jones, 1948).

The end result is that there are very different CFT biotopes in different conditions of exposure. The distribution of species will result from a balance between their ability to withstand vigorous water movement, and their need for water flow to assist their feeding processes. There is no need to enter into great detail here - the differences are to be readily seen from a comparison of the exposed and sheltered biotopes itemised in Appendix 1. Exposed areas tend to be dominated by coelenterates (e.g. *Alcyonium digitatum, Tubularia indivisa, Corynactis viridis)* and massive sponges (e.g. *Pachymatisma johnstoni, Cliona celata*). In contrast very sheltered communities are often dominated by ascidians (*Ascidia mentula, Ciona intestinalis*) and more delicate sponges (*Suberites carnosus, Polymastia boletiformis).* These are only general trends - under certain conditions coelenterates can dominate in shelter, and ascidians in exposure. In exposed sites differences will be found between those receiving extreme wave exposure (jewel anemones, bryozoan turfs, massive sponges, soft corals) and very strong tidal currents (barnacles, and the hydroid *Tubularia*). Hiscock (1985) presents very comprehensive lists of circalittoral rock species found under different conditions of water movement, discriminating the effects of waves and currents.

E. SUBSTRATUM

Two components of the substratum are relevant here, rock type and substratum stability.

In intertidal waters rock type is important because, amongst other factors, it influences water retention and radiative heating (see Hartnoll, 1983 for references). Subtidally these are not significant, but surface texture, erosion and rock hardness are factors of obvious relevance. A smooth surface will provide a different environment from one pitted with cracks and crevices. Friable eroding rocks are colonised by pioneer species, and the community characteristic of firm surfaces does not develop (Rubin, 1980). Very soft rocks, such as soft chalk or clay, allow the development of 'soft rock communities' characterised by boring molluscs (piddocks) or boring polychaetes (*Polydora*) (Hiscock, 1979; Wood, 1989).

Substratum stability is determined by whether it is comprised of bedrock, or of loose boulders or stones. The mobility of boulders and stones will be a function of wave exposure, and mobility of the substratum will selectively impact CFT species. Marked differences between the communities of bedrock and adjacent loose rocks has been recorded (e.g. Knight-Jones & Jones, 1955), and in the MNCR classification distinct biotopes are recognised for bedrock and loose substratum. Mobile substrata under exposed conditions have a community characterised by serpulid worms, barnacles and bryozoan crusts (Bunker & Hiscock, 1987; Dipper, 1983; Hiscock, 1981; Howson, 1988; Mitchell et al., 1983) rather than by the larger more delicate species which feature on the adjacent bedrock. Larger boulders which are not regularly displaced will provide a variety of cryptic environments on their undersides, but these will not be surveyed by the standard methods in use.

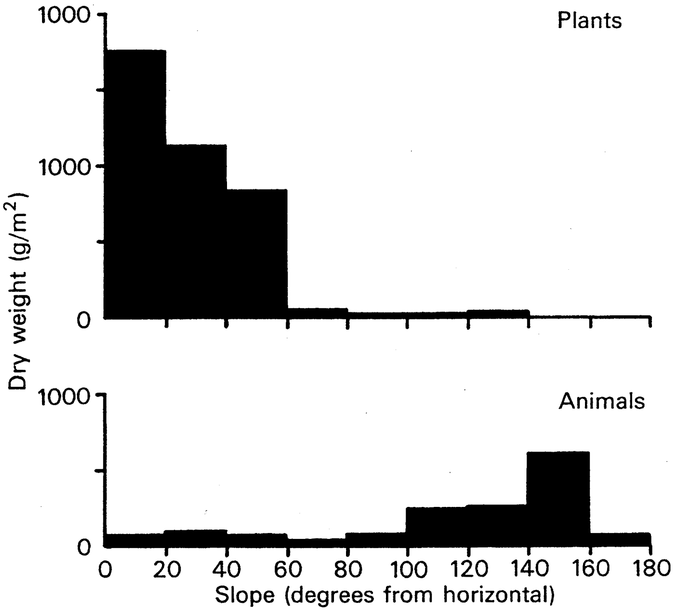

Figure 7. Dry weight biomass of plants and animals on rock surfaces of different slopes on Port Erin Breakwater (from Hartnoll, 1983).

F. SLOPE

The slope of the substratum influences the CFT community because it affects the amount of incident light, and consequently the abundance of algal growth. There are various studies which contrast the abundance of algae on upward facing surfaces with the animal domination of nearly verticals and overhangs, on both natural substrata (Kitching et al., 1934; Forster, 1958, 1961; Hiscock, 1979a) and artificial panels (Withers & Thorp, 1977). This is clearly illustrated by

Figure 7 which shows the biomass of plant and animal material on rocks of different slope at the same depth. The effect of this factor is that animal species which occur on rocks of all slopes at depths of 20 m or more become confined to steeper slopes, and then to verticals or overhangs, as the depth decreases: this is clearly shown by the soft coral *Alcyonium digitatum* in the Isle of Man (Hartnoll, 1975).

The other effect of slope is that is will affect the amount of silt settling out on the rock surface, and as discussed below certain species and communities are favoured or deterred by such silt settlement.

G. SUSPENDED MATTER

Transparency and water clarity are affected by both dissolved material and suspended particles in the water, and are important because they influence the penetration of light. This has been discussed above. Suspended particles may be of natural origin, but can also arise from anthropogenic impacts such as dredging.

Suspended material in the water can settle out of the water column, and this can affect both the settlement and the survival of CFT species. It is normally only a problem in shelter, and the slope of the rock is also important: little sediment will settle on verticals or overhangs (Hiscock & Hoare, 1975). Silt influenced CFT communities are generally dominated by ascidians and sponges (Collins & Mallinson, 1987; Emblow et al., 1994), though ascidians can be sensitive to siltation, particularly in the settlement stage (Lundälv, pers. comm). Overall the effect of increased siltation on circalittoral rock biotopes is to lead to a decrease in diversity, and any factor increasing siltation would be a serious management concern.

Material in suspension can affect the efficiency of filter feeding (Sherk, 1971; Morton, 1977), and most of the CFT species are filter feeders (see section III.B). Effects can include abrasion and clogging of gills, impaired respiration, clogging of filter mechanisms, and reduced feeding and pumping rates. Decreased growth rates in species experimentally exposed to suspended sediment have been reported (Lawrence, 1993), though other reports claim that effects are generally small (Mackin, 1961; Saila et al., 1972). Obviously results will differ depending on the species studied, sediment loadings, and duration of exposure. Relevant studies have been made on the typical CFT species *Alcyonium digitatum*, using sediment loads similar to those induced by dredging activity, and lasting 2 months (Hill et al., 1997). No adverse effects were seen, though the colonies did occasionally slough off layers of sediment-coated mucus. However, not all CFT species may be as tolerant.

In exposed situations suspended material can cause scour, but this is normally a result of the temporary resuspension of relatively coarse bottom material rather than of fine material in long-term suspension. See 'scour' as an environmental factor.

H. SCOUR

Scour is a factor in more exposed areas where the rock substratum is in proximity to fine sediment. Typically such situations are found where boulders lie on a sandy bottom, or in the regions where the bedrock merges with the level sea bed. The existence of impoverished communities of tolerant species under such conditions has long been recognised (Forster, 1961; Knight-Jones & Nelson-Smith, 1977; Hiscock, 1979a; Hoare and Peattie (1979). A common feature in these communities is the presence of the hornwrack, *Flustra foliacea.* In the MNCR classification a variety of moderately exposed 'sand-influenced' biotopes are described as 'bryozoan/hydroid turfs'. In all of these biotopes the bryozoan *Flustra foliacea* is a prominent element, together with the calcareous tube worm *Pomatoceros triqueter,* and hydroids such as *Tubularia indivisa* and *Nemertesia* spp. At the rock-sand interface the community is often dominated by the anemone *Urticina felina.*

I. SALINITY

As a result of the depths at which they occur, and the exposed locations of the majority of sites, reduced salinity is rarely a significant factor. Nevertheless reduced salinities do occur in sea lochs at depths of 30 m+ and specialised CFT communities occur there, as they do also in some south western rias. They have been described from Loch Etive (Howson et al., 1994), Loch Fyne, Loch Leven, Loch Long and Loch Ewe. The community is characterised by brachiopods, calcareous tubeworms and sponges. Reduced and variable salinity biotopes characterised by sponge-dominated communities have also been described from Plymouth Sound and other south-western rias (Moore, 1995).

J. GRAZING

So far the environment has been considered only in terms of physico-chemical variables, but biological factors can also influence community composition. Biological interactions will be considered in the following section, but grazing should be mentioned as it used as a descriptor in the MNCR classification - 'grazed fauna' on moderately exposed circalittoral rock. This grazed fauna is reminiscent of the scour-tolerant fauna above, including bryozoan crusts, calcareous tubeworms, hydroids, the anemone *Urticina,* and the grazing sea urchin *Echinus esculantus*.

K. KEY POINTS FROM CHAPTER II

- Sea temperature affects the geographical distribution of CFT communities and species. There are both southern and northern species with restricted distributions in Britain.

- The upper limit of CFT biotopes is set by light availability, and typically is between ten and twenty metres. Slope of the substratum is also important - CFTs occur shallower on overhangs and in caves.

- Water movement is a major factor affecting distribution: the primary division of CFT biotopes is into those characteristic of different degrees of wave action. Exposed biotopes are dominated by coelenterates and massive sponges, sheltered ones by ascidians and more delicate sponges. Very sheltered CFT biotopes are scarce in most of the candidate SACs.

- Suspended material reduces CFT diversity by blanketing the substratum, and by causing scour damage. Scoured biotopes are characterised by bryozoan/hydroid turfs.

- Reduced salinities are scarce in CFT biotopes, but support specialised communities.

III
BIOLOGY AND ECOLOGICAL FUNCTIONING

In the preceding section the various environmental factors influencing CFT species and communities were reviewed. The primary effect of these environmental factors is to determine which CFT species can potentially inhabit a given location, and this will depend on the biological characteristics of each species - such as size, habit, feeding method, and reproductive mode - as discussed in this section. However, not every species occurs throughout its potential range - its realised distribution is moderated by biological interactions such as competition, grazing and predation. These are also reviewed below.

A. BASIC HABIT

1. Sessile versus mobile

The facts that circalittoral rock provides a firm attachment, and that CFT biotopes are frequently in areas of strong wave action, mean that the sessile habit will confer advantages. It will prevent the organisms being swept away to what might be unfavourable conditions, and it will prevent them from being damaged by impact on rocks in the course of being moved by water action. Consequently, as is seen clearly in the section below, the great majority of prominent CFT species are **sessile**. Being sessile can be achieved in two ways. Most CFT species are attached permanently to the rock in one place - they are effectively glued to it. Sponges, tube worms, barnacles, byozoans and tunicates are all of this type: some of the adhesives which they use are highly efficient and are being commercially investigated. Others are sessile, but retain some powers of relocation. Anemones attach by a basal disc, but can creep slowly over the rock surface. Some bivalves attach by horny byssus threads, which they can discard and produce new ones to attach in another place. This sessile habit is possible only if the food supply comes to the animal (see below).

The prominent **mobile** CFT species consist mainly of decapod crustaceans, gastropod molluscs and echinoderms, and as grazers or predators these must be able to move to locate further food supplies. Even so, many of them are very well attached to the rocks, such as starfish and sea urchins with their many sucker-like tube feet. Others, such as the decapod crustaceans, are adept at finding refuges from the more severe water movement. There are other large mobile species, particularly fish, which are not considered part of the CFT community, but may nevertheless play an important structuring role.

In addition the CFT community includes a diverse **cryptofauna** of small organisms such as nemerteans, polychaete worms and amphipod crustaceans. These live permanently hidden amongst the larger sessile fauna, existing as grazers, micropredators or detritivores. They are not assessed by the standard visual survey techniques, and so do not feature in the biotope descriptions. They can only be collected by destructive sampling.

2. Growth form and strategy

In terms of being prostrate or erect there is a conflict of interest for CFT species. They are mostly filter feeders, and they frequently live in vigorous water movement. A prostrate habit protects them from the worst of the water movement, as well as giving them a very robust morphotype. However, it tends to place them in the boundary layer with limited water movement, and it is the water which carries their food. Furthermore, if taller erect species are present, they will have precedence in access to the food supply. Conversely erect species will be more prone to damage by turbulence or currents, and more fully exposed to them: but they will be in a position to maximise food intake.

The outcome is predictable. Under conditions of extreme exposure robust low-growing forms predominate - barnacles, massive sponges, short hydroids, bryozoans and tube-building polychaetes. As exposure moderates the taller erect forms come into prominence - the sea fans, soft corals and the like. These still tolerate considerable exposure though - they have a tough yet flexible structure which enables them to withstand turbulence and strong currents without damage. In shelter erect forms still predominate, but different ones which can tolerate the sediment loading and the reduction in food-bringing currents: tunicates and erect sponges occur, delicate forms which would not withstand exposure.

B. TAXONOMIC COMPOSITION AND FEEDING INTERACTIONS

1. Dominant taxa in the CFT.

By definition a 'faunal' turf must consist predominantly of animals, but as has been pointed out above the transition from the infralittoral is not clear cut, and the upper levels of the circalittoral will contain algae, the amount decreasing with depth. Crustose corraline algae are common (and usually unidentifiable in the field), and the other algae comprise a wide variety of small reds. Thus in a survey of the Dorset coastline (IOE Group, 1995) 16 species of red algae and 4 species of brown algae (**Appendix 2**) were collected from 'circalittoral bedrock'. This is probably representative of what is normally found.

As seen above (section III.A) there is a dominance of sessile species in the CFT communities, and so the animals would be expected to come predominantly from taxa which are basically sessile in habit. This is confirmed both by an analysis of the species composition on circalittoral bedrock in the Dorset survey cited above (IOE Group, 1995). An alternative approach, concentrating on the more prominent species, is to examine all of the 'characterising species' in CFT biotopes in the JNCC biotope classification (Connor et al., 1997) - these are listed in **Appendix 3**. The resulting breakdown is very similar to the above.

	Dorset Survey	Characterising CFT Species
Sessile groups		
Sponges	28	23
Coelenterates	27	24
Tube worms	6	3
Barnacles	2	1
Molluscs	12	5
Bryozoans	25	12
Tunicates	11	14
Mobile groups		
Annelids	1	2
Crustacea	9	4
Echinoderms	3	11
Fish	-	3

In the Dorset survey the sessile sponges, coelenterates, bryozoans and tunicates clearly dominate the community, making up more than 70% of the species. Of the remainder a number are also attached. Again the sessile taxa predominate among characterising CFT biotope species. The bryozoans are less well represented, since although common, individual species tend not to be conspicuous. The echinoderms make up a larger component - they tend to be very obvious elements in the community. However, it must be remembered that these breakdowns ignore the abundant cryptofauna which do not feature in any of the standard surveys.

2. Feeding strategies

The majority of the CFT organisms are filter feeders, depending on suspended material in the water column coming within their range. This suspended material may be living plankton, either plants in the form of phytoplankton or animals in the form of zooplankton, or it may be dead organic matter. The organic matter arises from various sources - such as by the breakdown of dead organisms, the shedding of fragments, the production of faeces, and the release of mucus. Since the majority of CFT communities occur in exposed or moderately exposed conditions the water movement will facilitate the supply of this suspended food. Phytoplankton tends to concentrate in the surface layers, but turbulent mixing will carry it down to the circalittoral zone. Much zooplankton makes diurnal vertical migrations, or remains at depth, making it available in the circalittoral zone. Particulate organic matter tends to settle to the sea bed, but the water movement will keep it in suspension. A number of the CFT taxa are clearly all or largely filter feeders - the sponges, tube worms, barnacles, bivalve molluscs, bryozoans, tunicates, and coelenterates. Certainly filter feeders predominate numerically, and they can be passive or active feeders.

Passive filter feeders depend entirely upon water movement to carry food particles to the filtering mechanism - hydroids and fan corals are of this type, as are most barnacles, and they would not be expected to flourish in extreme shelter. Active filter feeders, most of the other taxa (e.g. sponges, bryozoans, tunicates), create a water current to draw food into the collecting system. However, this current is in most cases quite weak and draws food from distances of a few centimetres at most. So whilst they can feed in static water, they nevertheless depend upon some water movements to replenish the local food resource. The coelenterates differ in feeding mode from the other groups above - they all depend upon a mixture of cilia, mucus and setal sieves to filter fine particles, and they can *only* filter fine particles, so they are obligate filter feeders. Coelenterates, however, have tentacles with stinging cells which they use to catch their prey, though some also employ mucus/ciliary mechanisms. Some feed only on small particles, and can be regarded therefore as functional filter feeders - this applies to hydroids, fan corals, and soft corals. The soft coral *Alcyonium* employs tentacular mechanisms to trap zooplankton, but at the same time filters phytoplankton with a mucus/ciliary mechanism (Roushdy & Hansen, 1961). Some anemones (e.g. *Urticina*) feed only on larger prey and are considered carnivores. However the plumose anemone (*Metridium*), whilst normally feeding on small particles, has retained the ability to capture larger prey.

A feature of filter feeders, particularly active ones, is their ability to modify the environment by reducing the concentration of suspended particles. This is probably only significant in semi-enclosed situations, but examples include the effects of mussel farming on the water clarity of fjord systems (Haamer, 1996), and of mussel populations in reclaiming disused docks (Wilkinson et al., 1996). In San Francisco Bay the bivalve population has the capacity to filter the volume of the bay daily, and is considered of far greater importance than the zooplankton in grazing down the phytoplankton (Cloern, 1982). Thus any change in the balance of filter feeders, both within or adjacent to CFT biotopes in enclosed situations, could affect water clarity and the supply of particulate food.

The conspicuous mobile taxa - decapod crustaceans, gastropod molluscs, and echinoderms - feed either as grazers, scavengers or carnivores. Grazing in this context relates to mode of feeding rather than diet, since there are few algae and grazers must subsist largely on an animal diet. Grazing is largely indiscriminate feeding as the organism moves over the rock surface, typified by sea urchins and some gastropod molluscs. Predation involves the deliberate selection, and sometimes pursuit, of prey. Starfish and decapod crustaceans are good examples. Usually predators seem poorly represented in hard-substratum communities, but they are often mobile and may only visit the biotope intermittently for feeding.

3. Biological interactions and keystone species

Circalittoral communities have been poorly studied in this respect. To determine the real role of species in a community generally requires experimental manipulation in the field. This has been done quite extensively in the intertidal, to a lesser extent in the infralittoral, but hardly at all in the circalittoral. It is largely a matter of the logistics of working at depth, but also the identification of significant questions to investigate. For hard substratum biotopes the most obvious questions usually relate to whether particular grazers or carnivores operate as **'keystone'** species - i.e. their role is so significant that changes in their abundance can have major effects on community composition and functioning.

Keystone species are considered to be important in the maintenance of biodiversity by limiting the ability of potential dominant species to monopolise the available space. The effects of grazers and carnivores as keystone species will be discussed first, followed by a consideration of competition between species.

a. Grazing

On intertidal rock limpets (*Patella* spp.) have such a role in Britain, and their removal can change barnacle-mussel dominated shores into fucoid algal dominated ones. This has been demonstrated experimentally (e.g. Jones, 1948; Hawkins, 1981), and was also seen following major limpet mortality after the *Torrey Canyon* disaster (Southward & Southward, 1978). In the infralittoral zone sea urchins play a similar role by grazing upon the algae and restricting the growth of kelps. In the Isle of Man it was found that removal of all of the common urchin *Echinus esculentus* from an area of rock substratum caused the lower boundary of the kelp forest to extend downwards by several metres (Jones & Kain, 1967). Off Norway sudden increases in the northern urchin *Strongylocentrotus droebachiensis* devastated the kelp beds to produce largely barren areas (Hagen, 1983) - examples of the classic 'urchin barren grounds'. It has been suggested that increased numbers of seals have reduced levels of the main urchin predator (the catfish *Anarhichas lupus*) allowing the urchins to proliferate (Sivertsen & Bjorge, 1980). In California reduction of lobsters which prey on sea urchins allowed urchins to proliferate and decimate the kelp canopies (Tegner & Levin, 1983). So there is evidence that grazing pressure on algae can moderate the depth of the infralittoral-circalittoral boundary, but the chain of events involved may be quite complex..

However, within the circalittoral zone itself there is less information on biological interactions, but sea urchins and starfish both have the potential to function in keystone roles. Sebens (1985a, b), working in the eastern USA, concluded that *Echinus* could prevent the development of the normal invertebrate community, maintaining a coralline crust which invertebrates would otherwise overgrow. This was confirmed by the experimental manipulation of urchin density, which also showed that certain species such as *Alcyonium* were less susceptible. Vertical and overhanging surfaces were grazed less effectively by urchins, and tended not to be reduced to the coralline crust status. Karlson (1978) and Vance (1979) have demonstrated a similar relationship in other American locations. In Norway, Sandness & Gulliksen (1980) excluded the urchin *Strongylocentrotus* with cages, and observed increased in barnacles and limpets. So urchins could perhaps also maintain a 'barren ground' scenario in the British circalittoral: in Scotland at least *Echinus* can reduce the diversity of the biota by intense grazing (Mitchell et al., 1983), and there is certainly scope for experimental study..

b. Predation

The starfish *Asterias rubens* is a common species and a major predator, particularly of mussels - it has even been used as a means of controlling mussel fouling on the legs of oil rigs (Ralph & Goodman, 1979). However, the effects of *Asterias* on common CFT species are less well known. It certainly preys heavily on the ascidian *Ciona intestinalis*, and can prevent this species attaining dominance (Gulliksen & Skjaeveland, 1973; Lundälv & Christie, 1986). It is also considered important in clearing space on rock by grazing barnacles, mussels and ascidians (Menge, 1982). On settlement panels in Sweden *Asterias* reduced the cover of sessile species to 20%, compared to 100% when they were excluded (Lundälv & Christie, 1986). Other predators include crabs, lobsters, and fish, but little is known of their roles in the British circalittoral. In S. Africa, Barkai & Branch (1988) excluded rock lobsters and observed marked changes. In Australia, Russ (1980) excluded fish, also with clear results.

Higher level predators are of interest because they may control the numbers of the major primary grazers and predators (urchins and starfish), so ultimately influencing community structure. In the eastern coasts of North America sea urchin populations have expanded over the past century, and this has been linked to the increase of lobster harvesting over the same period, on the assumption that lobsters were the most important urchin predators (Mann & Breen, 1972). However choice experiments indicate that urchins form a small part of lobster diet (Evans & Mann, 1977), and that crabs (*Cancer borealis*) form a major part (Sebens, 1985). Since crabs are important urchin predators, a decline in lobster numbers might in fact raise urchin predation. Relationships are complex, and currently unclear, but there is good reason to expect effects if the numbers of the top predators change (see section V.C).

c. Competition

There have been a great range of experimental studies, often using artificial substrata, investigating competition for space between sessile CFT species (see Sebens, 1985a, for a comprehensive list of references). Competitive success can result from a variety of mechanisms - physical and chemical aggression, bulldozing or smothering, shading, and perhaps localised food depletion. Erect species may limit competition for rock surface by having a small attachment area, resulting in niche partitioning (Jackson, 1977). A study of competion between rock wall species in Massachusetts over a two year period (Sebens, 1985a) enabled them to be ranked in a competitive hierarchy, with the colonial ascidian *Aplidium* and the plumose anemone *Metridium* at the top, and sponges and crustose algae at the bottom. Those species at the top of the hierarchy had thick and massive growth forms. These relationships were predominantly hierarchical, in contrast to the non-transitive ‘network’ relationships noted for cryptic coral reef fauna (Buss & Jackson, 1979). The implication is that undisturbed rock wall communities will progress to a ‘climax’ situation dominated by a few species, and that physical or biotic disturbance is important to generate and maintain diversity. In circalittoral biotopes physical disturbance seems to be uncommon, and biotic disturbance will be the major agent. Changes in abundance of keystone species could consequently have substantial effects on biodiversity. In Sweden areas from which starfish were excluded developed 100% cover of *Ciona*, but when they were present more species could co-exist (Lundälv & Christie, 1986).

Currently we do not know enough about biological interactions in British CFT biotopes. It is fairly certain that the space-occupying species are in a similar state of competition to that described by Sebens above - certainly competition was strong between species growing on artificial substrata (Hextall, 1994). The role of starfish, urchins and other higher level predators must be of similar importance to that demonstrated elsewhere. Relevant experimental studies are certainly needed, but as a precautionary measure major changes in abundance of potential keystone species must be taken seriously.

C. STABILITY OF CFT COMMUNITIES

1. Longevity of species and community fluctuation

For most CFT species there is little information under this heading, but for some of the more prominent ones studies have been made. Some of these have relatively long life spans ranging from 6 - 100 years.

The soft coral, *Alcyonium digitatum*, is a very prominent member of the CFT community. Observations of marked colonies have shown that colonies of 10-15 cm in height are between five and ten years old (Hartnoll, unpublished). The life span certainly exceeds 20 years - colonies have been followed for 28 years in marked plots (Lundälv, pers. comm.). The sea urchin, *Echinus esculentus* is the most prominent grazer in the CFT community, and a species which has suffered from commercial collecting (see section V.C). Specimens of 10 cm diameter are about 6 years old (Comely & Ansell, 1988). Gage (1992) determined an age of eight years for larger specimens, and suggested they may live to 16 or more years in Scottish waters. Nichols et al. (1985) give a life span of up to 12 years off Plymouth. The sea fan, *Eunicella verrucosa* is another species which has suffered from collecting. This is notoriously slow growing (5 cm height after 5 years, Keith Hiscock cited in Eno et al., 1996), colonies increasing in length by only about 10 mm per year at Lundy (Fowler & Pilley, 1992), and by 6 mm or less per year at Skomer where Bullimore (1986) suggested that the largest colonies may be over 100 years old. However, analysis of the detailed Skomer monitoring data (Gilbert, in prep.) suggests that smaller colonies grow faster, and that a colony of under 20 cm is probably no more than 5 years old. The various cup corals are described as slow growing and long lived on the basis of photographic monitoring (Fowler & Pilley, 1992). The starfish, *Asterias rubens*, is a common predator within many CFT biotopes. It has a life span of 7-8 years (Schafer, 1972). Some ascidians are long lived, 3-4 years in *Boltenia echinata,* 5-8 years in *Ascidia mentula,* and probably over 20 years in *Pyura tesselata* (Svane & Lundälv, 1981, 1982a, 1982b).

In contrast there are other CFT species which are short lived, essentially annual in fact. These include the ascidians *Ciona intestinalis, Clavellina lepadiformis, Ascidiella aspersa* and *A. scabra* (Costelloe et al., 1986; Dybern, 1965; Svane, 1983).

Information is restricted, but it is clear that a number of the more prominent members of the CFT community are relatively long lived, and fairly slow growing. It may be concluded that because of this communities which they dominate will be relatively stable with time, but that when they are damaged recovery to their original complexity may be slow. This recovery will be hindered by the fact that for a number of species recruitment was observed to be very spasmodic, particularly for species near the limits of their geographical range (Fowler & Pilley, 1992; Hiscock, 1998a). On the other hand communities dominated by the annual species will exhibit marked seasonal and year to year fluctuations - for example *Ciona intestinalis* (Costelloe et al., 1986). In general it appears that longevities, and community stability, increase with increasing depth, though hard data to support this are limited (Lundälv, 1985).

Detailed information on changes with time in circalittoral communities derive only from studies where fixed quadrats have been monitored (normally photographically) over a period of years. In Britain such studies have been carried out Lundy and the Scillies over the period from 1983 (see Fowler & Pilley, 1992 for summary), and at Skomer from 1982 (Bullimore, 1987). Various changes were detected, particularly in the abundance of species of cup corals.

- Thus in the Scilly Isles both *Leptopsammia pruvoti* and *Caryophyllia smithii* declined between 1984 and 1991.
- A number of the trends observed were similar at the Scilly, Lundy and Skomer sites, probably a response of southern species to climatic changes.
- Although various changes were observed, the general conclusions for studies at all three sites was that there was considerable stability both seasonally and from year to year, with conspicuous species represented by specimens of considerable age (Fowler & Pilley, 1992).

If this were generally true for CFT biotopes there would be encouraging implications for management strategies, and for the development of monitoring programmes to detect unusual levels of change. However, other studies discussed below show that in at least some CFT biotopes change on a seasonal and year-to-year basis are the norm rather than the exception.

The only other comprehensive north European studies are those on the Swedish west coast by Lundälv and his co-workers. Changes in abundance are described for a variety of ascidians and for the anthozoan *Protanthea* (for summary of work see Lundälv, 1985). Annual seasonal fluctuations were clear, and year-to-year variations also occurred, as did longer term trends: some changes were common to a series of sites, suggesting a common cause. The composition of the community at a site could change completely. One area was dominated by ascidians from 1970-81, but these were replaced by the tube worm *Pomatoceros* from 1982-93, with ascidians only beginning to reappear in the mid nineties (Lundälv, 1996). Lundälv's work generally tend to confirm that stability of communities increases in more stable environments - those which are deeper and more sheltered.

Another series of long term observations on fixed circalittoral sites was carried out on the east coast of the U.S.A. in Massachusetts (see Sebens, 1985a, for summary). Year to year variability occurred in the percentage cover of component species, but there was never a change in overall character. However the duration of study was six years, and it was seen in Lundälv's work that sites could be stable for that duration, yet still subsequently undergo major changes.

2. Reproductive modes and recruitment patterns.

We have seen that the majority of CFT species are sessile so how do they get to new areas? The answer is that whereas the adults are indeed fixed in one place, the larval stages are generally highly mobile. The majority of CFT species (well over 90%) have planktonic larvae which float or swim in the water column, are carried by the currents, and dispersed to new locations. Thus the common soft coral *Alcyonium digitatum* has an actively swimming larva with a large store of energy-yielding yolk (Hartnoll, 1977). In captivity some larvae were still actively swimming fourteen weeks after hatching (Hartnoll, 1975). That duration is probably unnaturally long, but with a 1 knot drift (a fairly average rate) a floating larva can be carried 100 km in a mere two days.

Dispersal is one thing, but reaching a suitable habitat at the end is another matter. Obviously there must be a great loss of larvae which never reach the right place to settle. However, settlement is not a random process - larvae do have limited powers of swimming, and they show adaptive behaviour patterns to help find a place where they can survive (Crisp, 1974). A combination of responses to light and gravity, for example, can ensure that settlement occurs only on steep or downwardly facing surfaces. A preference to settle near to adults of the same species means that the environment must be favourable for survival. Clearly, despite the risks, pelagic larvae are an effective reproductive strategy. Most common CFT species produce such larvae, and experimental deployment of settlement plates shows rapid recruitment by a variety of species (Hextall, 1994).

Nevertheless there are some CFT species which lack pelagic larvae, and others whose pelagic larvae normally settle very quickly. In the soft coral, *Parerythropodium coralloides*, the eggs are brooded and the larvae crawl away from the parent to settle nearby (Hartnoll, 1975). The species tends to occur in large patches (successful settlement will be almost guaranteed), but not very commonly, and it is not known how it disperses over distances. The conspicuous plumose anemone, *Metridium senile,* is interesting in that it has pelagic larvae produced by sexual reproduction, and also buds off daughter anemones asexually from its base (Kaplan 1983). This might seem an ideal way to hedge ones reproductive bets, but few species have such flexibility. Other anemones reproduce asexually such as *Gonactinia prolifera* and *Protanthea simplex.* The jewel anemone *Corynactis viridis* also reproduces asexually to produce patches of a single colour. Swimming larvae which often settle within minutes of release occur in various ascidians (Olson, 1983) and bryozoans (Young & Chia, 1981).

The relevance of reproductive strategy to SAC management is that any species lacking a planktonic dispersal phase, or with otherwise constrained dispersal power, must be regarded as more vulnerable to locally adverse conditions. Once removed, it may not easily reappear, and management strategies should take account of this.

3. Stochastic factors in community development.

Previously ecologists have tended to emphasise the predictability of community composition in relation to the physico-chemical environment. More recently though, stochastic factors, centred upon the availability of larvae and the creation of vacant space, have come to the fore. This is the topical 'supply side' hypothesis (Underwood & Fairweather, 1989).

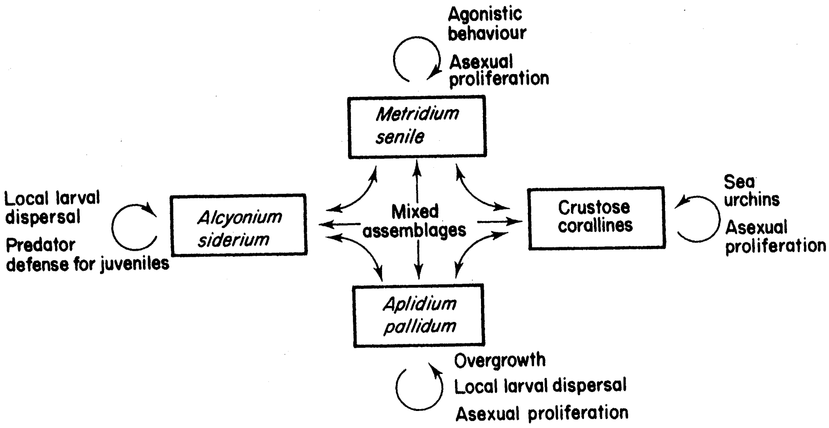

Figure 8. Alternative locally stable states of vertical rock wall community in Massachusetts. Positive feedback loops indicate processes that maintain each state.

> High levels of predation could destabilise *Alcyonium, Metridium* or *Aplidium*: massive sea urchin mortality or migration would destabilise the crustose corralines (from Sebens, 1985a).

One of the features of CFT communities is their fine-scale spatial variation - they tend to be very patchy. Whilst the infralittoral tends to be more predictable, circalittoral rock tends to be a mosaic of different species patches. The same is seen in some parts of the rocky intertidal, where it has been attributed to the effects of biological interactions and unpredictable recruitment (Hartnoll & Hawkins, 1985). Similarly in the subtidal, the different assemblages may represent 'alternate stable states' (Sutherland, 1974; Sebens, 1985a,b). In most CFT biotopes substratum space is very fully occupied, and the availability of space is a controlling resource for the settlement and growth of species. According to when free space is made available, and on which species are recruiting at that time, different assemblages of species may develop under the same physico-chemical conditions. Once established, often following a successional sequence (Hextall, 1994), these assemblages are stable for long periods (we have seen the long life span of many CFT species), and different assemblages may co-exist in close proximity. In Massachusetts Sebens (1985a) described four alternative locally stable states, dominated by the anemone *Metridium senile,* the soft coral *Alcyonium siderium,* the tunicate *Aplidium pallidum* and crustose corraline algae respectively. Once established each state is maintained by a different positive feedback loop (Figure 8).

The practical implications of this are that it makes the objective classification of communities, and the correlation of community composition with environmental variables, much more difficult - more discrete 'communities' will be described than in fact exist. If such areas are being monitored, community change may be considered an indication of environmental change, whilst it may be only part of a natural biological cycle involving a switch between stable states.

D. RELATIONS WITH OTHER COMMUNITIES

1. Import and export of biomass and energy

Some benthic communities are net producers of energy, others are net consumers (Hartnoll, 1983b), and so to a degree the latter must be considered dependant on the former. The infralittoral kelp-dominated biotopes are some of the most profligate net producers (Miller et al., 1971), with production levels of 40 000 kJ m^{-2} yr^{-1}, of which over 90% is exported. They produce far more energy by primary production than their resident herbivores can eat, and the rest is exported to fuel other ecosystems. Sheltered rocky shores, salt marshes, sea grass beds, and planktonic communities are all regions of high, and usually surplus, primary productivity.

Other biotopes lack a significant plant component, so cannot synthesise their own energy supply, and must import it. Sandy and muddy substrata, both intertidal and subtidal, are largely of this type in north temperate regions - though intertidal and shallow sediments may have significant production by benthic diatoms . Exposed rocky shores support only limited macroalgal growth. Subtidal rock surfaces with restricted light supply - the circalittoral - are basically animal dominated communities.

So the CFT communities depend primarily on food from outside - where does it come from? Since the primary consumers of the community are filter feeders, the food arrives via the water column, and more exposed conditions mean that the food supply is more regularly replenished by water movement. The suspended food is a mixture of living and dead organic matter. The living matter is the plankton, a mixture of small floating plants and animals. The dead material originates from many sources, part from the plankton, part from other benthic communities. Fragmented algae from shallower communities will contribute to this pool of energy.

Thus anything which affects primary production in the water column or in shallow-water ecosystems may ultimately affect the CFT: the impact of pollution or eutrophication, for instance, may well extend to these deeper areas. However, although not primary producers, CFT communities are important secondary producers. They accumulate and concentrate the primary production from a large water mass, and make this readily available to higher trophic levels.

The energy flow is not entirely one way though - the CFT will re-export some of the energy it has acquired. Some will be as detritus in the form of faeces, dead bodies, etc. Some will be as reproductive products, shed into the water, and contributing to the biomass of the plankton. A substantial proportion of the plankton consists of the larval stages of benthic species - the meroplankton. And some will be exported by visiting carnivores who come to feed on an abundant food source.

2. Nursery, shelter and food provision

Whilst most of the CFT species spend their larval life in the plankton, there are a few planktonic species which spend their early stages within the CFT biotopes. This is true, in rather different degrees, of the hydroids and the jellyfish.

We have seen in section III.B that hydroids are common and conspicuous members of CFT communities, but the attached hydroids are only the juvenile stages. The sexually reproducing mature stages are small medusae which are released into the plankton, where they reproduce to produce larvae which settle again. In contrast, for jellyfish the large adult medusae in the plankton are the prominent phase. The juveniles stages live attached to rocks as an inconspicuous scyphistoma stage in which the jellyfish overwinters. In spring this buds off a series of juvenile medusae, or ephyrae, which grow rapidly in the plankton to form the adult. Numbers of jellyfish are unpredictable, and dense aggregations are of environmental concern: factors affecting their juvenile stages could be of relevance to management.

A further way in which CFT communities interact with others is by the provision of food and/or temporary shelter to mobile species which are not permanent CFT fauna. Shelter is important to juvenile fish, which can find refuge (and food) amongst the dense turf of sessile species. A food source is provided to large mobile crustaceans and fish which are attracted by the rich and stationary food supply available on circalittoral rock. It is for this reason that anglers will fish in CFT biotopes, posing a possible impact threat (see below), and generating management implications.

E. IMPLICATIONS FOR BIODIVERSITY

1. Abundance/scarcity of CFT areas

On a national scale CFT biotopes cannot be considered scarce. There are large areas of suitable environment around the south-western, western and northern shorelines of Britain. Thus CFT biotopes as an entity can never be considered under threat - their abundance and frequent inaccessibility will ensure this. However there is a geographical difference in the frequency of distribution, in that CFT biotopes are generally scarcer and more scattered on the eastern and southern coasts (this is clear from their prevalence in the various candidate SAC sites - Figure 5).

However, this abundance does not mean that threats to biodiversity can be dismissed. Local biodiversity could be at risk in those areas where CFT biotopes are generally scarce, and in consequence possibly heavily utilised. This is discussed in relation to anthropogenic activities in Section V.

The other consideration is that whilst CFT communities as a whole are abundant, specific CFT biotopes may be relatively scarce. This could relate particularly to those biotopes characteristic of sheltered locations, and those found in areas of reduced or variable salinity. Such biotopes will not only tend to be scarce, but by the nature of their environment, more accessible and more prone to anthropogenic impacts. CFT biotopes will also decrease in abundance with depth (see section II.B) as a consequence of the reduced availability of hard substrata, yet deep communities may be particularly diverse (Jensen & Fredriksen, 1992), and not necessarily protected by their depth. There has recently been concern regarding the impact of deep sea trawling on *Lophelia* reefs. The representation of these scarcer biotopes in SACs requires attention.

2. Geographical factors.

This aspect can be examined in two ways - in terms of the geographical distribution of the MNCR biotopes, and by looking at the distribution of selected individual CFT species. In both cases this has been done by generating distribution maps from the JNCC's MNCR database (**Appendix 4**). It is appreciated that the information in this database is far from complete both in terms of availability of data, and inclusion of available data in the database.

From the maps in Appendix 4 it would appear that there are no biotopes with a widespread and general distribution around the British Isles, but this must be suspected an artefact of the restricted data input to the database. However, many have clearly regional distributions.

- Some biotopes have a very obvious northern distribution, such as ECR.CFa/CCparCar (Coralline crusts, *Parasmittina trispinosa, Caryophyllia smithii, Haliclona viscose,* polyclinids and sparse *Corynactis viridis* on very exposed circalittoral rock - App. 4, Fig.1a) and MCR.XFa/ErSSwi (Erect sponges and *Swiftia pallida* on slightly tide-swept moderately exposed circalittoral rock - App. 4, Fig 4d)..
- On the other hand there are others which are found only in the south, e.g. MCR.ByH/Flu.Hocu (*Haliclona oculata* and *Flustra foliacea* with a rich faunal turf on tide-swept sheltered circalittoral boulders or cobbles - App. 4, Fig. 6b) and MCR.As/MolPol (*Molgula manhattensis* and *Polycarpa* spp. with erect sponges on tide-swept moderately exposed circalittoral rock - App. 4, Fig. 8a).
- Yet other biotopes are predominantly on the east coast, such as MCR.ByH/Flu.Flu (*Flustra foliacea* on slightly scoured silty circalittoral rock or mixed substrata - App. 4, Fig 5c).

In order to conserve a full range of CFT biotopes it is clearly necessary not only that CFTs as a whole are adequately represented in the SACs, but that these SACs are appropriately distributed geographically. This will ensure that the geographically-limited biotopes are all represented. The distribution of Demonstration SACs where ‘reefs’ are a special feature (Papa Stour, Berwickshire and North Northumberland Coast, and Lleyn Peninsula and the Sarnau) provides a fair geographic coverage, but excludes the extreme south west to which a variety of important CFT biotopes and species are restricted. The presence of a number of CFT communities in the Plymouth Sound SAC in part redresses the balance. However, the various Candidate SCAs which are not selected as demonstration sites provide a comprehensive geographic coverage, with Lundy and the

Pembrokeshire Islands presenting a diversity of CFT communities in the south west which have already been extensively studied as a result of their Marine Reserve status.

The fundamental reason why biotopes are geographically restricted is not basically that the particular habitats are themselves geographically restricted, but that in different geographical areas these habitats are occupied by species with restricted ranges. Examples of species distributions are shown in the figures in Appendix 4**.**

- A variety of species have broad general distributions around Britain, and their distribution probably mirrors the overall distribution of CFT biotopes. Such species include *Alcyonium digitatum* (App. 4, Fig 13c), *Cliona cellata* (App. 4, Fig 12a), *Flustra foliacea* (App. 4, Fig 12c), *Metridium senile* (App. 4, Fig 14d), *Nemertesia antennina* (App. 4, Fig 13a) *Pomatoceros triqueter* (App. 4, Fig 16b) and *Tubularia indivisa.*
- However, there are other species with clearly limited distributions. *Eunicella verrusosa* (App. 4, Fig 14a) and *Balanophyllia regia* (App. 4, Fig 15b) are restricted to the south west, *Swiftia pallida* (App. 4, Fig 14c) to the north west, and *Strongylocentrotus droebachiensis* (App. 4, Fig 16d) to the far north in the Shetlands.
- *Corynactis viridis* (App. 4, Fig 15a) is widely distributed up the western seaboard from the Scillies to the Shetlands, but is absent from eastern shores. Other widespread species absent from eastern areas include *Pentapora foliacea* (App. 4, Fig 12d) and *Pachymatisma johnstoni* (App. 4, Fig 12b).

Most of the above examples of species with restricted distributions are used to characterise one or more CFT biotopes. The implication is that some CFT biotopes are ecological equivalents of other biotopes, which they replace geographically. Thus MXR.XFa/ErSEun (erect sponges, *Eunicella verrucosa* and *Pentapora foliacea* on slightly tide-swept moderately exposed circalittoral rock) is restricted to the south west. In the north west it is replaced by the equivalent MXR.XFa/ErSSwi (erect sponges and *Swiftia pallida* on slightly tide-swept moderately exposed circalittoral rock), where one sea fan species is replaced by another.

3. Species of special interest.

CFT communities are extremely diverse, which is one of their attractions for conservation purposes. Notes on habitat and distribution, and illustrations of most common CFT species can be found in Erwin & Picton (1990). However, this very diversity makes the selection of species of special interest an invidious task. Nevertheless some selection and prioritisation is essential, since they will be necessary to help determine the species and the biotopes to be included in the SAC monitoring programmes described in section VI.C.

Selection criteria can be species-specific, and site specific. The former will define a list of species of general interest, the latter will restrict that list to one relevant for each particular SAC. However, the benefits of regional comparisons should be kept in mind (see section VI.C) and SACs in the same area should, where possible, highlight similar lists of species. Hiscock (1998a, section 4.2.2) identifies a number of general selection criteria for species to be included in ACE surveys, and these have been used as a starting point for selecting criteria appropriate to CFT species.

a. Species-specific criteria

These are not in any rank order - in some cases they may apply more strongly in some SACs that others. Thus, for example, the ‘risk from exploitation’ may well be a local rather than a general phenomenon.

- Species at risk from exploitation.
- Species used to characterise CFT biotopes.
- 'Keystone' species influencing the dynamics of CFT biotopes.
- Species of limited distribution or general rarity.
- Biodiversity action plan species.
- Species known to be in decline.
- Species with limited dispersal powers.
- Long-lived slow growing species.
- ‘Indicator species’ known to be sensitive to environmental change.

b. Site-specific criteria.

- Species present in the area..
- Species near the limit of their geographic range.
- Species at risk from localised impacts.
- Species locally or regionally rare.

This list of criteria is not exhaustive, and not all criteria are of equal weighting. For example it would be mandatory to include Biodiversity Action Plan species in any monitoring programme, but most of the other criteria involve subjective decisions, or there is a lack of definitive information. In most instances species meeting a greater range of criteria would be more likely to merit inclusion. In Table 1 an attempt is made to categorise a selection of CFT species according to the species-specific criteria - neither the list of species, nor the criteria used, should be regarded as exhaustive, and the procedure needs developing in more detail.

This table provisionally identifies certain species as meeting more of the criteria than others. The following species feature under four or more headings - *Alcyonium glomeratum, Eunicella verrucosa, Hoplangia durotrix, Leptosammia pruvoti, Pentapora foliacea* and *Echinus esculentus.* Thus they should be regarded as ‘species of special interest’ under this analysis, and should feature in any monitoring and management programmes.

4. Biodiversity Action Plan species.

The number of CFT species (fairly broadly defined) included in the Biodiversity Action Plan list is fairly small (eight species), and there are no reasons given for their inclusion, nor for the exclusion of other species which might seem equally (or more) eligible. The included CFT species are listed below, with brief details of their occurrence and distribution in the U.K. where relevant, and a few key references. When action plans have been developed for these species, these plans will need to be taken into account for management purposes when the species occur within SACs.

Coelenterates (details mostly from Manuel,1981).
Aiptasia mutabilis: The trumpet anemone, restricted to the extreme south-west of England and Wales. From the intertidal down to about 30 m, in sheltered habitats. Reproduces asexually, and by viviparity (Stephenson, 1935).
Alcyonium glomeratum. A soft coral - red sea fingers (Beldam & Robins, 1971; Robins, 1968). A typical CFT species, found in areas with minimal algal cover and out of light, generally from 10-50 m. Prefers limited wave action. Restricted to south and west coasts.
Amphianthus dohrnii: An anemone, grows epizoically on gorgonians, hydroids and other organic structures (Stephenson, 1935; Carlgren, 1949). In Britain generally grows on *Eunicella* or

Tubularia, from 10 m to deep water. Formerly common in English Channel and around southern Ireland, but now considered rare with few recent records.

Eunicella verrucosa: The pink sea fan (Carpine & Grasshoff, 1975). Restricted to the south and west coasts (App. 4, Fig 14a). On vertical or overhanging rocks from 10-100 m in moderate exposure, a typical CFT species.

Hoplangia durotrix: The Weymouth carpet coral (Best, 1969), a small colonial coral restricted to the coasts of Devon and Cornwall. Occurs out of the light in caves and crevices down to 25 m.

Leptosammia pruvoti: The sunset star coral, a solitary coral (Best, 1969). In North Devon and various localities in the English Channel. In clefts, under cave roofs or in steep-sided gullies, 10-40 m.

Parazoanthus axinellae: A colonial zoanthid, found mainly on organic substrata such as sponges, worm tubes and dead gorgonians, but also on rock. Limited to extreme south west of Britain, in depths of 6-100 m.

Sea urchins

Strongylocentrotus droebachiensis: The northern sea urchin (Britt & Petersen, 1982; Hagen, 1995), restricted to the north east (App. 4, Fig 16d). In sheltered areas, but also those exposed to strong currents.

G. KEY POINTS FROM CHAPTER III

- Most prominent CFT species are sessile - ranging from tall erect species like sea fans and soft corals to flattened crusts like many bryozoans. There are also large mobile species, mostly decapod crustaceans and echinoderms, and a diverse fauna of small mobile cryptic species.

- Under conditions of extreme exposure robust low-growing forms predominate. As exposure moderates the taller erect forms come into prominence.

- The prominent CFT species are dominated by a few taxa - sponges, coelenterates, serpulids, bryozoans, echinoderms and tunicates.

- Most species, including almost all the sessile ones, are filter feeders. Mobile species are grazers (e.g. sea urchins), scavengers or carnivores (e.g. starfish).

- The role of ‘keystone species’ such as sea urchins, starfish, crabs and lobsters is suspected to be important. However sound data are scarce for British CFT biotopes.

- Many prominent CFT species are slow growing and long lived. However others, including some tunicates, are annual. Many CFT biotopes seem stable with time, but there is evidence of annual and longer-term cycles in some. Data are scarce.

- Most CFT species have pelagic larvae. These are important in the spread of species, and recolonisation of biotopes. Species without pelagic larvae must be considered at particular risk from local impacts.

- CFT communities are patchy, and space for colonisation is a scarce resource. Stochastic factors are important in determining community composition.

- CFT communities are not self contained. They import energy/biomass in the form of suspended food, and export energy/biomass as faeces and reproductive products. They provide food and shelter for mobile animals.

- CFT biotopes are generally abundant. However those in shelter and reduced salinity are scarce, and some biotopes and species are very limited geographically.

- A format is suggested for identifying ‘species of special interest’. This has species-based and site-based criteria.

- Eight CFT species occur in the UK Biodiversity Action Plan list, and must feature in any SAC management plan.

IV
SENSITIVITY TO NATURAL EVENTS

A. GLOBAL WARMING/SEA LEVEL CHANGES

Predictions of temperature rise as a consequence of global warming vary greatly, from 0.5°C to 2.5°C by 2030 (Schneider & Rosenberg, 1989). With such uncertainty there is limited benefit in trying to predict detailed outcomes, but two possible effects may be briefly considered. Firstly, the direct effect of a rise in sea temperature may change the geographic distribution of species. Secondly, any changes in sea level will affect the environment of CFT communities. In preceding sections the influence of environmental factors, and the regional nature of many species and biotope distributions, have both been emphasised.

Global warming can be expected to affect the geographical range of species reaching their northern or southern limits within the British Isles. Southern species with limited ranges in the south west such as *Eunicella verrusosa* (App. 4, Fig 14a) and *Balanophyllia regia* (App. 4, Fig 15b) may be expected to extend their ranges. Conversely northern species like *Swiftia pallida* (App. 4, Fig 14c) and *Strongylocentrotus droebachiensis* (App. 4, Fig 16d) may retreat. Examples of such temperature-mediated distribution changes have been described for intertidal species following long-term intensive monitoring - the studies on the barnacles *Chthamalus* and *Semibalanus* in the south-west of Britain provide the clearest example (Southward, 1967, 1991). It will require similarly detailed monitoring to reveal such changes subtidally, but it is necessary to recognise such naturally mediated changes as being distinct from anthropogenic impacts.

Estimates of sea level changes, as a result of global warming, are equally highly variable. They range from 0.5m to 3.5m over the next hundred years (Boorman et al., 1989), though most estimates are near the low end of this range (Houghton et al., 1990). Such changes might have a marginal effect on the position of the infralittoral/circalittoral boundary, but major direct effects on the CFT biotopes, which cover a substantial depth range, would not be expected even from the higher estimates. Indirect effects are more likely, where changes to the coastal environment may promote rapid erosion with increased levels of turbidity and siltation.

B. WEATHER AND STORMS:

The exposed position of many CFT biotopes places them at risk from severe weather conditions. However, two factors will mitigate against damage. One is the depth of most biotopes, usually 20 m or greater, and the rapid rate at which wave induced exposure attenuates with depth is described in section II.D. The other is the generally robust nature of exposed CFT species, which are adapted to withstanding severe water movement. In coral reef biotopes there are records of storm damage to substantial depths - to 27 m in Hawaii (Walsh, 1983), to 30 m in Jamaica (Huston, 1985), and to over 35 m in French Polynesia (Harmelin-Vivien & Laboute, 1986). However there are no confirmed reports of similar effects in British CFT biotopes, though the systematic recording to detect such damage is probably lacking. In the Gulf of Maine rock wall communities were monitored by Sebens (1985a) through a series of violent storms, but no damage was observed. In fact a modest amount of storm damage would not necessarily have adverse effects. By creating patches of free space it can limit dominance by a few species and maintain high levels of biodiversity - the ‘intermediate disturbance hypothesis’.

There are two biotopes more likely to suffer storm damage. Scour-prone biotopes on unstable substrata are clearly at risk, from scouring action, and from covering by mobile sediments. However these generally have an impoverished community of scour-tolerant species, so storm effects may be difficult to detect. CFT communities in relatively shallow waters, normally on vertical or steeply sloping surfaces, would also be sensitive to storm damage. These shallow biotopes are relatively scarce, and their accessibility gives them added value and requirement for management consideration. Only intensive monitoring programmes will determine the extent to which storm damage actually occurs.

Indirect effects of weather can arise from the effects of heavy rains and floods, which can be mediated by climatic cycles such as the N.A.O. These can affect rate of nutrient transport to the sea, water stratification, and the initiation of plankton blooms. These effects are more likely to impact shallow and semi-enclosed biotopes.

C. PROLIFERATION/REDUCTION OF PREDATORS AND GRAZERS

The density of predators and grazers can be subject to wide natural variations. The fluctuations of the northern sea urchin, *Strongylocentrotus droebachiensis*, have been well documented (Hagen, 1995). The endoparasitic nematode *Echinomermella matsi* appears important in mediating these fluctuations (Skadsheim et al., 1995; Hagen, 1996). The major role which grazers can play in controlling infralittoral algal populations has been discussed. A grazer reduction can allow the lower depth limit of canopy algae to extend downwards, though only to the levels which they are naturally capable of reaching, which will not impact on the main body of the circalittoral zone. Predators such as *Asterias* are also suspected to have importance in structuring communities, but less is known of their fluctuations in number. More needs to be known concerning the dynamics of predator and grazer numbers in CFT communities - very little is known of the factors which regulate their numbers. Until this understanding is available there will be substantial difficulties in separating natural variability from anthropogenic impacts.

D. KEY POINTS FROM CHAPTER IV

- Global warming may affect the geographical extent of CFT species and biotopes, especially those with their current limits within the British Isles.
- Any sea level changes resulting from global warming will have minimal impacts on CFT biotopes.
- There are no records (but little systematic monitoring) of storm damage to CFT biotopes - they are largely protected by their depth.
- Changes in abundance of keystone grazers and predators can affect CFT community structure. Little in known of the natural causes and extent of such fluctuations.

V
SENSITIVITY TO HUMAN ACTIVITIES

In the previous section there has been a discussion of the sensitivity of CFT species and communities to changes in the natural environment. The environment may also be changed as a result of human activities - anthropogenic impact - and one of the concerns of management is to distinguish the two. There are two broad categories of human impact which can affect natural communities. One is the addition of substances to the environment, broadly classified as 'pollution'. The other is human activity in the marine environment, such as fishing and diving. The two will be considered in turn. However, not all human activity is necessarily negative in its impact on CFTs - see section E.

A. POLLUTION

Pollution is clearly a major concern in the management of SACs, but problems posed are considerably more complex than those which arise in relation to other human activities. Activities such as fishing are relatively clear-cut in terms of origin, effects and potential for control. By contrast pollution may be difficult to analyse on all these counts, and can pose major problems for effective management, because:

- The origin of pollution may not be a known point source, with a limited distribution, but may have uncertain origins and be diffuse over a wide area.
- A pollutant may affect the CFT community in situ, or it may affect the pelagic larval phase whilst in the water column, possibly in a different location. In either case little is known of the sensitivity of CFT species to concentrations of specific pollutants, and even less of synergistic effects.
- Pollutants may build up in organisms and through the food chain, so that concentrations in the water or sediment may be of little direct relevance.
- Most pollution will arise outside the SAC, limiting management options.

The following pollutants will be considered - sewage (and other organic based effluents with the same basic effects), oil, synthetic organic compounds, and heavy metals.

1. Sewage

Sewage and other organic-based effluents present several environmental problems.

- They contain inorganic plant nutrients, and induce potentially serious impacts which are considered below under eutrophication.
- They add dissolved and particulate material to the water which will reduce light penetration and deposit sediment onto the substratum.
- Perhaps most importantly, they utilise the dissolved oxygen in the water.

The majority of CFT biotopes occur on open coasts in areas of vigorous water movement, and either in or close to waters of considerable depth. They are not generally near sources of discharge of organic pollutants, such as sewage, and even if they were, they would be considered as *Higher Natural Dispersion Areas*, and therefore apparently at little risk. The only exceptions are the limited CFT biotopes in sheltered semi-enclosed situations such as in the Scottish sea lochs and south western rias. These would be exposed to risk of depletion of dissolved oxygen if there was a substantial organic input, and because of their scarcity, have a high conservation value. Past experience in Scandinavian fjords and bays has shown this to be a real threat. The choice of

SACs is based upon the existing quality of environment, which means that they are not currently in an area receiving excess organic input. Any proposed change in effluent treatment or discharge regimes, or new source of organic input (e.g. intensive fish farming) would be a management concern, and must be evaluated in the context of the water dispersion patterns within the SAC. Fortunately all such proposals will (it is to be hoped) be subject to strict consent conditions.

2. Oil

Another important form of organic pollution is oil, and in contrast to the above, serious oil pollution incidents are quite unpredictable. For the purposes of SAC management, the treatment of oil pollution can present conflicts of interests for different biotopes, and the optimal measures for CFT biotopes cannot be pursued in isolation. Untreated oil is not a risk, since it is concentrated mainly at the surface, and the CFT biotopes are protected by their depth. If oil is treated by dispersant the resulting emulsion will penetrate down the water column, especially under the influence of turbulence. However, the target response of the Marine Pollution Control Unit is to spray offshore when spraying is required, and spraying inshore should be a last resort. An oil spill contingency plan is an integral part of every SAC management programme, but it will concentrate on vulnerable (or valuable) components of the system - marine birds and mammals, soft intertidal sediments, aquaculture developments, and amenity sites. CFTs will inevitably, and realistically, come low on the list of considerations.

3. Synthetic organics and heavy metals

Synthetic organic compounds include pesticides, PCBs and TBT antifouling. Heavy metals include cadmium, lead, and mercury. All are known to have toxic effects in low concentrations, with larval stages being particularly sensitive, and to be capable of high levels of bioaccumulation. Because of this bioaccumulation they often affect higher trophic levels most severely, and become a serious consideration in any species used for human consumption. If there are any suspected point sources within or near the area of the SAC, then they will have to be a feature of management plans. Their potential impact upon the dispersive larval stages means that there influence cannot be ignored beyond the boundaries of SACs, since they may affect recruitment to the communities.

B. EUTROPHICATION

Eutrophication is the build up of inorganic plant nutrients in the water body. The effects, in extreme circumstances, can result in reduced water clarity, lowered dissolved oxygen levels, and toxic water quality. The causes, effects and monitoring of eutrophication are considered in turn.

The nutrients of primary concern are nitrates and phosphates, and these enter the seawater by a variety of routes: outflow in rivers, direct discharges of sewage and industrial effluents, and atmospheric input all contribute. The concentrations of these nutrients have increased substantially in many British coastal areas in recent years, and are a matter of increasing concern. Thus in the Irish Sea nutrient levels have roughly doubled over the past forty years (Allen et al., in press), and some of the symptoms of eutrophication described below are becoming increasingly evident (Shammon et al., 1997).

The primary effect of eutrophication is to stimulate algal growth, both benthic macroalgae and the microscopic phytoplankton. The adverse effects of excess macroalgal growth are largely aesthetic, caused when increased amounts are cast up on the strandline, or when dense algal

growth carpets intertidal areas. However, the effects of phytoplankton proliferation are more serious. Phytoplankton blooms fall into two categories. ‘Nuisance’ algae (e.g. *Noctiluca, Phaeocystis*) can create problems by discolouring the water, creating aesthetic nuisance, and more severely by de-oxygenating the water and killing fish and benthic organisms. ‘Toxic’ algae such as *Dinophysis* can be taken up by shellfish which if eaten may produce diarrhoetic shellfish poisoning (DSP), whilst *Pseudonitzchia* can induce amnesic shellfish poisoning (ASP). Both of the above genera were recorded in the Irish Sea in 1997 (Shammon et al., 1997), and there are established guideline levels and monitoring procedures (Anderson, 1996).

Although the process of eutrophication is unambiguously linked to increased nutrient levels, there is no clearcut correlation between specific nutrient concentrations and degree of eutrophic phenomena. Nutrient levels associated with serious eutrophic damage in one area may be without obvious effect in others. The problem is complicated by the wide fluctuations in surface nutrient levels during the year, from winter maxima to virtual absence in the summer (see Kennington et al., 1997 for a recent case study in the Irish Sea). For management purposes the only appropriate strategy is to take account of the standards proposed by the Comprehensive Studies Task Team (CSTT) of the U.K. Government in relation to meeting the requirements of the E.U. Urban Waste Water Treatment Directive (UWWTD). An area is considered to be ‘hypernutrified’ if the winter nutrient concentrations exceed 12 mmol DAIN (dissolved available inorganic nitrogen) m^{-3} in the presence of at least 0.2 mmol DAIP (dissolved available inorganic phosphorus) m^{-3} (CSST, 1997).

Since by definition CFT communities are essentially animal dominated, the effects of eutrophication will be indirect. One effect of eutrophication will be the way it influences the growth of benthic macroalgae, which may influence the level of the boundary between the infralittoral and the circalittoral. Improved macroalgal growth might be expected to lower this boundary, but at the same time increased phytoplankton density will reduce light penetration, perhaps more than compensating for any improved growth. Observations confirm that eutrophication does in fact raise the lower limit of macroalgal growth (Kautsky et al., 1986; Michanek, 1972; Svane & Gröndal, 1988) - in the Baltic from 11.5 m in 1944 to 8.5 m in 1984 (Kautsky et al., 1986). On the Swedish west coast subtidal rocky areas previously algal covered had been taken over by mussels in 1988 (Lundälv, 1990). Large algae are also affected by the improved competitive advantage of ephemeral filamentous algae in higher nutrient concentrations (Lundälv et al., 1986; Rueness, 1973; Wallentius, 1984). It is unlikely that effects on the macroalgae will have major implications for the CFT biotopes.

Changes in the phytoplankton are more likely to produce impacts. Increased phytoplankton densities will change the food supply for the predominantly filter feeding CFT species - the effects will be uncertain. Blooms of toxic algae may affect survival of CFT species, perhaps particularly in their planktonic larval stages. Algal blooms are often considered a near-surface phenomenon, and more likely to pose a threat in sheltered conditions. However, major effects of toxic algal blooms (especially of the species *Chrysochromulina polylepis* and *Gyrodinium* aureolum) have been reported from exposed sites along the Norwegian and Swedish Skagerrak coasts down to depths of 25-30 m (Bokn et al., 1990; Lundälv, 1990, 1996). So neither depth nor exposure necessarily offer protection. As well as the toxic impact of blooms, deoxygenation of the water will clearly have adverse effects. CFT communities in exposed high energy situations (which includes the majority in British waters) are probably at little risk from this, but those in semi-enclosed locations may be (Marchetti, 1992), and the risk of bottom water deoxygenation should be considered. Low bottom oxygen levels in Scandinavia have been linked to eutrophication (Lundälv, 1990).

Overall eutrophication poses a variety of threats to CFT communities, though it is currently impossible to relate risk directly to nutrient levels, and probably SAC management can exert little control over nutrient inputs. As for other forms of pollution, shallow water and sheltered area CFTs, such as those in sea lochs and rias, will be most at risk. A monitoring programme should include an assessment of eutrophication related phenomena.

C. FISHING

1. Indirect effects

Three categories of fishing activity are of concern: the use of towed gear, the use of static gear, and rod and line angling.

a. Towed gear

Towed gear is potentially the most destructive, and has been the subject of the most intensive study (MacDonald et al., 1996, and references cited there). Nevertheless most accounts of environmental damage are anecdotal, and controlled experimental studies are only now being evaluated (Lart et al., 1993; Curry & Parrie, 1996; Hill et al., 1997). From the point of view of most CFT biotopes towed gear is generally not a major threat, since the generally steep and rocky substrata are unsuitable for both trawls and dredges. However there are types of towed gear designed for rocky areas - the rockhopper otter trawl, and the Newhaven scallop dredge - and these could pose a risk to CFT communities on gently sloping or level rock, or on mixed substrata - e.g. the low lying bedrock reefs in Papa Stour Sound. All species would be at serious risk from such heavy equipment, especially fragile long-lived ones. Currently there is considerable concern that reefs of the deep sea coral *Lophelia* are being destroyed by the recent upsurge in deep sea trawling. These reefs are unlikely to be a concern in any of the present SACs, but the risk to CFT biotopes from towed gear clearly exists.

Whilst towed gear may not directly cross CFT biotopes, the activities of dredging and trawling on nearby level bottoms with softer sediments could have effects on neighbouring CFT communities. Towed gear results in the suspension of fine sediment (Jones, 1992), and may leave the sediment considerably coarser in grade than before (Caddy, 1973). Experimental dredging studies off the Isle of Man (Hill et al., 1997) have shown that dredging can double the suspended matter content of the water, and that this effect is likely to persist for several days. The influence of suspended matter on CFT biotopes is discussed in section II.G. Whilst some species are adversely affected by sediment, increase in suspended particulates may benefit filter feeders (Morton, 1977). Off the Swedish west coast it is suspected that various deep rocky circalittoral communities are being affected by resuspended sediment resulting from intense otter trawling (T. Lundälv - pers. comm.). Any other activity increasing the suspended sediment loading, such as dredge spoil dumping, would have a similar impact. Thus the management of SACs must take account of fishing and similar sediment generating activities in adjacent areas.

b. Static gear

Static gear is deployed regularly on rocky grounds, either in the form of pots or creels, or as bottom set gill or trammel nets. Whilst the potential for damage is lower per unit deployment compared to towed gear, there is a risk of cumulative damage to sensitive species if use is intensive. Damage could be caused during the setting of pots or nets and their associated ground lines and anchors, and by their movement over the bottom during rough weather and during recovery. Prior to the study by Eno et al. (1996) the impact of pots and creels had received little examination, and was generally considered to be small. They carried out observational and experimental studies on rocky substrata, and found no evidence for significant general community damage resulting from potting. Specimens of the brittle ‘ross coral’ *Pentapora foliacea* were broken, but the pink sea fan (*Eunicella verucosa*) bent under the weight of passing pots, and returned to an upright position. Based on these short-term studies potting damage would seem to be limited and specific. However long term damage may nevertheless occur as a result of cumulative sublethal damage to impacted animals, and further study is needed. Large colonies of *Pentapora* provide habitats for a wide variety of epibiotic species (Bunker & Mercer, 1988 recorded 94 species in 24 colonies), so in certain sites there may be a need to prohibit potting to protect this vulnerable species.

Pot fishing is notoriously difficult to monitor, in terms of both effort and catches, compounded by the fact that many boats operate simultaneously inside and outside the reserve area. In the Skomer Marine Nature Reserve there are an estimated “over 500 pots” in use at any one time over the summer months (Blaise Bullimore, pers, comm.). In the Lundy Reserve a similar estimate of about 500 pots fished has been made (Neil Downs, Devon Sea Fisheries, pers. comm.).

c. Angling

Rod and line angling is the least likely activity to produce incidental damage from the fishing itself - the main risk is damage from the **anchoring** of the angling boats. Rocky areas are often very popular with recreational anglers, due to the concentrations of fish feeding and sheltering there, and this form of activity can be locally intensive. Frequent anchoring in areas which often experience strong tidal flow is an obvious problem. Furthermore, areas where angling is common can accumulate a residue of tackle discarded after fouling the bottom, which is both unsightly, and a potential risk to divers. Lines have been observed entangling sea fan colonies, which could be at risk of damage.

The overall effects of fishing activity, and of other forms of disturbance, are to encourage a shift from long-lived and slow recruiting species to more opportunistic species. There is always uncertainty whether the original communities will return following heavy disturbance (see MacDonald, 1993, for discussion), but in any case long recovery times are anticipated.

2. Direct effects - harvesting.

The main traditional harvesting activity in CFT areas has been for crabs, lobsters and crayfish by potting, and by bottom-set tangle or gill nets. The latter also target fish as a by-catch. The obvious effect is the reduction in numbers of the target species, which are an important component of the aesthetic appeal of these communities. The reduction in these large predatory species will also have effects on the rest of the community, but these have not been evaluated in British waters. In South Africa, however, the removal of crayfish has been shown to have striking knock-on effects on the benthic community structure (Barkai & Branch, 1988). In the USA the effect of changes in numbers of crabs and lobsters has been debated (see discussion in section III.B.3).

More recently other CFT species have also been harvested by diving in the U.K. - it is immaterial whether by commercial divers, or incidentally by sports divers, the effects are the same. The sea urchin *Echinus esculentus* has been harvested commercially (Nichols, 1978). This harvesting was initially for marketing as souvenirs for the tourist trade, with subsequently the possible harvesting for human consumption, mainly for the Japanese market (Comely & Ansell, 1988). This has resulted in over-exploitation in parts of southern Britain, with a development of interest in the Scottish west coast. This activity is concentrated in the shallower infralittoral, but the substantial effects of major changes in urchin density on the plant-animal balance have been discussed above. Other species harvested for the souvenir trade include fan corals, and the large bryozoan *Pentapora*. Such species can very easily be stripped from an area, with regeneration being a slow process - a result which would not maintain a ‘favourable condition of interest features including typical species’.

D. DIVING

Diving can be a commercial activity for the harvesting of benthic species, as mentioned above. However this is not widespread, and should generally not be taking place within an SAC. Recreational diving is much more widespread, is common within many SACs, and its effects need evaluation.

Diving can damage CFT communities in two ways. There can be direct damage as a result of the collection of animals either for food, or as souvenirs. The impacts will be of exactly the same type as from commercial harvesting (see above). The collection of specimens by sports divers is generally to be discouraged, and this concept is incorporated in the codes of practice of many diving organisations, for example: “Be conservation conscious....Do not bring up sea-fans, corals, star fish or sea urchins”.

Indirect damage is a more pervasive problem, and can result from **anchoring** of dive boats, and from accidental damage by the divers themselves. Dive boats are generally lighter than commercial boats, and use correspondingly lighter ground tackle, but the cumulative effects in heavily used sites will be damaging. One solution could be to install permanent mooring points in popular areas, so that anchoring would not be necessary.

The damage from divers themselves whilst underwater is largely a result of inexpert techniques, and can be reduced by training, and by diver education programmes pointing out the problems that they can cause. It is by no means clear how much damage divers do cause within British CFT biotopes. On coral reefs in the tropics there is clear evidence that the damage can be substantial and result in serious degradation of reef quality (Hawkins, 1991, and references listed therein). However, the brittle and often fragile nature of hard corals contrasts with the generally more robust and flexible nature of CFT species. Also some of the obviously-damaged reefs are subject to very high visitor numbers, up to 6000 a day in the Key Largo Marine Sanctuary (Ward, 1990). British CFT communities are protected from such vast numbers by their depth, low water temperatures, and in many cases their difficulty of access, and much lower usages are recorded. In the Lundy Island Reserve the minimum estimate for 1997 was 2265 ‘diver days’ (Liza Cole, Lundy Warden, Pers. comm.). For the Skomer reserve the annual number of ‘diver days’ has ranged from 1745 to 3338 over the past ten years (Skomer MNR Annual Report for 1997). The above factors mean that mostly more experienced divers make up the bulk of the visitors. Nevertheless, the lack of evidence of obvious damage (systematic surveys for this seem to be lacking) should not be a reason to avoid caution and care. There are delicate and spectacular CFT species such as sea fans and the bryozoan *Pentapora foliacea*, which divers could easily damage. There is also the disturbance factor, by which frequent diving could alter the behaviour patterns and approachability of the mobile species within the community.

E. ARTIFICIAL SUBSTRATA

Oil platforms, and other man-made offshore structures such as breakwaters and shipwrecks, create circalittoral hard substratum in areas where it did not exist before. The amount of substratum is probably fairly insignificant, but its position may play a role as a staging post in promoting spread of species. Certainly artificial structures quickly accumulate a diverse animal community (Forteath et al., 1983). This is not so much a question of man posing a problem for CFT communities, as the other way round.

In terms of their effect on the structures CFT species increase drag, and accelerate corrosion (Pipe, 1981). Detail would not be appropriate here, but a better understanding of the biology of the important species involved (*Tubularia* spp., *Akcyonium digitatum, Metridium senile, Pomatoceros triqueter, Balanus* spp.) could perhaps help to mitigate the problem.

Whilst CFT communities are not desired on most artificial structures, there are some which are deliberately constructed to promote natural communities. These are the ‘artificial reefs’, developed primarily to provide increased habitat for fish and shellfish. An integral aspect of this is the establishment of a complex community to provide habitat and food for the target species. An example of such a development is the Poole Bay Project where the reef was constructed of stabilised coal-fired power station waste (Collins et al., 1990; Jensen et al., 1994).

G. KEY POINTS FROM CHAPTER V

- Oil pollution is largely a surface phenomenon and should not seriously impact CFT biotopes. Point-source pollutants such as sewage and industrial effluents should be controlled as part of an SAC management plan, and their impact on pelagic stages outside the SAC boundaries evaluated.

- Eutrophication is increasing in British waters, and algal blooms have impacted CFT communities in Scandinavia. The threat should be monitored, especially for shallow and sheltered CFT biotopes.

- The indirect effects of towed gear are potentially damaging, both by direct impact, and by resuspending sediment. Short-term studies indicate limited impact from potting, but longer term studies are needed. Removal of target species within SACs will need strict control.

- For various activities, such as angling and diving, the anchoring of boats poses a greater risk of damage than the activity itself. Consideration must be given to providing mooring buoys at key sites.

- The effects of current levels of recreational diving are probably small, provided accepted codes of practice are followed. However, in the absence of critical studies the effects should be monitored, especially in the more popular sites.

VI
MONITORING AND SURVEILLANCE OPTIONS

Two aspects of monitoring are not considered in detail here as they are general to the management of the SAC as a whole, and are not specific to the CFT component. However, they are both essential to formulating an effective monitoring strategy for CFTs in the first instance, and for interpreting the subsequent outcome of these monitoring programmes.

- There is an obvious need for detailed initial surveys of the SAC to determine the range and distribution of CFT biotopes present - presumably on the lines of the MNCR ‘Seasearch’ surveys, though with a more rigorous protocol.
- There is an ongoing requirement to monitor water quality both within the SAC, and in the surrounding areas. Basic hydrographic variables such as temperature, salinity, transparency, suspended solids, dissolved oxygen and nutrients should be examined as a matter of course. Other factors should be included where they are perceived as a potential threat.

The purpose of monitoring is to ensure that the SAC retains those qualities which were responsible for its initial selection. There is a requirement that European Marine Sites should be managed in order to contribute to the maintenance or restoration of favourable conservation status of their natural habitats and species. In order to accomplish this it is necessary to clearly define the aims of the monitoring exercise, and then to establish a monitoring programme which will achieve those aims whilst being practicable and affordable. For conservation purposes monitoring is often divided into two components.

Surveillance monitoring - an attempt to detect unanticipated impacts, particularly ones that may be wide ranging, subtle or that only slowly become large and obvious. This is essentially an information gathering exercise.

Condition (or compliance) monitoring - survey undertaken to detect departures from agreed or predicted amounts of disturbance. The aim here is to provide a feedback to management, so that agreed management strategies can be triggered, or new strategies developed.

In both surveillance and condition modes an understanding of the range of ‘natural’ variation in the biotopes and species under study is implicit. The null hypothesis is that “change will stay within that normal in an environment affected only by natural events” (Hiscock, 1998). For surveillance monitoring ‘impacts’ can only be discriminated when the background variation is understood, and for condition monitoring the range of natural variation must be known in order to set agreed limits of disturbance. Although surveillance and condition monitoring have discrete aims, the information required in each case is substantially the same (changes in species presence or abundance, or in community parameters) and would normally be obtained from the same monitoring programmes.

There are two major problems in relation to the monitoring of CFT biotopes. Firstly there is limited information on the natural variation in both CFT species and CFT biotopes (see section III.C.1). This will mean that the monitoring of CFTs must in some cases initially serve to provide the information needed to define agreed limits of disturbance, and only later serve in a condition mode. Secondly the logistics of available methods impose severe constraints on the type and scale of monitoring programmes which can be accomplished, so that the aims must be very specific.

A. METHODOLOGY

CFT biotopes are on hard substrata, and these substrata are generally steep and irregular and close inshore. They are mostly in depths exceeding 20 m, and often in areas of considerable wave action and strong currents. These factors severely constrain the methods which can be used in monitoring programmes. A general review of potential methods is given by Worsfold & Dyer (1997).

Surface operated remote sampling methods are inappropriate. Quantitative methods such as grabs and corers, suitable for soft substrata, will not work. Semi-quantitative methods such as rock dredges or rock-hopper trawls are unacceptably damaging, and provide very poor quality data. In the context of SAC management monitoring procedures should, where possible, be non-destructive in any case. Fortunately most of the larger CFT species are clearly visible on the rock surface and can be identified and enumerated *in situ*, and visual census methods are both practicable, and desirable. These visual methods unavoidably miss the smaller cryptic CFT species, but hopefully if the status of the larger species is preserved, than the habitat and well-being of the cryptofauna will be protected.

Visual monitoring can be carried out using several methods.

1. Manned submersibles.

These have been used very successfully in deep sea work, but their deployment and operation in the more dynamic inshore environment is untested. In any case their limited availability and very high capital and operating costs rule them out as an instrument in routine SAC monitoring, though they could be valuable in the surveying of deeper sites.

2. Remote recording.

Towed sledge-mounted camera systems are used successfully on soft bottoms, but cannot be used on irregular hard substrata. The only suitable method for working on CFT biotopes is to use a remote operated vehicle (ROV), which can be controlled and manoeuvred via an umbilical cable from the surface and equipped with still and video cameras. ROVs are used routinely for inspection work on offshore structures and pipelines, but so far only on a trial basis for monitoring work in the circalittoral (Donnan, 1997, 1998). Although they can be positioned with considerable accuracy (c 0.5 m) it would, for instance, still be impossible to position a ROV accurately enough to re-photograph fixed quadrats with the same precision that a diver can achieve. However the technology is available (see Auster, 1993), the cost of the cheaper systems is of the order of £30K, and this may be the only practicable method for monitoring the deeper CFT areas below the depths where divers can operate effectively (see below), and for certain purposes may be as cost effective as diving in shallower conditions. There are considerable areas within candidate/possible SACs which are beyond the range of conventional diving methods, but are of substantial scientific and conservation interest.

3. Diving

Almost all of the previous and ongoing monitoring of CFT communities has been carried out by SCUBA diving, and it is assumed that this will be the predominant technique used in SAC monitoring of CFTs for the immediate future. Diving must be carried out within the framework of the Health and Safety Commission Divers at Work Regulations, and SAC monitoring would normally be conducted under the *Approved Code of Practice for Scientific and Archaeological Diving*. Whilst this newly established code offers greater flexibility than the preceding legislation, it imposes various limits in the interests of safety. Of major relevance, the limit of safe diving is considered 50 metres. However, without on-site recompression facilities (which are unlikely to be available) the practical limit under the regulations would be 40 metres (to give 30 minutes bottom time and <20 minutes in-water decompression), and in many situations 30 metres would be a more realistic lower limit. In some of the more remote SACs the length of travelling time to recompression facilities may make any diving within the regulations difficult. The increasing use of nitrox gas mixtures and rebreathing systems by scientific divers will improve bottom time capability, but will have limited impact on depth limits. Within the proposed limits of the cSACs most of the CFT biotopes should be within diving range (but not necessarily easily diveable), but significant areas will not. Furthermore, a case may exist for designating SACs in the future to include more of the deeper circalittoral rock biotopes which will be well below diving depths. The design of a monitoring programme must consider the logistics of the diving operations from the earliest stages, and a risk assessment made for each procedure at each location. Realistically diving must be the technique of choice at the current time for most monitoring of CFTs, but alternatives must be developed (see below, and comments above on the use of ROVs).

Various techniques can be used by divers to collect information during monitoring. Direct recording of observations can be made using tick lists, writing pads, voice recorders or waterproof data-loggers. Alternatively records can be made using still or video photography. The second approach has advantages in that it maximises the use of bottom time, much of the recording work may not need scientific skills, and the analysis can be done subsequently at lower cost in the laboratory. Additionally a permanent record is available. However, the recording methods may be constrained by the monitoring format - see below.

B. MONITORING FORMAT

There are two basic monitoring formats appropriate to CFT biotopes.

1. Broadscale surveys

Broad-scale surveys use abundance scales and check lists to record the presence and abundance of conspicuous species. This is the *In situ surveillance of sublittoral (epibiota) biotopes using abundance scales and checklists at exact sites (ACE surveys)*, described in detail in Connor & Hiscock (1996) and Hiscock (1998b). The principle is that divers survey specified habitats in a defined location, and record the abundance of listed species. Abundance is recorded as density or percentage cover as specified for each species, subjectively averaged over the area of the survey. These values are then converted to points on a six-point abundance scale (see Hiscock, 1998a, Appendix 6, for details of scales appropriate to different types of organism).

The advantage of this method is that it enables rarer species as well as common ones to be assessed, and it provides a quantitative measure which can be compared with earlier surveys, or with other areas. It can also be carried out quite quickly and requires little specialist equipment beyond that needed for diving.

However, it has disadvantages. The results cannot be subjected to statistical analysis. Workers must have the required knowledge to identify species and assess abundance. There is considerable worker variability, though this can be limited by training, precise protocols, and careful definition of area of survey and included habitats. There is no permanent visual record for validation.

Despite the ‘noise’ in this method, with experienced operators it should be reasonably reliable. Differences of more than one abundance grade should be considered significant - however this does represent a very substantial change in abundance. It involves a change in density of two orders of magnitude, or a fourfold change in percentage cover.

Video recording with subsequent laboratory analysis is not a satisfactory substitute for *in situ* recording by divers. Species are likely to be missed, and variability will be increased. However both still and video photography can supplement the ACE procedures, and provide a permanent visual record.

2. Quadrat surveys

This is the recording of the presence and abundance of species in small quadrats, typically 50 cm by 50 cm or similar in size. Recording can be done *in situ*, but photography is used in almost all programmes, and its use will be assumed here.

The initial decision is to choose between random and fixed quadrats. The advantage of random quadrats is that they can be subjected to extensive statistical analysis, including the calculation of confidence limits and the rigorous comparison of consecutive sampling exercises. Nevertheless, the environmental complexity of most CFT environments, and the very patchy and diverse distribution of biotopes, would pose serious problems. Given the level of effort which would be practicable, it is likely that the discrimination of a random sampling strategy would be coarse and unlikely to reveal subtle biological change (Lundälv, 1985). Lundälv argues the case for the use of fixed quadrats, which remove the problem of environmental heterogeneity, and permit the detection of relatively small changes. There are problems of the ‘representativeness’ of the selected quadrats, and that changes within them may be an artefact of biological processes such as switching between stable states, rather than of ‘real’ community change. There are constraints on the statistical analysis of time series based on fixed quadrats. However, the overall advantage of the fixed quadrat option is convincing, and previous and current programmes on subtidal rock use this procedure. It has the added value that information on the recruitment, growth rate, longevity and survival of individual species is obtained.

The basic procedure is to select and mark a range of quadrats, and then to photograph each quadrat on each sampling occasion. To ensure that the photos can be accurately compared the quadrats are marked by pegs inserted into the rock, and the camera located using a frame which fits over the pegs. Detailed procedural guidelines are given by Hitchcock (1998b) for straightforward photography. There are advantages in the use of stereophotography (Lundälv, 1971; Torlegård & Lundälv, 1974), which provides added information content: computer analysis facilitates the interpretation of such photographs. The underwater component of this form of monitoring can be carried out quickly once the initial establishment of the quadrats has been completed. However, the laboratory processing of the photographs is time consuming. For some purposes the use of image analysis systems may increase efficiency, as may the introduction of digital cameras.

C. SUGGESTED MONITORING STRATEGIES

It is not possible to detail precise monitoring programmes - these will need to be tailored to the requirements and nature of each SAC. However some general guidelines are presented, and it is suggested that each programme should include both broadscale ‘ACE’ surveys, and fixed-quadrat photographic monitoring. These will provide different, but complementary, information.

The ACE surveys should not attempt to assay all species - it would be impracticable to attempt to determine the full species diversity. The time needed, and the requirement for field identification, both preclude this approach: the results would in any case be unreliable based on a purely visual survey. Each survey should cover a limited number of species (certainly not more than 20, preferably rather less) which can be unambiguously identified. The selection of species for inclusion should be based on the criteria discussed in section III.E.4, including: species of limited geographic distribution; species characteristic of that habitat; species of high ‘interest’ value; species known or suspected to be declining; and species at risk from known or suspected impacts. The number of survey sites within each SAC will depend upon the range of CFT biotopes present, and their significance in the context of that SAC. It is not expected that all CFT biotopes present will be included.

Fixed site photographic monitoring would also be carried out at several sites within the SAC, though since the time commitment is greater, probably at fewer sites that the ACE survey. The number of sites, and number of replicates at each site, should be determined on a local basis (see Hitchcock, 1998b, for guidelines on replicate numbers).

D. MONITORING INTERPRETATION

The ACE surveys will detect gross changes in the abundance of the target species. The *ad hoc* assumption that a change of more than one abundance grade indicates ‘real’ change is the only guideline available. It must be suspected that such a change indicates a non-natural level of variation, though for most species there is little data on which to base such an assumption. Adopting a precautionary approach, such a change should be regarded as an index that management measures should be triggered or modified - an element of Compliance Monitoring.

The fixed quadrat monitoring will detect quite small changes in abundance within the quadrats - changes of 20% in abundance or percentage cover should be reliably detected (Hitchcock, 1988b). However, with current knowledge the interpretation of such changes is difficult: there is not sufficient knowledge regarding natural variation in CFT communities, and there will be uncertainty regarding the applicability of quadrat changes to the biotope as a whole. The long-tern cyclical changes described in section III.C.1 indicate the problem posed by the scale of natural variation. At this stage fixed quadrat monitoring must be considered primarily as a data gathering exercise, but a very necessary one for the formulation of improved future management policies. Large changes in species abundance within quadrats must be considered as warning signs, but it is not possible at this stage to propose compliance limits.

A key feature to look for in monitoring results is an increase in r-selected opportunistic species, which usually indicates that a perturbation (either natural or anthropogenic) has taken place. Increased mortality of the normal long-term dominants in a biotope creates free space which is rapidly occupied by the quickly colonising opportunists. Species of this type include the tube worm *Pomatoceros triqueter,* the mussel *Mytilus edulis,* and annual ascidians such as *Ciona* and *Ascidiella.*

There will be benefits from conducting monitoring to common protocols in the different SACs. When species or communities are found to vary synchronously in a number of separate sites the interpretation must that that some diffuse natural or anthropogenic factor (more probably the former) is responsible, rather that a purely local phenomenon which is more likely to be anthropogenic. Examples of synchronous changes at a number of sites, attributed to climatic factors, were discussed in section III.C.1 for both Britain (Fowler & Pilley, 1992) and Scandinavia (Lundälv, 1985).

E. KEY POINTS FROM CHAPTER VI

- The aim of monitoring is to detect real change in CFT communities, determine whether this is due to human activity, and provide feedback to the management process.

- For the immediate future most monitoring of CFT biotopes will be carried out by diving. This seriously constrains the depths at which work can be usefully done (basically to above 40 m), and limits working time. All monitoring must be geared to the diving logistics.

- Two monitoring strategies are recommended for CFT biotopes. Abundance scale surveys using a check list of selected species (ACE surveys), and photographic monitoring of fixed sites.

- Because of limited background on natural variation these programmes must be regarded as primarily for surveillance purposes. Their use for condition monitoring will initially be constrained.

VII
GAPS AND REQUIREMENTS FOR FURTHER RESEARCH

A. IMPROVED ENVIRONMENTAL CHARACTERISATION

The primacy of various environmental variables in determining the distribution of CFT communities and species has been emphasised, particularly water movement ('exposure'). However, *in situ* quantitative measurements are rare. Do the same biotopes occur in different areas under similar exposure regimes, and can their occurrence be predicted? Do ‘alternate stable states’ in fact occur under the same environmental conditions? The increasing availability of compact and cheap self contained data loggers means that these variables can now be measured more efficiently in the field. An integrated programme to study water clarity/light intensity, water movement, and suspended sediment in relation to CFT community composition in several locations would provide extremely interesting data.

B. NATURAL SPATIAL/TEMPORAL VARIATION

Any attempt to evaluate the effects of anthropogenic impact, or to identify environmental benefits following the establishment of SACs, requires an understanding of the range of natural variation within the communities under consideration. Some CFT communities are assumed to be relatively stable, whilst others are known to undergo annual and year-to-year fluctuations. However the degree of stability, and on the scales on which temporal variation occurs, are both poorly known for British CFTs. Programmes of long term monitoring are required to investigate these variables, and patterns of settlement and recruitments in CFT biotopes. The monitoring programmes described in section VI must be considered as data gathering exercises at this stage, which will address this data gap, with only a limited management role as condition tools.

There is also limited understanding concerning the importance of ‘keystone’ species, such as sea urchins and starfish, in CFT biotopes (see section III). Information on the extent to which they determine community structure, and on the factors which control their abundance, are both sparse. Their roles can only be evaluated by suitable manipulative field experiment programmes, as has been effectively demonstrated in the intertidal and the infralittoral. Despite the logistic problems, similar programmes need to be initiated in the circalittoral. Their abundance over time will be monitored by including them in the checklists for the ACE surveys (section VI), and better knowledge of their fluctuations may indicate what factors are determining their abundance.

C. ANTHROPOGENIC DAMAGE

The evidence for incidental damage by anchoring, potting, and diving activity is largely anecdotal, or based on short term experimental or observational studies. It is generally assumed that such damage is limited in most CFT biotopes, but this assumption requires verification. The most appropriate protocol requires exclusion areas with adequate controls, monitored over long periods, though experience in evaluating the effects of dredging on soft bottom biotopes has shown this to be hard to conduct rigorously (Hill et al., 1997). An alternative approach is to compare areas which are heavily used (by potting, diving, etc) with those which are little used, but identical in other respects (which will be hard to establish). There is invariably the problem of identifying appropriate controls, and also of determining whether any changes observed over time are outside the range of natural variation.

Risks from increased siltation due to dredging and trawling, spoil dumping and coastal development also require further evaluation.

D. IMPROVED METHODOLOGY FOR WORK IN THE CIRCALITTORAL

The main constraints on the type and amount of work which can be carried out on circalittoral hard substrata result from the limitations of the available methods. At present, and for the immediate future, almost all work will be carried out by SCUBA diving, with the attendant restrictions on working depth and bottom time discussed in section VI. There are diving technologies used in the offshore industries which can overcome these limitations - including mixed gas diving, saturation diving, rigid atmospheric pressure suits, and submersible recompression facilities. However the cost and the level of training required will place these outside the realm of SAC management programmes. Furthermore, it is unlikely that they could ever be deployed safely in an inshore environment, since they depend on either substantial fixed surface facilities, or on a large mother ship. The same limitations apply to the use of the current range of manned submersibles operating at surface atmospheric pressure.

Improvements in the short term will arise from three lines of development.

- There are rapid developments in the diving systems available to sports and scientific divers, which do not unreasonable escalate either the costs or the form of training required. Nitrox gas mixtures are already in use, with improved bottom times and reduced recompression requirements. Partial and total rebreathing systems are being introduced now, which will produce similar benefits. Nevertheless, the scope of activity by diving will continue to be restricted by low water temperatures, exposed and often remote locations, and the requirements of health and safety legislation.

- Improvements can also be made by maximising the use of the limited underwater time which divers have. Technological developments in diver location and communication systems, in underwater tools for establishing marked survey sites, in still and video photographic systems, and in underwater data recorders are all ongoing.

- The third potential development will lie in the use of affordable non-diving technologies. The potential for the use of ROVs in the circalittoral rock environment needs to be further explored - can the types of data obtained be used for appropriate monitoring programmes? Cheap *in situ* data loggers to record variables such as temperature and water movement are now available, and their usefulness in the circalittoral needs investigation. They can be left in place for months, and subsequently recovered and downloaded.

VIII
SYNTHESIS AND APPLICATION FOR SAC MANAGEMENT

In this final chapter the information presented above will be evaluated in terms of its contribution to determining strategies for site management. There are two major aspects of management, which are considered in turn. Firstly programmes to determine the status of the CFT biotopes, and to reveal any changes beyond normal natural variation. Secondly control measures which can influence the impact of human activities within the SAC.

A. MEASURES TO MONITOR SITE STATUS

Monitoring of CFT biotopes can only be carried out by diving, or by the use of ROVs or manned submersibles. Given the depth range involved, usually >20 m, and the often exposed situations, diving will be demanding (and difficult to carry out in compliance with Health and Safety Regulations, though the new HSE Codes of Practice may ease this problem). The use of ROVs or manned submersibles for routine monitoring programmes is a largely untried field, with potential problems of cost, availability, and protocols. Consequently diving will be the main technique used for the immediate future (though the potential of ROVs for certain purposes is promising), and the logistics of any programme must be carefully evaluated in terms of practicalities and return for effort. This will apply particularly to the more remote and exposed SAC locations - and it may be desirable (or essential) to locate the more demanding programmes in the more accessible locations.

Two monitoring methods are recommended, to run in parallel in all (or at least in most) SACs. One method is an abundance scale assay of a check list of selected species - ACE surveys. Species will be selected using a range of criteria designed to designate those of highest ‘importance’ in each SAC, and will detect major changes in abundance of those species. Although local importance is a major factor in compiling the check list, these should be reasonably uniform on a regional basis since the universality of changes is a species’ abundance is an important guide to possible cause. The other method is a fixed-site photographic survey. This will reliably detect small changes within the quadrats, but the extrapolation of these changes to the broader biotope must be done with caution.

These programmes will serve three purposes. They will provide feedback for management - condition monitoring. However, with current knowledge their effectiveness in this role will be limited. They will detect impacts - surveillance monitoring - but to do so they must discriminate human impacts from natural variations. Thirdly they will operate as a research programme which will provide the data to enable the first two aims to be accomplished with increasing efficiency.

B. ACTIONS TO LIMIT ANTHROPOGENIC DAMAGE

There are a number of human impacts which can damage CFT biotopes. Some of these impacts are unlikely to be moderated by any measures within the scope of an SAC management plan, but they must be recognised so that changes resulting from them may be discriminated from those where remedial action may be initiated. Impacts of this type are:

- Eutrophication.
- Global warming.
- Diffuse pollutants.

In contrast there are those impacts which pose a recognised risk, and which might be controlled by management measures.

- Point source pollutants - effluents, spoil dumping.
- Static gear fishing - anchoring, setting and hauling of pots, removal of target species.
- Towed gear fishing - direct damage, sediment resuspension, removal of target species.
- Sports angling.
- Commercial diving - anchoring, incidental damage, removal of target species.
- Sports diving - anchoring, incidental damage, collecting.

All of these risks can be mitigated by limiting the level of such activities, or by banning them, or by regulating the ways in which they are carried out. Decisions on banning or limiting these activities usually involve political expediency as well as biological necessity.

Point source pollutants should ideally not be a problem. They should not seriously impact upon an SAC at the time of its designation, and any new inputs should require consent agreement. The status of any existing inputs should be monitored as part of a management plan.

Static gear fishing is predominantly pot fishing for lobsters and crabs, and can present a management minefield. Many of the best CFT areas are also prime potting areas where operations have traditionally been pursued for long periods - by operatives who attract substantial local support and sympathy. Whilst evidence to date suggests than the incidental damage from potting is small, long term studies are still needed. The removal of large numbers of crabs and lobsters would of necessity impoverish the community, however, and limitation of potting, and its banning in parts of the SAC, should be a management objective. Effective change must almost certainly be by mutual agreement, and experience has shown how difficult this is to obtain. Carrots are invariably better than sticks, and there are positive arguments to propose. The creation of fishing exclusion zones in parts of the SAC may provide refuges for the more effective restocking of adjacent regions. Currently there is limited information on the success of this tactic (Dugan & Davis, 1993), though there is evidence that they have value in relation to abalone in Australia and California (Shepherd & Brown, 1993; Tegner et al., 1982), spiny lobsters in Florida (Davis & Dodrill, 1989) and sea urchins in Japan (Tegner, 1989). An SAC can also be a special attraction to visiting divers, whose transport will provide an alternative revenue for fishermen.

The use of **towed gear** over certain areas may result in damage to CFT communities. Generally such areas are only peripheral parts of dredging or trawling grounds, and the requirement for the regulation of such activities in SACs should be minimal.

Anchoring may need control, especially where the bottom community is sensitive to physical damage.

Commercial diving to harvest target species (e.g. sea urchins, sea fans) tends not to generate public support. A total ban would normally be the appropriate regulation measure in a SAC.

Properly conducted **sports diving** is not a serious risk, and diving groups are usually very amenable to sensible codes of practice. The principle of not removing specimens is generally acceptable, and incidental damage limitation is a matter of proper training. For example the British Sub Aqua Club has a comprehensive voluntary code of practice which covers most of the points which an SCA management plan would wish to make. A compulsory code of practice for sports divers in SACs is unlikely to be opposed by responsible diving organisations. Damage from anchoring tends to be less with the light ground tackle used by many dive boats (often RIBs), but in some situations the provision of permanent mooring points could pose benefits.

C. SUMMARY OF KEY POINTS

- Monitoring and surveillance activity of CFTs must currently be conducted almost exclusively by diving: the cost, safety and logistics of such activities must be carefully evaluated at the planning stage.

- Monitoring programmes should incorporate ACE surveys (abundance scale assays of selected species at designated sites) and photographic surveys of fixed quadrats.

- In the present state of knowledge these programmes will serve primarily to collect further data and for surveillance monitoring. Their effectiveness for condition monitoring will be constrained initially by ignorance of the limits of natural change.

- Impacts from eutrophication and global warming must be sought and identified, though SAC management plans can do little to control such impacts.

- Fishing poses risks to the condition of CFTs. The use of towed gear on or near CFTs should be prevented. Potting appears to have low impact on current evidence, but long-term effects are unknown. The precautionary principle indicates that it should be controlled, and if possible banned in some areas to conserve the target species.

- Sports diving, conducted under approved codes at current levels of activity, is not considered a serious impact, though damage from anchoring is a risk.

- It is tentatively suggested that for SAC management purposes, CFT communities will pose one of the less contentious problems, with fewer conflicts of interest than in most other biotope complexes.

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Appendix 1. Listing of 'faunal turf' biotopes, taken from Connor et al (1997). All Circalittoral Rock biotopes are listed, those not classed as CFTs are marked by an asterisk. Faunal dominated and faunal rich Infralittoral Rock biotopes are also included.

Higher code	**Biotope code**	**Biotope**
CR		**CIRCALITTORAL ROCK (and other hard substrata)**
ECR		**EXPOSED CIRCALITTORAL ROCK**
ECR.EFa		**Faunal crusts or short turfs (wave-exposed rock)**
ECR.EFa	CCParCar	Coralline crusts, *Parasmittina trispinosa*, *Caryophyllia smithii*, *Haliclona viscose*, polyclinids and sparse *Corynactis viridis* on very exposed circalittoral rock
ECR.EFa	CorCri	*Corynactis viridis* and a crisiid/*Bugula*/*Cellaria* turf on steep or vertical exposed circalittoral rock
ECR.EFa	PomByC	*Pomatoceros triqueter*, *Balanus crenatus* and bryozoan crusts on mobile circalittoral cobbles and pebbles
ECR.Alc		***Alcyonium*-dominated communities (tide-swept/vertical)**
ECR.Alc	AIcTub	*Alcyonium digitatum* with dense *Tubularia indivisa* and anemones on strongly tide-swept circalittoral rock
ECR.Alc	AIcMaS	*Alcyonium digitatum* with massive sponges (*Cliona celata* and *Pachymatisma johnstonia*) and *Nemertesia antennina* on moderately tide-swept exposed circalittoral rock
ECR.Alc	AlcSec	*Alcyonium digitatum* with *Securiflustra securifrons* on weakly tide-swept or scoured moderately exposed circalittoral rock
ECR.Alc	AIcC	*Alcyonium digitatum*, *Pomatoceros triqueter*, algal and bryozoan crusts on vertical exposed circalittoral rock
ECR.BS		**Barnacle, cushion sponge and *Tubularia* communities (very tide-swept/wave-sheltered)**
ECR.BS	BalTub	*Balanus crenatus* and *Tubularia indivisa* on extremely tide-swept circalittoral rock
ECR.BS	TubS	*Tubularia indivisa*, sponges and other hydroids on tide- swept circalittoral bedrock
ECR.BS	BalHpan	*Balanus crenatus*, *Halichondria panicea* and *Alcyonidium diaphanum* on extremely tide-swept sheltered circalittoral
	rock	
ECR.BS	CuSH	Cushion sponges, hydroids and ascidians on very tide-swept sheltered circalittoral rock
ECR.BS	HbowEud	*Halichondria bowerbanki*, *Eudendrium arbusculum* and *Eucratea loricata* on reduced salinity tide-swept circalittoral mixed substrata

MCR		**MODERATELY EXPOSED CIRCALITTORAL ROCK**
MCR.XFa		**Mixed faunal turfs (moderately exposed rock)**
MCR.XFa	PhaAxi	*Phakellia ventilabrum* and axinellid sponges on deep exposed circalittoral rock
MCR.XFa	ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora foliacea* on slightly tide-swept moderately exposed circalittoral rock
MCR.XFa	ErSPboISH	Cushion sponges (*Polymastia boletiformis*, *Tethya*), stalked sponges, *Nemertesia* spp. and *Pentapora foliacea* on moderately exposed circalittoral rock
MCR.XFa	ErSSwi	Erect sponges and *Swiflia pallida* on slightly tide-swept moderately exposed circalittoral rock
MCR.ByH		**Bryozoan/hydroid turfs (sand-influenced)**
MCR.ByH	SNemAdia	Sparse sponges, *Nemertesia* spp., *Alcyonidium diaphanum* and *Bowerbankia* spp. on circalittoral mixed substrata
MCR.ByH	Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata
MCR.ByH	Flu.Flu	*Flustra foliacea* on slightly scoured silty circalittoral rock or mixed substrata
MCR.ByH	Flu.HByS	*Flustra foliacea* with hydroids, bryozoans and sponges on slightly tide-swept circalittoral mixed substrata
MCR.ByH	Flu.SerHyd	S*ertularia argentea, S. cupressina* and *Hydrallmania falcata* on tide-swept circalittoral cobbles and pebbles
MCR.ByH	Flu.Hocu	*Haliclona oculata* and *Flustra foliacea* with a rich faunal turf on tide-swept sheltered circalittoral boulders or cobbles
MCR.ByH	Urt	*Urticina felina* on sand-affected circalittoral rock
MCR.ByH	Urt.Urt	*Urticina felina* on sand-scoured circalittoral rock
MCR.ByH	Urt.Cio	*Urticina felina* and *Ciocalypta penicillus* on sand-covered circalittoral rock
MCR.CSab*		**Circalittoral Sabellaria reefs**
MCR.CSab*	Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock
MCR.M*		**Mussel beds (open coast circalittoral rock/mixed substrata)**
MCR.M*	MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide- swept moderately exposed circalittoral rock
MCR.M*	Mus	*Musculus discors* beds on moderately exposed circalittoral rock
MCR.M*	ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
MCR.Bri*		**Brittlestar beds**
MCR.Bri*	Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata
MCR.Bri*	Oph.Oacu	*Ophiopholis aculeata* beds on slightly tide-swept circalittoral rock or mixed substrata

MCR.GzFa		**Grazed fauna (moderately exposed or sheltered rock)**
MCR.GzFa	FaAlC	Faunal and algal crusts, *Echinus esculentus*, sparse *Alcyonium digitatum* and grazing-tolerant fauna on moderately exposed circalittoral rock
MCR.GzFa	FaAIC.Abi	Faunal and algal crusts, *Echinus esculentus*, sparse *Alcyonium digitatum, Abietinaria abietina* and other grazing-tolerant fauna on moderately exposed circalittoral rock
MCR.As		**Ascidian communities (silt-influenced)**
MCR.As	StoPaur	*Stolonica socialis* and/or *Polyclinum aurantium* with *Flustra foliacea* on slightly sand-scoured tide-swept moderately exposed circalittoral rock
MCR.As	molpol	*Molgula manhattensis* and *Polycarpa* spp. with erect sponges on tide-swept moderately exposed circalittoral rock
MCR.As	MolPol.Sab	Dense ascidians, bryozoans and hydroids on a crust of *Sabellaria spinulosa* on tide-swept circalittoral rock
MCR.SfR		**Soft rock communities**
MCR.SfR	Pid	Piddocks with a sparse associated fauna in upward-facing circalittoral very soft chalk or clay
MCR.SfR	Pol	*Polydora* sp. tubes on upward-facing circalittoral soft rock
SCR		**SHELTERED CIRCALITTORAL ROCK**
SCR.BrAs		**Brachiopod and solitary ascidian communities (sheltered rock)**
SCR.BrAs	AntAsH	*Antedon* spp., solitary ascidians and fine hydroids on sheltered circalittoral rock
SCR.BrAs	SubSoAs	*Suberites* spp. and other sponges with solitary ascidians on very sheltered circalittoral rock
SCR.BrAs	AmenCio	Solitary ascidians, including *Ascidia mentula* and *Ciona intestinalis*, on very sheltered circalittoral rock
SCR.BrAs	AmenCio.Met	Large *Metridium senile* and solitary ascidians on grazed very sheltered circalittoral rock
SCR.BrAs	Aasp	*Ascidiella aspersa* on sheltered circalittoral rocks on muddy sediment
SCR.BrAs	NeoPro	*Neocrania anomala and Protanthea simpler* on very sheltered circalittoral rock
SCR.BrAs	NeoPro.CaTw	Brachiopods, calcareous tubeworms (*Placostegus tridentatus, Hydroides*) and sponges on variable salinity circalittoral rock
SCR.BrAs	NeoPro.Den	*Neocrania anomala*, *Dendrodoa grossularia* and *Sarcodictyon roseum* on reduced or low salinity circalittoral rock
SCR.Mod*		**Sheltered Modiolus (horse-mussel) beds**
SCR.Mod*	ModCvar	*Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata
SCR.Mod*	ModHAs	*Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata

		CIRCALITTORAL ROCK (OTHER)
CR.FaV		**Faunal turfs (deep vertical rock)**
CR.FaV	Ant	*Antedon bifida* and a bryozoan/hydroid turf on steep or vertical circalittoral rock
CR.FaV	Bug	*Bugula* spp. and other bryozoans on vertical moderately exposed circalittoral rock
CR.Cv		**Caves and overhangs (deep)**
CR.Cv	SCup	Sponges, cup corals and *Parerythropodium coralloides* on shaded or overhanging circalittoral rock
COR*		**CIRCALITTORAL OFFSHORE ROCK (and other hard substrata)** Only one type currently defined. Classification requires expansion here
COR.Lop*		*Lophelia* reefs
		INFRALITTORAL ROCK (and other hard substrata)
EIR		**EXPOSED INFRALITTORAL ROCK**
EIR.SG		**Robust faunal cushions and crusts (surge gullies & caves)**
EIR.SG	SCAn	Sponge crusts and anemones on wave-surged vertical infralittoral rock
EIR.SG	SCAn.Tub	Sponge crusts, anemones and *Tubularia indivisa* in shallow infralittoral surge gullies
EIR.SG	SCAs	Sponge crusts and colonial ascidians on wave-surged vertical infralittoral rock
EIR.SG	SCAs.DenCla	*Dendrodoa grossularia* and *Clathrina coriacea* on wave-surged vertical infralittoral rock
EIR.SG	SCAs.ByH	Sponge crusts, colonial (polyclinid) ascidians and a bryozoan/hydroid turf on wave-surged vertical or overhanging infralittoral rock
EIR.SG	SC	Sponge crusts on extremely wave-surged infralittoral cave or gully walls
EIR.SG	CC	*Balanus crenatus* and/or *Pomatoceros triqueter* with spirorbid worms and coralline crusts on severely scoured infralittoral rock (No description at this level)
EIR.SG	CC.BalPom	*Balanus crenatus* and/or *Pomatoceros triqueter* with spirorbid worms and coralline crusts on severely scoured vertical infralittoral rock
SIR		**SHELTERED INFRALITTORAL ROCK**
SIR.K		**Silted kelp (stable rock)**
SIR.K	EchBriCC	Echinus, brittlestars and coralline crusts on grazed lower infralittoral rock
		Infralittoral rock (other)
IR.FaSwV		**Fauna and seaweeds (shallow vertical rock)**
IR.FaSwV	CorMetAlc	*Corynactis viridis, Metridium senile* and *Alcyonium digitatum* on exposed or moderately exposed vertical infralittoral rock
IR.FaSwV	AlcByH	*Alcyonium digitatum* and a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock

IR.FaSwV	AIcByH.Hia	*Hiatelia arctica*, bryozoans and ascidians on vertical infralittoral soft rock

Appendix 2. Algal species typical of circalittoral bedrock (IOE Group, 1995).

Red algae
Bonnemaisonia hamifera
Meredithia microphylla
Phyllophora crispa
Phyllophora pseudoceranoides
Schottera nicaeensis
Gigartina acicularis
Plocamium cartilagineum
Calliblepharis ciliata
Rhodymenia pseudopalmata
Griffithsia corallinoides
Griffithsia flosculosa
Sphondylothamnion multifidum
Cryptopleura ramosa
Delesseria sanguinea
Hypoglossum hypoglossoides
Heterosiphonia plumosa
Brongniartella byssoides
Rhodomela confervoides

Brown algae
Cutleria multifida
Halopteris filicina
Dictyopteris membranacea
Dictyota dichotoma

Appendix 3. 'Characterising species' in CFT biotopes in the JNCC biotope classification (Connor et al., 1997), listed taxonomically. Integrated list for all biotopes.

SPONGES
Axinella dissimilis
Axinella infundibuliformis
Cliona celata
Dysidea fragilis
Esperiopsis fucorum
Halichondria bowerbanki
Halichondria panicea
Haliclona oculata
Haliclona viscosa
Hemimycale columella
Myxilla fimbriata
Pachymatisma johnstonia
Phakellia ventilabrum
Polymastia boletiformis
Polymastia mamillaris
Raspailia hispida
Raspailia ramosa
Stelligera rigidia
Stelligera stuposa
Suberites carnosus
Sycon ciliatum
Tethya aurantium
Porifera indet crusts

COELENTERATES
Hydroids
Abietinaria abietina
Aglaophenia tubulifera
Bougainvillia ramosa
Halecium halecinum
Hydrallmania falcata
Nemertesia antennina
Nemertesia ramosa
Polyplumaria frutescens
Sertularia argentea
Tubularia indivisa

Corals and anemones
Actinothoe sphyrodeta
Alcyonium digitatum
Alcyonium glomeratum
Balanophyllia regia
Caryophllia smithii
Corynactis viridis
Eunicella verrucosa
Hoplangia durotrix
Leptopsammia pruvoti
Protanthea simplex

Sagartia elegans
Sagartia troglodytes
Swiftia pallida
Urticina felina

ANNELIDS
<u>Tube worms</u>
Pomatoceros triqueter
Portula tubularia
Sabellaria spinulosa
<u>Other worms</u>
Lanice conchilega
Polydora

ARTHROPODS
Balanus crenatus
Cancer pagurus
Carcinus maenas
Munida rugosa
Pagurus bernhardus

MOLLUSCS
<u>Gastropods</u>
Calliostoma zizyphinum
<u>Bivalves</u>
Barnea candida
Barnea parva
Pholas dactylus
Pododesmus patelliformis

BRACHIOPODS
Neocrania anomala
Terebratulina retusa

BRYOZOA
Alcyonidium diaphanum
Bugula flabellata
Bugula plumosa
Cellepora pumicosa
Crissidae
Eucratea loricata
Flustra foliacea
Parasmittina trispinosa
Pentapora foliacea
Porella compressa
Vesicularia spinosa
Bryzoa indet crusts

ECHINODERMS
Antedon bifida
Aslia lefevrei
Asterias rubens

Crossaster papposus
Echinus esculentus
Henricia oculata
Holothuria forskali
Luidia ciliaris
Marthasterias glacialis
Ophiothrix fragilis
Stichastrella rosea

TUNICATES
Ascidia mentula
Ascidia virginea
Ascidiella aspersa
Botryllus schlosseri
Ciona intestinalis
Clavelina lepadiformis
Corella parallelogramma
Dendrodoa grossularia
Diazona violacea
Didemnidae
Molgula manhattensis
Morchellium argus
Polycarpa
Polyclinum aurantium

FISH
Ctenolabrus rupestris
Labrus bergylta
Labrus mixtus

Appendix 4. Distribution maps for MNCR CFT biotopes (figs 1-11) and for selected CFT species (Figs 12-16). Based on information in the JNCC's MNCR database. See Appendix 1 for details of biotope codes.