A review of the status, ecology and conservation of horse mussel *Modiolus modiolus* beds in Scotland

Report No. F99PA08

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This report should be quoted as:

Mair, J.M., Moore, C.G., Kingston, P.F. & Harries, D.B. (2000) A review of the status, ecology and conservation of horse mussel *Modiouls* modiolus beds in Scotland. *Scottish Natural Heritage Commissioned Report F99PA08*.

SCOTTISH NATURAL HERITAGE

COMMISSIONED REPORT

Summary

A REVIEW OF THE STATUS, ECOLOGY AND CONSERVATION OF HORSE MUSSEL *MODIOLUS MODIOLUS* BEDS IN SCOTLAND

Report No.: F99PA08
Contractor : Centre for Environmental Resource Management, Heriot-Watt University

BACKGROUND

Horse mussel *Modiolus modiolus* beds are recognised as an important element in Scotland's nearshore marine environment. The beds support a range of associated fauna and flora and are identified as biogenic reefs under the Habitats Directive description of reefs. The natural heritage importance of such beds is also recognised by the UK Biodiversity Action Plan produced under the Global Biodiversity Convention in 1992. The aim of this report is to identify and collate existing information on *Modiolus* beds and to describe the results of a comparative field study of beds from 3 geographically distinct areas in Scotland: tidal swept beds in Lochs Duich, Long and Alsh (NW Scotland); sheltered sea loch beds from Loch Creran (W Scotland); and sheltered beds in Busta Voe and Olna Firth (Shetland). The literature and database review concentrates on information on the status, ecology and conservation of *Modiolus* within Scotland, the UK and, where appropriate, other parts of the world.

MAIN FINDINGS

- During the site surveys data on habitat and physical attributes were recorded and collected. Attributes included: sediment characteristics and organic carbon levels on and off *Modiolus* beds; size and continuity of the beds; age and size structure of the *Modiolus* populations; and the ratio of dead shells to live *Modiolus*.
- Recordings were taken of the associated fauna and flora living on the *Modiolus* beds and within the matrix of shells, byssus threads and attached sediment. MNCR Phase 2 surveys and 'clump' collections were the methods employed.
- Some differences were noted amongst the sites and these were related to the combination of the various environmental and ecological parameters present. Each *Modiolus* bed studied was assigned a biotope to characterise it..
- The substrates within all 3 *Modiolus* beds in this study consisted of very mixed, poorly sorted, sediments in terms of particle size - a broad range of size fractions was generally always present in the samples. There appears to be some indirect indication of the relationship of sediment structure to the presence of *Modiolus*.
- There were close to 300 taxa of fauna and flora identified from the *Modiolus* clumps collected at all 3 sites. The general species composition of communities associated with clumps at the 3 sites showed many similarities throughout the taxonomic groupings.

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ABSTRACT

Key words: *Modiolus*; ecology; conservation; biotopes; pSACs; Scotland.

1. A review of available information on the status, ecology and conservation of the horse mussel, *Modiolus modiolus,* within Scotland was carried out and presented.

2. Targeted studies of three distinct *Modiolus* bed types were undertaken in 1999. The study sites were in Busta Voe, Shetland, at Kyle Akin, Loch Alsh (within the pSAC Lochs Duich, Long and Alsh) and in pSAC Loch Creran (Upper Basin).

3. During the site surveys data on habitat and physical attributes were recorded and collected. Attributes included: sediment characteristics and organic carbon levels on and off the *Modiolus* beds; size and continuity of the beds; age and size structure of the *Modiolus* populations; and the ratio of dead shells to live *Modiolus*.

4. Recordings were taken of the associated fauna and flora living on the *Modiolus* beds and within the matrix of shells, byssus threads and attached sediment. MNCR Phase 2 surveys and 'clump' collections were the methods employed.

5. Some differences were noted amongst the sites and these were related to the combination of the various environmental and ecological parameters present. Each *Modiolus* bed studied was assigned a biotope to characterise it.

6. The results are fully discussed and recommendations are given.

ACKNOWLEDGEMENTS

The following people in Heriot-Watt University, Edinburgh are thanked for their valuable contribution to this study:

Dr Martin Wilkinson, Dr Alastair Lyndon and Miss Fiona Ware of the Department of Biological Sciences.

Mr Ian Oxley of the Department of Civil and Offshore Engineering.

Dr Yuri Rzhanov of the Department of Computing and Electrical Engineering.

Dr James Young and Ms Hilary Anderson in Edinburgh College of Art, Geomatics Unit.

The authors would like to thank David Donnan, Alistair Davison and Graham Saunders of SNH for their valuable advice and guidance throughout the project.

The field workers would also like to express their appreciation for the cheerful and helpful assistance always provided by Mr Jock Slorance of Creran Moorings.

1 SUMMARY

The aim of this study is to identify and collate existing information on horse mussel, *Modiolus modiolus*, beds (which are recognised as an important element of Scotland's nearshore marine environment) and to describe the results of comparative field studies of *Modiolus* beds from three geographically distinct areas in Scotland:

- Tidal swept *Modiolus* beds in Lochs Duich, Long and Alsh pSAC (North-west Scotland)
- Sheltered sea loch *Modiolus* beds from pSAC Loch Creran (West Scotland)
- Sheltered *Modiolus* beds in Busta Voe and Olna Firth (Shetland)

The field studies of the above targeted sites were undertaken in 1999 in order to provide information on the possible variants or types of horse mussel beds in Scotland with a view to assessing relevant conservation requirements. The data obtained from these site surveys, along with existing published information, are used to provide an assessment of the ecological and conservation requirements of the *Modiolus* bed types. The natural heritage importance of such beds is recognised by the UK Biodiversity Action Plan (UK BAP) produced under the Global Biodiversity Convention in 1992. One of the key actions of the UK BAP for *Modiolus* is that there is an assessment made of the variation and resource value of these communities in Scotland. Similar complementary work on the conservation and management of *Modiolus* beds is currently being carried out in Wales and Northern Ireland.

At each study site, the main factors studied were *Modiolus* distribution, population structure and the associated communities. Other attributes assessed included:

- substrate composition around and within the beds;
- particle size and organic content of the sediments;
- current/wave exposure conditions;
- turbidity and character of the water;
- extent, density and continuity of the mussel beds including live/dead shell ratios;
- size and age structure of the *Modiolus* within the beds including presence of spat;
- presence and abundance of large organisms by means of MNCR Phase 2 surveys;
- presence and abundance of smaller organisms associated within the matrix of the bed by means of clump collection and subsequent laboratory analysis.

Modiolus abundance/distribution and associated organisms at the study sites were recorded by a variety of techniques including direct diver observations (MNCR Phase 2 survey methodology, transect/quadrat counting and spot diving) and by analysis of stills photography and video recordings (diver-held and drop-down techniques). *In situ* counting of *Modiolus* abundance by divers is time consuming and not necessarily consistent or accurate. A more rapid, alternative method involving the measurement of percentage cover was developed and adopted in which a square 0.25m^2 quadrat was used that had cross strings at 10cm intervals creating a total of 16 intersections within the quadrat frame. At each survey station 5 replicate quadrat recordings were made of the number of string intersections directly overlying live *Modiolus*. The results revealed that percentage cover and abundance were correlated ($r=0.542$; $p<0.05$). Direct collection of *Modiolus* and associated organisms was also undertaken to confirm and supplement field observations by subsequent laboratory analytical methods.

The extent of the particular *Modiolus* beds under study at the three sites was mapped. The *Modiolus* bed at Loch Creran could be described as a congregation of *Modiolus* clumps, the clumps being closer together at the centre of the bed and more dispersed towards the edges. In contrast there was less obvious 'clumping' at the Busta Voe and Loch Alsh sites

where the *Modiolus* formed rather more of a continuous cover on the seabed. The overall densities of *Modiolus*, at the main 'central' sample station chosen at each site, showed a trend increasing in the order of Loch Creran (28 m^{-2}), Busta Voe (45 m^{-2}) and then Loch Alsh (106 m^{-2}), perhaps reflecting the increasing exposure to tidal currents in the areas studied. The bed in upper Loch Creran is in an extremely sheltered location whereas the Loch Alsh bed is subject to high tidal currents. Whilst the Busta Voe site is within a sheltered voe it can probably be regarded as intermediate in terms of water currents. In addition the ratio of dead shells to live *Modiolus* was least at the Loch Alsh site.

From analysing the abundance and composition of the larger species in the MNCR Phase 2 studies it would appear that the biotope at the tidal Loch Alsh site fitted more closely to the **MCR.Oph.Oacu** (*Ophiopholis aculeata* beds on slightly tide-swept circa littoral rock or mixed substrata) designation than any other one – *Ophiothrix fragilis, Ophiocomina* and *Ophiopholis* were recorded as superabundant. This classification is in general agreement with previous studies reported in this area. The findings at the study site at Busta Voe were in general agreement with the designation previously recorded of **SCR.ModHAs** (*Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata). At the very sheltered Loch Creran site the biotope would appear to be a mix between the two closely allied biotopes **SCR.ModHAs** and **SCR.ModCvar** (*Modiolus modiolus* with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata**)**. The **SCR.ModCvar** biotope is reported as characteristic of Strangford Lough. The Upper Loch Creran bed also has the *C. varia* and *Pyura microcosmus* of this biotope. It should be noted that in Loch Creran there are several different *Modiolus* biotopes within a relatively small geographical area and therefore some mix of associated species may be inevitable, i.e. the sheltered upper loch basin (this study), another in the nearby Creagan narrows that links the upper and lower basins (MNCR records), and one further bed described as **CMX.ModHo** (sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment) at Barcaldine in the lower basin but also relatively close to Creagan narrows.

The lack of obvious major recruitment apparent from close study at the three sites in this study may be of importance in terms of conservation management and may require further study. There may have been exceptionally high mortality of juveniles over the last few years but it may also be possible that *Modiolus* beds can be maintained with only occasional successful recruitment, e.g. every 10 years. Recruitment of spat to horse mussel populations is described as being sporadic by other researchers. Long term study of this would be required on a site to site basis.

Long term study of the associated fauna may also prove useful since, at the Loch Creran site, changes in species over the long term are noticeable. For example, the 1989 MNCR survey at the Dallachulish site indicated *Ophiopholis* to be frequent whilst, in the 1999 survey reported here, this species was not recorded. Without further study it is difficult to relate this observation directly to long term natural changes or to possible human induced causes.

Further development and standardisation of methods for divers using quadrats for counting shells or assessing percentage of coverage would be beneficial. A rapid and easy to use method (such as the intersection method used in the present study) could be combined with on-site verification by an appropriate amount of sample removal (necessary for population structure and ageing analysis in any case).

It is recommended that regular collaboration, co-ordination and exchange of information amongst groups working on *Modiolus* around the British Isles and other countries (such as the workshop held in 1999) should be encouraged and promoted.

2 INTRODUCTION

Horse mussel (*M. modiolus*) beds are recognised as an important element of Scotland's nearshore marine environment. *Modiolus* beds support a range of associated fauna and flora and are identified as biogenic reefs under the Habitats Directive description of reefs. The natural heritage importance of such beds is also recognised by the UK Biodiversity Action Plan (UK BAP) produced under the Global Biodiversity Convention in 1992. Factors such as biogeographic position within Scotland, habitat availability and environmental conditions (current regime etc.) affect the structure and function of *Modiolus* beds. The diversity and composition of the associated communities also vary throughout Scotland. One of the key actions of the UK BAP for *Modiolus* is that there is an assessment made of the variation and resource of these communities in Scotland. Similar complementary work on the conservation and management of *Modiolus* beds is currently being carried out in Wales and Northern Ireland.

The aim of this report is to identify and collate existing information on *Modiolus* beds and to describe the results of a comparative field study of *Modiolus* beds from three geographically distinct areas in Scotland:

- Tidal swept *Modiolus* beds in Lochs Duich, Long and Alsh pSAC (North-west Scotland)
- Sheltered sea loch *Modiolus* beds from pSAC Loch Creran (West Scotland)
- Sheltered *Modiolus* beds in Busta Voe and Olna Firth (Shetland)

The review of existing publications and databases (section 3) concentrates on information on the status, ecology and conservation of *Modiolus* within Scotland, the UK and, where appropriate, other parts of the world.

Field studies of the above targeted sites were undertaken in 1999 in order to provide further information on the possible variants or types of horse mussel beds in Scotland with a view to assessing relevant conservation requirements. Specifically, at each site, the main factors studied were *Modiolus* distribution, population structure and associated communities (sections 4 & 5). At each site several attributes were assessed including:

Habitat, environment and physical conditions

- substrate composition around and within the bed
- particle size and organic content of the sediments
- current/wave exposure conditions
- turbidity and character of the water
- extent, density and continuity of the mussel bed including live/dead shell ratios
- size and age structure of the *Modiolus* within the bed including presence of spat

Associated fauna and flora

- Presence and abundance of large organisms by means of MNCR Phase 2 surveys
- Presence and abundance of smaller organisms associated within the matrix of the bed by means of clump collection and subsequent laboratory analysis

The data obtained from these site surveys, along with existing published information, are used to provide an assessment of the ecological and conservation requirements of the *Modiolus* bed types (section 6). A comparison of the three sites is made and the relative sensitivity and vulnerability of the beds to possible anthropogenic effects is considered. A list of recommendations is provided (section 7).

3 INFORMATION REVIEW

3.1 Methodology

Relevant literature and information sources (e.g. the MNCR database) were consulted to provide the following review of available information on the status, ecology and conservation of *M. modiolus*.

3.2 Geographical distribution of *M. modiolus* and its biotopes

M. modiolus is a northern species occurring in both the Pacific and Atlantic Oceans. Within Britain the species is found more frequently in northern and western areas. According to the MNCR database and published sector reviews *Modiolus* has been recorded at sites in all MNCR sectors within Scotland (Sectors 1,2,3,4,5,11,12,13,14 and 15) ranging from Eyemouth, in the south-east, to Silloth Channel, Solway Firth in the south-west (Brazier *et al*., 1998; Covey, 1998). At points in between *Modiolus* is recorded as occurring in: the outer Firth of Forth; the Cromarty and Moray Firths; Orkney and Shetland; Loch Eriboll on the north coast; and at many sites all along the west coast of Scotland, including the Inner and Outer Hebrides and Rockall (Barne *et al*., 1997a, b, c; Beaver & Connor, in prep.; Dipper *et al*., in prep.; JNCC, in prep.). There are relatively few MNCR sites on Scotland's east coast, especially in the north-east, and the recorded distribution of *Modiolus* on the east coast is probably less complete than the more extensively surveyed west coast and Northern and Western Isles. The search of the MNCR database revealed 817 Habitat and Site records in Scotland and a total of 517 site sheets were listed. Local distribution of *Modiolus* can vary from sparsely distributed individuals, discontinuous 'clumps' of individuals, more closely associated 'clumps', to a more or less continuous 'bed' of *Modiolus*. It is however often difficult to define when a 'bed' of *Modiolus* exists. To assess the number of MNCR sites in which possible 'beds' of *Modiolus* may occur the MNCR database was searched for recorded 'Abundant' and 'Superabundant' *Modiolus*. This produced 67 sites in Scotland, most of which occurred in Shetland (sector 1) and North-west Scotland (sector 15) although several occurred in Orkney (sector 2), Outer Hebrides (sector 14), West Scotland (sector 13) and Clyde Sea (sector 12). Holt *et al.* (1998) cite dense beds having been recorded in the vicinity of the Farne Islands but no information appears to exist as to possible 'beds' in the extreme south-east of Scotland (part of sector 5) although areas of sporadic *Modiolus* are recorded (Brazier *et al*., 1998). In a survey of benthic environments of the estuary and the Firth of Forth a *Modiolus* association was recorded off Crammond by Elliott & Kingston (1987).

A number of journal papers and published and unpublished reports mention or describe the presence of what may be 'beds' of *Modiolus* in North America and Europe. These include:

North America:

Gulf of Maine, USA (Ojeda, 1987); Puget Sound, USA (Hatfield, 1991; Wekell *et al.*, 1996); Canada (Navarro & Thompson, 1997); Bay of Fundy, Canada (Muschenheim & Milligan, 1998; Wildish *et al.*, 1998a).

Iceland:

(Eiriksson, 1997).

Norway:

(Davenport & Kjorsvik, 1982; Gulliksen & Stromgren, 1973; Naes, Knutzen & Berglind, 1995; Naes, Oug & Knutzen, 1998; Strand & Volstad, 1997).

Sweden:

Knahaken, (Goransson & Karlsson, 1998).

The Black Sea:

(Gomoiu, 1995).

Ireland:

(Leahy, 1991).

Isle of Man:

(Holt & Shalla, 1997; Holt, Shalla & Brand, 1996; Jasim, 1986; Jasim & Brand, 1989; Jones, 1951; Ward, 1988).

Northern Ireland:

Strangford Lough (Brown, 1976; Roberts, 1975; Service & Magorrian, 1997; Magorrian & Service, 1998; Magorrian, Service & Clarke, 1995).

Wales:

Penrhyn Bay, North Wales (Wilson, 1977).

The North Sea:

(Rees & Nicholson, 1989).

England:

Bristol Channel (George & Warwick, 1985); Humber, North Norfolk (Kenny, 1995); Wash basin (Fowler, 1987).

Scotland:

Yell Sound, Shetland (May, Smith & Bartlett, 1991); Sullom Voe (Coackley, Bache & Smith, 1981; Pearson & Eleftheriou, 1981; Mair, Kingston & Hill, 1986; IOE, 1979-1995; ERT, 1995-2000); Shetland Voes (Comely, 1981); Busta Voe and Olna Firth, Shetland (Entec, 1996; Howson, 1999; Murray *et al*., 1999); Lochs Duich, Long and Alsh (SNH, 1999); Loch Linhe (Pearson, 1970); Lochs Linhe, Eil, Creran and Aline (Connor, 1990); Firth of Lorn, Loch Fyne (James, 1989); Clyde Sea and West Coast (Collins, 1986; Comely, 1978; Dipper & Beaver, 1999).

Scottish beds regarded as biogenic reefs are reported from Lochs Creran, Eil and Leven (Howson *et al.*, 1994), off the Ards peninsula, relatively small areas in Lochs Duich, Long and Alsh (SNH, unpublished information), and the Shetland Voes (Howson, 1999). More beds are thought to probably occur elsewhere, especially on the West of Scotland.

Classified biotopes are described by Connor *et al.* (1995, 1997) and in Scotland three were listed as being characterised by *Modiolus*:

MCR.ModT (***Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata): Shetland (Pearson, Coates & Duncan, 1994; Howson, 1988; Howson, 1999) and west coast sealochs (Howson, Connor & Holt, 1994).**

SCR.ModHAs (***Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata): Shetland (Hiscock, 1986; Pearson, Coates & Duncan, 1994; Howson, 1999) and west coast sealochs (Howson, Connor & Holt, 1994; and MNCR survey records).**

CMX.ModHo (**Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment): Shetland (MNCR survey records; Howson, 1999); Skye sealochs, Lochs Duich, Ewe and Broom (MNCR survey records); Clyde sealochs and SW Scotland sealochs (Howson, Connor & Holt, 1994).**

Another biotope (CMX.ModMx **– *Modiolus modiolus* bed on circalittoral mixed sediment) was indicated, from MNCR records, as being present in Orkney (Holt *et al.*, 1998; Murray *et al.*, 1999) and Shetland (Howson, 1999).**

Holt *et al.* (1998) list the presence of biogenic reefs in UK Marine SACs. In Scotland these include pSAC Lochs Duich, Long and Alsh, pSAC Loch Creran, and they are also listed as occurring in Busta Voe and Olna Firth.

3.3 Environmental requirements and attributes of *Modiolus* reefs/beds

The following is a list of publications dealing with, or including, topics related to the environmental requirements and physical attributes of *Modiolus* beds:

Norwegian intertidal population (Davenport & Kjorsvik, 1982);
Mid-tidal rock pools (Wilson, 1977);
Deep water *Modiolus* (Collins, 1986);
Rocky subtidal community structure (Ojeda, 1987);
Bottom fauna (Jones, 1951);
Hard bottom reef communities (George & Warwick, 1985);
Reefs (Holt & Shalla, 1997);
Reef construction (Gomoiu, 1995).
Modiolus from the Scottish west coast (Comely, 1978);
Sediments (Meadows & Shand, 1989);

Marine sediment stability (Shand, 1987);
Benthic characterisation, Ireland, using polychaetes (Leahy, 1991);
Benthic communities, Strangford Lough, Northern Ireland (Erwin, 1970);
Habitat preference, bioindicators (Naes, Oug & Knutzen, 1998);
Physiological energetics in cold ocean environment (Navarro & Thompson, 1996);
Benthic brachiopod growth rate and mortality (Collins, 1991);
Bryozoans on loose, dead shells, temperate water communities (Ward, 1988).

3.4 Biology and ecology of *M. modiolus*

A large body of literature exists of works reporting and discussing various biological and ecological aspects of *Modiolus* and *Modiolus* communities. The following is a list of relevant publications that include these various topics divided into general subject areas (some of the publications cover more than one of the topics):

Life cycle/reproduction/larval biology

Comparative sperm morphology (Kafanov & Drosdof, 1998);
Comparison of reproductive cycles (Seed & Brown, 1977);
Reproductive biology (James, 1989);
Observations on reproduction (Jasim & Brand, 1989);
Periostracal adventitious hairs on spat (Dixon *et al.*, 1995);
Larval development (Schweinitz & Lutz, 1976; Fuller, 1986);
Geographical variations in the reproduction of the horse mussel (Brown, 1984);
Aspects of nursery cultivation of bivalve molluscs (Mohammed, 1987).

Physiology/biology

Respiratory physiology (Harris, 1990);
Respiratory physiology of subtidal bivalves (Morris, 1978);
Water balance (Pierce, 1970);
Physical and biochemical condition of *Modiolus* in selected Shetland Voes (Comely, 1981);
Molecular diversity of marine glues (Rzepecki *et al.*, 1991);
Cold water communities, physiological energetics (Navarro & Thompson, 1996);
Microbial utilization of neurotoxin (Stewart *et al.*, 1998);
Survey of paralytic shellfish poisons (Wekell *et al.*, 1996);
Influence of the natural food supply on physiological energetics and biochemical storage cycles (Navarro, 1990);
Byssal thread analysis (Meadows & Shand, 1989);
Absorption efficiency, food capture rate, (Lesser, Witman & Sebens, 1994);
Antibacterial activity (Tunkijjanukij & Olafsen, 1998);
Bacterial toxins, biochemistry/ biophysics (Tunkijjanukij, Mikkelson & Olafsen, 1997);
Functions of carotenoids in Mollusca (Vershinin, 1996);
Growth as a strategy for survival (Seed & Brown, 1978);
Gill abfrontal surface (Dufour, 1998);
Gill secretory cell, effect of copper sulphate (Clements, 1983);
Euryhalinity and isosmotic regulation (Lange, 1970);
General biology, growth and economic significance (Wiborg, 1946);
Age determination, growth rate and population structure (Anwar, Richardson & Seed, 1990);
Population analysis based on estimated age, valve allometry and biomass (Wildish *et al.*, 1998a);

Comparative growth analysis (Brown, Seed & O'Connor, 1976);
Fossil bivalvia variation (Hodges, 1988).

General ecology

Ecology of *Modiolus* (Brown 1976);
Autoecology (Brown & Seed, 1977);
Some ecological aspects of *Modiolus* (Jasim, 1986);
Predator deterrence by flexible shell extension (Wright & Francis, 1984);
Biology of marine gravel deposits (Kenny, 1995);
Epibenthic communities, extent and temporal variation (Service & Magorrian, 1997);
Epifauna, taphonomic processes (Collins, 1986);
Deep water environmental assessment (James, 1989);
Disturbance, competition and mutualism in rocky, subtidal communities (Witman, 1984);
Benthic boundary layer processes (Muschenheim & Milligan, 1998);
Biodeposition during spring diatom bloom (Navarro & Thompson, 1997);
Annual macroflora production in hard bottom reef community (George & Warwick, 1985);
Biological control of marine sediment stability by mussels (Shand, 1987);
Influence of reproductive cycle, growth and mortality on population structure (Seed & Brown, 1975);
Species abundance (Magorrian & Service, 1998).

Regional descriptions of communities

Synopses and reviews by MNCR Sector (Hiscock, 1998b);
Sublittoral ecology of the Wash basin (Fowler, 1987);
Bottom fauna off the south of the Isle of Man (Jones, 1951);
Investigations into a community in Strangford Lough (Roberts, 1975);
Loch Linnhe benthic ecology (Pearson, 1970);
Sullom Voe benthic ecology (Pearson & Eleftheriou, 1981).

Associated fauna

Growth rate and substrate related mortality of a benthic brachiopod population (Collins, 1991);
Ecology of ascidians (Hatfield, 1991);
Asterias vulgaris in sub-tidal community structure (Hulbert, 1980);
Ecology of subtidal encrusting bryozoans (Ward, 1988);
Role of mobile predators (Ojeda, 1987);
Species composition (Goransson & Karlsson, 1998);

A list of associated fauna found at sites with *Modiolus* beds in Scotland was produced from the MNCR database (Appendix 2 of this report).

3.5 Sensitivity to natural events and to human activities

Taphonomic processes in deep water *Modiolus* (Collins, 1986);
Dynamic sensitivity characteristics (Holt *et al.*, 1998);
Responses to aerial exposure (Coleman, 1973);
Use of mussels to monitor environmental stresses (Arimoto, 1981);

Paralytic shellfish poisoning and domoic acid in predatory gastropods (Wekell *et al.*, 1996);
Influence of disturbance in ecology of rocky subtidal communities (Witman, 1984);
Coastal ecosystems in the Black Sea (Gomoiu, 1995);
Aspects of nursery cultivation of bivalve molluscs (Mohammed, 1987).
Accumulation of PAHs in littoral indicator organisms (Naes, Oug & Knutzen, 1998);
Trends in lead levels (Rees & Nicholson, 1989);
Investigations of a polluted *Modiolus* bed (Barr, 1982);
Effect of copper sulphate upon gill secretory cell nature etc. (Clements, 1983);
Pre and post drilling surveys (Holt & Shalla, 1997; Holt, Shalla & Brand, 1996);
Oily water discharge effects in Sullom Voe, Shetland (IOE, 1979-1995; ERT, 1995-2000);
Distribution of heavy metals in Sullom Voe (Coackley, Bache & Smith, 1981);
Aluminium, PAHs, smelter discharges in Norway (Naes, Knutzen & Berglind, 1995);
Dredging impacts (Kenny, 1995);
Impact of physical disturbance (Magorrian & Service, 1998);
Extent and temporal variation of disturbance of epibenthic communities (Service & Magorrian, 1997);
Recreational harvesting (Wekell et al 1996);
Iceland molluscan fisheries (Eiriksson, 1997);
Norway molluscan fisheries (Strand & Volstad, 1997).

3.6 Survey methods for *Modiolus*

The following list of reports and publications deal with the various methods that can be employed in sampling and surveying *Modiolus* beds:

Surveying *Modiolus* communities (Bradley, 1998);
Monitoring and surveillance options (Holt *et al.*, 1998);
Quadrat sampling (Murray, 1998);
ACE surveys (Hiscock, 1998);
Diving survey (Erwin, 1970);
Broadscale survey (Entec, 1996; SNH, 1999);
Photographic survey (Holt, Shalla & Brand, 1996);
Analysis of underwater visual data to assess impact (Magorrian & Service, 1998);
Surveying extent and temporal variation (Service & Magorrian, 1997);
Acoustic remote sensing, predicting distribution of biotopes, video and GIS (Johnston & Davison, 1997);
Acoustic detection and characterisation of sublittoral bivalve reefs – ROV, video (Wildish *et al.*, 1998b);
Acoustic monitoring techniques (Davies, 1999).

3.7 Conservation of Modiolus

The following papers relate to conservation considerations for *Modiolus*:

The conservation of coastal ecosystems on the Black Sea (Gomoiu, 1995);
Review of marine biological information for Shetland (Hiscock and Johnston, 1990);
Economic significance (Wiborg, 1946).

A recent report has been produced dealing specifically with conservation requirements of *M. modiolus* communities (Bradley, 1998).

6.3 **Previous work and reports describing the study sites of pSAC Loch Creran, Busta Voe and Olna Firth, and pSAC Lochs Duich, Long and Alsh**

3.8.1 *Loch Creran*

Gage (1972); Moore (1996); Moore, Saunders & Harries (1998); SNH (in prep.). Numerous unpublished research studies have also been carried out by staff and students of Heriot-Watt University and the Dunstaffnage Marine Laboratory.

6.3.1 Busta Voe

Earll (1982); Entec (1996); Howson (1999).

6.3.2 Lochs Duich, Long and Alsh

Dipper (1981); Smith (1985); Connor (1989); Hiscock & Covey (1991); Scott (1991); SNH (1999 – interim report).

4 GENERAL METHODS

4.1 Distribution of Modiolus modiolus *beds*

4.1.1 Percentage cover

Preliminary testing of methods indicated that assessment of the abundance of *Modiolus* by quadrat counts was not a viable approach. As a consequence of the tendency for *Modiolus* to form clumps, it was found that accurate density measures could only be achieved by complete removal of shells within a quadrat. This is a potentially damaging and very time-consuming operation, exacerbated by the associated reduction in visibility.

An alternative method involving the measurement of percentage cover was adopted. This employed a square 0.25m^2 quadrat with cross strings at 10cm intervals creating a total of 16 intersections within the quadrat frame. At each survey station 5 replicate quadrat recordings were made using the following methodology. The quadrat was placed randomly on the seabed and the number of string intersections directly overlying live *Modiolus* recorded. Also recorded was the depth, the presence of dead shells and the nature of the substrate using the following classification: mud, sand, mud and sand, mud and gravel, mud and pebbles, rock. In a total of 18 quadrats both percentage cover and total counts of *Modiolus* (by removal of all live shells) were recorded. The results revealed that percentage cover and abundance were correlated ($r=0.542$; $p<0.05$).

Percentage cover was measured by performing spot dives and, especially along rapid depth gradients, by recording along transects. The transects were established by laying a 200 m negatively buoyant groundrope from a boat. The groundrope was weighted and buoyed at both ends and marked with station numbers at 20m intervals, as well as distance marks every 5m. The inshore end of the groundrope was first laid and the boat was then steered along a compass bearing with the groundrope being kept taut. Differential GPS position fixes were made at both ends of the groundrope. A diver took five replicate quadrat measurements at each 20m station to a maximum depth of 30m. Station names along a transect are preceded by the transect name (e.g. T1), followed by the station number (e.g. T1/5), with station 0 being at the inshore end of the transect.

4.1.2 Presence/absence

The presence of *Modiolus* was also determined by a remote-control drop-down video system, especially as a confirmatory tool to verify supposed absence, particularly in deeper water. The nature of the seabed and conspicuous fauna were also recorded. The video camera was deployed vertically from a slowly drifting vessel for a period of about two minutes, the depth and position being recorded.

4.1.3 Video transects

Video transects were employed to record the physiognomy and spatial continuity of the beds as well as the nature of the seabed, the relative abundance of dead and live *Modiolus* shells and the larger epifaunal species. The video equipment consisted of a Panasonic NV-DX110B digital video camera within a Seapro housing. The transects used were a subset of

those employed for percentage cover estimation (see above). The video recording was made by diver, swimming parallel to the transect ground rope at a distance of c. 30 cm above the seabed with the camera lens at an angle of c. 45° from the vertical. Groundrope station markers were filmed, so that at 20 m intervals along the transect the depth and position could be subsequently determined.

4.1.4 Video mosaicing

This technique allows a photographic mosaic to be compiled covering an extensive area of the seabed, thereby providing a record of the distributional pattern of *Modiolus* and other large epifaunal species. At each survey site a 5 x 5m grid was constructed on the seabed using rope pinned to the seabed. The grid was divided into 0.5m wide lanes at Loch Alsh and Busta Voe, and 0.25m wide lanes at the lower visibility site in Loch Creran. A diver videoed each lane, swimming in the same direction, and pointing the camera vertically downwards. The video footage was then downloaded to a computer and in-house designed software used to mosaic consecutive frames into photographic strips and then join contiguous strips together into a photographic image of the entire grid. An example of the resulting mosaic image is given later in this report.

4.2 Associated fauna and flora

4.2.1 MNCR Phase 2 surveys

At each site a central area within the *Modiolus* bed was chosen for MNCR Phase 2 surveying, which followed the standard methodology (Hiscock, 1996). *In situ* recording of abundances was supplemented by some collection of unidentified specimens and stills photography using a Nikonos V camera with close-up lens and 15 mm wide angle lens, and close-up video photography using the diver-held Panasonic system.

4.2.2 Clump collection

Semiquantitative data on the epifauna and infauna of the *Modiolus* beds were acquired by collecting four replicate clumps of *Modiolus* from a central area at each site. A diver carefully removed each clump, whose size just enabled it to be placed into a 5 litre bucket. The bucket was sealed with a lid before transport to the surface. In the laboratory the volume of the clump was determined by displacement and the associated fauna and flora retained on a 0.5 mm mesh sieve counted and identified following the species nomenclature of Howson & Picton (1997).

For each clump the number of species was determined and the Shannon-Wiener diversity and Pielou evenness indices (employing $\log_2$) calculated for the quantified species. Differences in species number and diversity between sites were assessed by one-way analysis of variance and Tukey *a posteriori* comparisons, after checking for homogeneity of variances.

Similarity between replicate clumps and between sites in terms of the composition of the associated fauna and flora was assessed by cluster analysis and ordination. The analyses were performed on log(x+1) transformed abundance data, with the abundance of species recorded only qualitatively (algae and colonial animals) being allocated an abundance of 1.

Cluster analysis used the Bray-Curtis similarity coefficient and group average sorting. Ordination was by non-metric multidimensional scaling, again using the Bray-Curtis similarity coefficient. Significant differences in species composition between the sites were formally assessed using analysis of similarities (ANOSIM).

4.3 *Modiolus* population analysis

At each site within the central region of each bed at least four replicate 0.25 m^2 quadrats were cleared of *Modiolus* shells, which were taken to the surface in separate bags. The number of live and dead *Modiolus* shells in each quadrat was counted.

Additional *Modiolus* were collected from the same sites to bring the total live shells to over 100. The length, width and height of each *Modiolus* was measured to the nearest millimetre using digital callipers and length/frequency analysis of the sample performed.

At each site three of the larger shells were selected for growth analysis. In the time available only a fairly rapid means of growth rate determination was possible. The shell was polished using fine sandpaper and brushed with hydrochloric acid to emphasise the year rings. The distance from the umbo to each year ring was measured using digital callipers. As growth rings towards the margin of the shell become increasingly difficult to identify with certainty, a von Bertalanffy growth curve was fitted to the age/length data for the first 16 rings. This permits estimation of length at any age.

4.4 Physico-chemical analysis of the sediment

In addition to visual determination of the nature of the sediment by diver and photography (see above), single 10cm long core samples of the sediment were taken by diver at a number of sites within and outwith the beds at each survey area using a 5cm diameter coring tube. The samples were retained in a coolbox prior to being stored in a deep freeze. The sediment was analysed for carbon content and particle size.

Organic carbon content was measured by suspending 20g of defrosted sediment in 1 litre of water and removing four 72ml subsamples. The sediment in each subsample was washed with 1 litre of distilled water on Whatman GF/C glass microfibre filters and oven dried. The dried sediment was ground for 1 minute by pestle and mortar and analysed for organic carbon content using the method of El Wakeel & Riley (1956).

For particle size analysis the sediment samples were dried to constant weight at 95°C and 120g sediment mixed with 1.2 litre tapwater and 48ml aqueous sodium hexametaphosphate ($6.2g.l^{-1}$). The samples were stirred mechanically for 15 min and allowed to soak overnight, after which they were restirred for 15 minutes and wet-sieved through a 63µm screen. The screenings were redried to constant weight and sieved on a sieve shaker for 15 minutes using sieves at 0.5phi intervals.

4.5 Position and depth datums

Position fixing was by GPS using a Furuno GP35 DGPS on RV *Serpula* and a Garmin GPS40 + differential receiver on MV *Loren*. All positions are given with respect to OSGB1936 datum. All depths quoted are given in relation to chart datum.

5 THE STUDY SITES – METHODOLOGY AND RESULTS

5.1 Loch Creran

5.1.1 *Site methods*

Loch Creran was studied on three occasions, working from the research vessel RV Serpula:

12-13 August 1999 – location of the upper basin *Modiolus* bed, testing of methods, collection of *Modiolus* clumps.
29-31 October 1999 – video and cover estimation transects, MNCR Phase 2 survey, collection of *Modiolus* for size analysis.
13-14 December 1999 – cover estimation along transects and by spot dives, video transects, sediment coring, drop-down video and video mosaicing.

The *Modiolus* bed studied lies off the southern shore of the very sheltered upper basin of Loch Creran, east of Dallachulish (Connor, 1990). Although *Modiolus* can be found in low numbers as single individuals or clumps over a large area within the upper basin, preliminary dives established that the area of dense *Modiolus* along the southern shore was confined to a strip of seabed no more than 750 m long. *Modiolus* is also abundant in strong tidal currents at Creagan Narrows, at the entrance to the upper basin, about 1 km to the west (Connor, 1990).

The fairly discrete nature of the Dallachulish *Modiolus* bed renders it amenable to mapping. Percentage cover was measured along four depth transects (T1-T4), one longitudinal transect (T5) and at two stations (A and B) (Fig. 5.1). Observation of the seabed by drop-down video was performed at a further four sites.

Video transects were carried out along T1, T2, T3 and T4, although due to very poor visibility and equipment malfunction useable recordings were obtained only along transects T1 and T4.

Whereas at the other study sites video mosaicing was performed within a grid of 0.5 m wide lanes, at Creran the visibility was so poor that the lane width was reduced to 0.25 m. The grid was established at a depth of 10 m on transect T1. This was on the upper edge of the *Modiolus* bed but the light conditions deeper down were too poor for good quality video images without artificial light. An artificial lighting system capable of eliminating shadows, which may interfere with the mosaicing process, was not available.

Core samples for particle size and organic carbon determination were taken at 10 stations (Fig. 5.1). These stations lay along two transects: one transect (adjacent to T1) passed along the depth gradient through the central part of the bed, the other transect ran parallel to the shore at a depth of about 15 m, again passing through the centre of the bed.

Station T1/3 at a depth of 15 m was chosen for detailed study as it lay near the centre of the bed and constituted one of the densest areas of *Modiolus* cover.

In the vicinity of T1/3 percentage cover measurement was made in nine replicate 0.25 m^2 quadrats and all the shells subsequently removed for estimating abundance, dead/live shell composition and for size and age analysis. This material was supplemented by collection of additional *Modiolus* to bring the total to about 100 live *Modiolus*.

Four replicate *Modiolus* clumps were collected from the vicinity of station T1/3 for analysis of the associated fauna and flora (see Table 5.1 for collection details). An MNCR phase 2 survey was carried out at the same site. Diver observations were supplemented by 20 still photographs (10 habitat, 10 close-up) (Appendix 1) and close-up video photography.

5.1.2 *Modiolus distribution*

Fig. 5.2 shows the belt of enhanced *Modiolus* abundance at the study site. Scattered individuals and clumps are known to occur outwith this belt especially to the west. Within the belt *Modiolus* was found to be common within the depth range 10-23 m, attaining >20 % cover in patches. Near the centre of the bed (station T1/3) replicate quadrat counts gave a mean abundance of 28/m^2.

Modiolus was found to occur predominantly in well-separated clumps on mixed sediment made up of a matrix of sandy mud with abundant dead shells and small stones (Table 5.2). The dead shell/live *Modiolus* ratio at site T1/3 was 1.1, although elsewhere live *Modiolus* were generally greatly outnumbered by empty shells. In shallow water above the bed the substrate changed to a muddy sand with a dense surface cover of pebbles and gravel. Below the bed there was no obvious change in the sediment corresponding to the disappearance of *Modiolus* (Fig. 5.3). There were changes in sediment type corresponding to the eastern and western limits of the bed (Fig. 5.4). To the west (station A) the sediment graded into a muddy sand with the minimum mud content recorded, while to the east (station B) the sediment became a comparatively well-sorted mud. There was no correlation between *Modiolus* coverage and the silt/clay content of the sediment.

The highest sediment carbon content (4.5%) was recorded to the east of the *Modiolus* bed in an area of the weakest tidal currents, whilst the lowest contents were also found outside the bed: to the west (2.8%) in the strongest tidal currents and at stations shallower and deeper than the bed (all 2.7%) (Fig. 5.5, Table 5.3). However, there was no evidence for organic enrichment of sediments by *Modiolus*. There was no correlation between organic content and percent cover of *Modiolus* but there was a very strong correlation (r=0.858; p<0.01) between organic carbon and silt/clay content of the sediment.

5.1.3 *Modiolus population structure*

The size structure of a sample from the population is shown in Fig. 5.6, while the age at any length can be obtained from the growth curve given in Fig. 5.7. It should be noted that the annual rings were difficult to discern, especially close to the anterior end. The size structure of the population was basically unimodal, with virtually all specimens lying between 60-135 mm in length (age, 7-21) , with the peak at 110-115 mm (age, 16). It appears that very little recruitment to the population has taken place for the last seven years. Spat were fairly plentiful amongst the larger shells, although the great majority of these were *Mytilus edulis*. In addition to the single spat of *Modiolus* found in this sample, a few spat were also recorded in the *Modiolus* clumps collected for study of the associated fauna.

5.1.4 *Associated community*

The results of the MNCR Phase 2 survey are summarised in Table 5.4 and the fauna and flora found within the *Modiolus* clump samples are described in section 6.

5.2 Busta Voe

5.2.1 *Site methods*

Busta Voe was studied from 20-23 August 1999 using the 45 ft landing craft MV Loren. The area examined lay mostly off the northern coast of Linga (Fig. 5.8). *Modiolus* beds have been found to occur extensively in this area and have already been mapped (Entec, 1996). The variation in *Modiolus* cover with depth was studied along two transects off Linga (TA and TB) and the variation in cover over a wider area was examined using spot dives at eight stations (1-8) and drop-down video at eight stations (A-I). Video transects were carried out along TA and TB.

Core samples for particle size and organic carbon determination were taken at nine stations, including stations both within and outwith *Modiolus* beds (Fig. 5.8).

Station 1 at a depth of 14 m, northeast of Linga, was identified as a well-developed *Modiolus* bed and was selected for detailed study.

Video mosaicing was carried out at station 1.

Percentage cover measurement was made in five replicate 0.25 m^2 quadrats at station 1 and all the shells subsequently removed for estimating abundance, dead/live shell composition and for size and age analysis. This material was supplemented by collection of additional *Modiolus* to bring the total to over 100 live *Modiolus*.

4 replicate *Modiolus* clumps were collected from the vicinity of station 1 for analysis of the associated fauna and flora (see Table 5.1 for collection details). An MNCR phase 2 survey was carried out at the same site. Diver observations were supplemented by 20 still photographs (10 habitat, 10 close-up) (Appendix 1) and close-up video photography.

5.2.2 *Modiolus distribution*

Howson (1999) describes beds of *Modiolus* occurring between depths of about 5 and 25 m around the sides of the voes in this area on mixed muddy sediments. This agrees closely with the distribution of *Modiolus* revealed by the present survey, although only very low densities at the extremes of the depth range were found. The pattern of distribution of beds within the area as revealed by transects, spot dives and drop-down video agrees well with the mapping of the ModHAs biotope given in Howson (1999).

On transect TA (see Fig. 5.8) a red, *Trailliella*-like algal mat covered much of the sediment from a depth of 6 to 14 m and *Modiolus* was extremely infrequent in this area. From 15-20 m percentage cover averaged 10%, before declining again from 20-22 m. Maximum coverage of 26% was recorded at nearby site 1 at a depth of 14 m, where quadrat counts gave a mean abundance of 45/m^2. On transect B there was a dense cover of *Laminaria saccharina* out to 9 m overlying very sparse *Modiolus*. *Modiolus* cover increased from 8% at 10 m to a transect maximum of 16% at the deepest station recorded at 19 m. Although percentage cover estimates were not made beyond 19 m, the video transect shows the bed to extend to about 22m, with scattered individuals found down to the end of the transect at 24 m. Observations from the other diver and drop-down video stations confirm that the *Modiolus* beds lie mainly between 14 and 22 m. No *Modiolus* was seen beyond 25 m. Unlike the case at Creran, the *Modiolus* bed at Busta Voe tended to take the configuration of a single layer of shells, although some raised clumps were also present.

The video mosaic results are shown in Fig. 5.9.

The *Modiolus* bed occurred on a very mixed muddy sediment with many empty shells (Fig. 5.10, Table 5.5). At station 1, where the densest cover of *Modiolus* was recorded, the dead shell/live *Modiolus* ratio was 2.5. Although there was no correlation between *Modiolus* coverage and silt/clay content, the two stations with the highest coverage of *Modiolus* (1 and 5) also had the highest silt/clay content.

Organic carbon content of the sediment (Table 5.3) was somewhat higher than in Loch Creran with maximum values (>6%) being recorded from the stations with the highest percentage cover of *Modiolus* (1 and 5). However, there was no correlation between percentage cover and organic content and, as at Creran, the organic content closely followed the silt/clay content of the sediment ($r=0.754$; $p<0.05$).

5.2.3 *Modiolus population structure*

The size structure of a sample from the population is shown in Fig. 5.6, while the age at any length can be obtained from the growth curve given in Fig. 5.7. It should be noted that the annual rings were very difficult to discern at Busta Voe due to heavy fouling of the shells and abrasion of the anterior end. The growth rate and size structure of the population was similar to Creran, although mean length was a little greater. The unimodal frequency distribution ranged from 85-155 mm (age, 10-25), with the peak at 115-120 mm (age, 16-17). No spat were found at Busta Voe and it appears that recruitment to this population has not taken place for about 10 years.

5.2.4 *Associated community*

The results of the MNCR Phase 2 survey are summarised in Table 5.6 and the fauna and flora found within the *Modiolus* clump samples are described in section 6.

5.3 Loch Alsh

5.3.1 *Site methods*

Loch Alsh was studied from 4-7 September 1999 using RV Serpula. The area examined lay to the south of Kyle of Lochalsh in an area of moderately strong tidal currents (Fig. 5.11). *Modiolus* is widespread in this area (SNH, 1999) and so it was decided that the distributional study should concentrate on the variation in cover with depth in an area of abundant *Modiolus*. Accordingly transect T1 to the southeast of String Rock was examined as it passes through a rich bed and lies outside the main navigational channel. To confirm that this was not an isolated patch of *Modiolus*, additional stations were examined to the west (station A) and east (station B) of this area. Additionally, two measurements of percentage cover were made at station 1 adjacent to the transect. A video transect was also carried out along T1. The drop-down video equipment failed to function at this site.

Core samples for particle size and organic carbon determination were taken at seven stations, including stations both within and outwith *Modiolus* beds (Fig. 5.11).

Station 1 at a depth of 20 m was identified as a well-developed *Modiolus* bed and was selected for detailed study.

Percentage cover measurement was made in four replicate 0.25 m^2 quadrats at station 1 and all the shells subsequently removed for estimating abundance, dead/live shell composition and for size and age analysis.

Four replicate *Modiolus* clumps were collected from the vicinity of station 1 for analysis of the associated fauna and flora (see Table 5.1 for collection details). An MNCR phase 2 survey was carried out at the same site. Diver observations were supplemented by 20 still photographs (10 habitat, 10 close-up) (Appendix 1) and close-up video photography.

5.3.2 *Modiolus distribution*

Along transect T1 (Fig. 5.11) at the String Rock study site it was found that the shallow limit of the *Modiolus* bed was very distinct at a depth of 19 m. From station T1/4 at a depth of 19 m until the deeper end of the transect, station T1/10, at 25 m *Modiolus* was abundant with an average cover of 45%. *Modiolus* cover of the seabed was mostly as a single layer of shells with small patches of bare sediment, although some raised clumps were present, especially in shallower water. The abundance of *Modiolus* was determined at station 1, at 20 m depth, close to the transect. Four quadrat counts provided a mean abundance of 106/m^2.

From the percentage cover records at stations A and B and the results of three MNCR surveys carried out in the area it appears that *Modiolus* is abundant in the channel between Eileanan Dubha and Skye from at least 5° 42.32'W to 5° 42.78'W and between depths of 7 and 41 m. The record of abundant *Modiolus* at a site north of String Rock at a depth of 7-10 m (MNCR database) contrasts with the much deeper inshore limit recorded along transect T1. This difference may be related to current speed. The inshore end of transect T1 is likely to experience reduced current rates as it lies at the mouth of an embayment and is protected to the east by the Rubha Ard peninsula and to the west by a reef running out from the Skye coast to String Rock.

The *Modiolus* bed was found to occur on a sediment containing a wide mix of mud, all sand grades, gravel and stones, with empty shells (Fig. 5.12, Table 5.7). At station 1 the ratio of dead shells/live *Modiolus* was found to be relatively low at 0.6. Along transect T1 there were some distinct changes in sediment type that could be interpreted as being influenced by variation in current speed caused by shelter and the presence of the dense *Modiolus* bed. At the inshore end of the transect (T1/0) the probable reduction in current speed resulted in a muddy fine sand sediment. With progression towards the main channel the sediment coarsened to a medium-coarse sand with the smallest mud content recorded during the survey (T1/3). Farther along the transect the presence of the *Modiolus* bed, at a similar depth to T1/3, corresponded to a large increase in mud content, which may have been due to the baffling effect of the bed or the production of pseudofaeces. However, there was no correlation between *Modiolus* coverage and silt/clay content of the sediment.

As might be expected in a region of comparatively strong currents, the organic content of the sediment (Table 5.3) was lower than at Creran and Busta Voe (0.4-2.4%). However, the organic content was related neither to the abundance of *Modiolus* nor to the amount of silt/clay in the sediment (p>0.05).

5.3.3 *Modiolus population structure*

Modiolus was distinctly smaller at Loch Alsh than at the other sites, with the unimodal frequency distribution spanning a wide size range, 45-120 mm (Fig. 5.6) and age range, 5-29 (Fig. 5.7) Although in the early years the growth rate of *Modiolus* appears similar to the

other sites, after 10 years growth becomes slower than elsewhere. No spat were observed and it appears that recruitment has not taken place for five years.

5.3.4 *Associated community*

The results of the MNCR Phase 2 survey are summarised in Table 5.8 and the fauna and flora found within the *Modiolus* clump samples are described in section 6.

6.3 A comparison of community parameters amongst the three study sites

Data on the associated fauna and flora of the *Modiolus* clumps were subjected to species diversity and multivariate analyses. Table 5.10 summarises, for each of the analysed clump samples from the three study sites, the number of species recorded and Shannon-Wiener diversity and Pielou evenness. Analysis of variance of these results indicates that there is no significant difference between the Loch Creran and Loch Alsh sites in terms of number of species and diversity. However, compared to the other two sites, the numbers of species in the Busta Voe samples were significantly less ($p = 0.002$) as were diversity values ($p = 0.01$).

Cluster analysis (Fig. 5.13) indicates that the clump samples separate out into three distinct clusters corresponding to the three survey sites. The results of multidimensional scaling ordination (Fig. 5.14) substantiates this finding that all samples within a study site are very similar but that the samples at the three geographically dispersed study sites are more or less equally different from each other. The ANOSIM test confirmed that species composition at all sites were significantly different ($p<0.05$).

Some of the main differences in presence/absence and abundance/rarity of taxa at the three study sites are highlighted in Table 5.11.

6 DISCUSSION

6.3 Environmental and physical attributes of the *Modiolus* habitat

It is clear that the substrates within all three *Modiolus* beds in this study consisted of very mixed, or poorly sorted, sediments in terms of particle size – a broad range of size fractions was generally always present in the samples. Sediment taken from the denser areas of the beds tended to have proportionally higher percentages (compared to samples taken from outside the beds) of a mixture of both silt/clay size particles and larger fractions of greater than 4000µm. Although there is no apparent statistical evidence of the influence of *Modiolus* on particle size (silt/clay content) there appears to be some indirect indication of the relationship of sediment structure to the presence of *Modiolus*. For example, at Busta Voe, the two sample sites with the densest *Modiolus* also had the highest silt/clay proportions of the samples analysed. What is perhaps more striking was the very distinct boundary of the Loch Alsh *Modiolus* bed at 19 m depth between stations T1/3 and T1/4 and the corresponding rapid change between the relatively sandy/low-silt sediment (at T1/3) and the nearby core sample stations (1 and T1/7) on dense *Modiolus* cover where the sediments were of the generally characteristic poorer-sorted and higher-silt/clay types. No evidence of correlation between organic carbon content and the abundance of *Modiolus* was observed although, as might be expected, higher organic content was generally closely related to sites with higher proportions of silt/clay. Whilst the physical presence of *Modiolus* undoubtedly will have some effect on the sediment characteristics of an area it is more probable that there is a combination of this physical baffling effect of the dense nests of *Modiolus* and the associated ophiuroid arms on the surface boundary layer, the production of pseudofaeces, the localised current regime (see section 5.3.2) and an influence of preferred habitat selection (sediment type) by *Modiolus* (Meadows & Shand, 1989; Muschenheim & Milligan, 1998; Shand, 1987).

The 'bed' at Loch Creran could be better described as a congregation of *Modiolus* clumps, the clumps being closer together at the centre of the bed and more dispersed towards the edges. In contrast there was less obvious 'clumping' at the Busta Voe and Loch Alsh sites where the *Modiolus* formed rather more of a continuous cover on the seabed. The overall densities of *Modiolus*, at the main 'central' sample station chosen at each site, showed a trend increasing in the order of Loch Creran (28 m^{-2}), Busta Voe (45 m^{-2}) and then Loch Alsh (106 m^{-2}), perhaps reflecting the increasing exposure to currents in the areas. The bed in upper Loch Creran is in an extremely sheltered spot and Loch Alsh is in an area of high tidal currents. Whilst the Busta Voe site is within a sheltered voe it can probably be regarded as more exposed to water currents and wave exposure than the Loch Creran site. The ratio of dead shells to live *Modiolus* was least at the Loch Alsh site. Although the measured overall dead/live ratio (taken in samples covering 2.25 m^2) at Loch Creran was 1.1, the observational impression of divers at this site was of a preponderance of dead shells. In another similar study in April 1998 in outer Sullom Voe, Shetland (Mair *et al*., in prep.), the *Modiolus* bed investigated was in a channel swept by strong tidal currents and the measured densities of *Modiolus,* by comparable physical collection, were even higher (150 m^{-2} – taken over a sample area of 2m^2) and the ratio of dead shells to live *Modiolus* (0.23) was lower than at the tidal Loch Alsh site (values of 106 m^{-2} and 0.6 respectively).

The length/frequency distributions and age estimates of *Modiolus* measured at the three study sites indicated that the population at Loch Alsh had a smaller median shell length and slower growth rate than at the more sheltered sites of Loch Creran and Loch Alsh. The length frequency distributions measured at the tidal Sullom Voe site (Mair *et al*., in prep) also indicated smaller maximum shell lengths, similar to the Loch Alsh site in this study. Although year rings were not measured in the Sullom Voe population, it is postulated that the smaller, overall shell lengths found at the sites with stronger tidal currents (Loch Alsh

and Sullom Voe) may be due to either the current regime or the presence of higher observed densities of brittle-stars which, at these sites, may compete with the *Modiolus* for food filtered out of the water column. These factors have been studied in more detail by, amongst others, Lesser, Witman & Sebens (1994) in the Gulf of Maine.

The absence of observed spat and very young specimens of *Modiolus* at Busta Voe and Loch Alsh, and their scarcity at Loch Creran, would indicate that there appears to be well established beds at these sites despite very little successful recruitment in the last five to ten years. In contrast, in 1998 at the Sullom Voe study site, there was a noticeable bimodal distribution of *Modiolus* length/frequency measurements with a distinct cohort in the 13-40mm (approximating to 2-5 years of age) group (Mair *et al*., in prep.). There have been numerous previous studies reported of populations of *Modiolus* and their shell length/age structure (e.g. Anwar, Richardson & Seed, 1990; George & Warwick, 1985; Wildish *et al*., 1998a). Bimodal size frequency distributions are often recorded in *Modiolus* populations. Seed & Brown (1975) describe the bimodal distribution in their study in Strangford Lough as being due to rapid growth in juvenile specimens and very high predation pressure on specimens below a critical size range of about 30-40 mm.

Comely (1978) reports the monthly comparative settlements of *Modiolus* spat (over a period of 18 months) at the Creagan site in Loch Creran and he found that spawning appeared to occur typically in the spring and early summer. Recruitment to the adult population will depend on the variables of spat settlement and predation pressure of the vulnerable young juvenile stages. Further long term monitoring at the study sites would be necessary to be able to draw any firm conclusions about the size/age structure of the populations sampled in 1999 at the three study sites

6.2 The associated fauna of *Modiolus* beds

There were close to 300 taxa of fauna and flora identified from the *Modiolus* clumps collected at the three sites in this study and equivalent numbers have been found over the years from similar collections at Sullom Voe (Mair *et al*., in prep.). However, without further detailed study, and due to the semi-quantitative nature of the sample collection method, it is difficult to speculate accurately on how many, or which, species are associated directly with the matrix of *Modiolus* shells and their byssus threads and how many are taken from the underlying sediment lifted as a clump sample is collected. Clump collection is a standard method for studying the associated community of *Modiolus* beds and there are several other lists of associated species reported from different regions (e.g. Comely, 1981; Goransson & Karlsson, 1998; IOE, 1979-1985; plus the MNCR database – see Appendix 2).

The general species composition of the communities associated with the *Modiolus* clumps at the three study sites showed many similarities throughout the taxonomic groupings. This is perhaps not surprising since *Modiolus* beds provide distinctive habitats that will attract similar associated species. However multivariate analysis showed differences amongst the sites (Figs. 5.13 & 5.14) and the number of taxa and diversity were significantly lower at the Busta Voe site (Table 5.10). The main distinguishing differences amongst the three sites (highlighted in Table 5.11) may be due to a variety and mix of environmental and ecological factors. For example, the number of algal species was greatest at Busta Voe at the sample site depth of 14m. The waters in Busta Voe are probably reasonably clear compared to the often turbid waters in upper Loch Creran where, at approximately the same sample depth (15m) the number of algal species was very small. The number of algal species at Loch Alsh was only slightly greater than at Loch Creran and, although the clarity of the waters at the Loch Alsh site is probably generally higher than at Loch Creran. The deeper sample

depth (20m) may account for the reduction in Loch Alsh algal taxa compared to the Busta Voe site.

There are several small species that are present in low numbers at one site and absent at the other two study sites and others absent only at one of the sites. Without larger and more extensive samples it is difficult to interpret whether some of these differences are species/site specific associations or an artefact of sample size. However some of the more apparent differences are discussed below.

Alcyonium digitatum was one of the species found at the Loch Creran site but absent from the clump fauna at the other two sites. The MNCR Phase 2 survey also failed to find this species at Busta Voe although it was noted as rare in the Phase 2 survey at Loch Alsh.

Noticeable by its abundance at the Loch Creran site was the caprellid amphipod, *Phtisica marina* that is normally closely associated with epifaunal hydroid species. The porcelain crab *Pisidia longicornis* was also present in abundance in the Loch Creran clumps. Compared to the other two sites, the distinctive absence or lack of abundance of particular species in the Loch Alsh samples include the barnacles, *Verruca stroemia and Balanus crenatus*, the ascidian *Dendrodoa grossularia* (absent also from the MNCR Phase 2 observations) and the blue mussel, *Mytilus edulis*. Several specimens of mussel spat were however found in the clumps at the Loch Alsh site that may have been *M. edulis*. Species that were more distinctive by their presence at the Loch Alsh site and absence or rarity at the other two sites include the fire shell (*Limaria hians*) and the brittle *stars (Ophiopholis aculeata* and *Ophiocomina nigra*). These brittle stars were recorded in MNCR Phase 2 observations as superabundant at the Loch Alsh site and at the other sites either occasional (*O. nigra*) or absent (*O. aculeata*). The other brittle star, *Ophiothrix fragilis*, was also superabundant at Loch Alsh, while it was recorded as abundant at Busta Voe and common at the Loch Creran site. The feather star, *Antedon bifida*, was recorded as common at the Loch Alsh and Loch Creran sites but absent at Busta Voe. The number of bryozoan species was noticeably high in the Loch Alsh samples, intermediate at Busta Voe and low at Loch Creran. This trend may reflect the decreasing water current strengths/degree of exposure at the three sites. The ascidian, *Pyura microcosmus*, appeared to be characteristic of the very sheltered Loch Creran site (in clump analysis and MNCR Phase 2 observations) and was absent from the two other sites.

From analysing the abundance and composition of the larger species in the MNCR Phase 2 studies it would appear that the biotope at the tidal Loch Alsh site fitted more closely to the **MCR.Oph.Oacu** (*Ophiopholis aculeata* beds on slightly tide-swept circa littoral rock or mixed substrata) designation than any other one – *Ophiothrix fragilis, Ophiocomina* and *Ophiopholis* were recorded as super abundant. This classification is in general agreement with previous studies reported in SNH (1999). The findings at the study site at Busta Voe were in general agreement with the designation reported in Howson (1999) of **SCR.ModHAs** (*Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata). At the very sheltered Loch Creran site the biotope would appear to be a mix between the two closely allied **SCR.ModHAs** and **SCR.ModCvar** (*Modiolus modiolus* with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata**)** biotopes. The **SCR.ModCvar** biotope is reported as characteristic of Strangford Lough (Connor *et al*., 1997). The Upper Loch Creran bed also has the *C. varia* and *Pyura microcosmus* of this biotope. It should be noted that in Loch Creran there are several different *Modiolus* biotopes within a relatively small geographical area and therefore some mix of associated species may be inevitable. There is the site in the sheltered upper loch basin (this study), a strong tidal rapid site at the nearby Creagan narrows that links the upper and lower basins (MNCR records), and a site described as **CMX.ModHo** (Sparse *Modiolus modiolus*, dense

Cerianthus lloydii and burrowing holothurians on sheltered circalittoral stones and mixed sediment) at Barcaldine in the lower basin but also relatively close to Creagan narrows (Moore, unpublished information).

6.3 Conservation considerations

Bradley (1998) provides a useful review of conservation requirements of *Modiolus* communities.

The lack of obvious major recruitment apparent from close study at the three sites in this study (Loch Creran, Loch Alsh and Busta Voe) may be of importance in terms of conservation management and may require further study. There may have been exceptionally high mortality of juveniles over the last few years but it may be possible that *Modiolus* beds can be maintained with only occasional successful recruitment, e.g. every 10 years. Recruitment of spat to horse mussel populations is described as being sporadic (Brown, 1984). Long term study of this would be required on a site to site basis.

Long term study of the associated fauna may also prove useful since at the Creran site, changes in species over the long term are noticeable. For example, the 1989 MNCR survey at the Dallachulish site indicated *Ophiopholis* to be frequent whilst, in the 1999 survey reported here, this species was not recorded. Without further study it is difficult to relate this observation to long term natural changes or to possible human induced causes. Holme (1984), on examining long-term records, reported major changes to brittle star beds off Plymouth apparently linked to changes in the population of the predatory starfish *Luidia ciliaris*.

Damage caused to *Modiolus* beds by activities such as shellfish dredging and bottom trawls have been described by Jones (1951), Brown (1989), Macdonald *et al*. (1996), Magorrian (1996), Magorrian & Service (1998) and Service & Magorrian (1997). No obvious effects of fishing gear damage were observed at the three study sites in Scotland although it is suspected that an isolated event of some fishing for queen scallops may have taken place several years ago on the bed in upper Loch Creran (Donnan, personal communication).

At the Busta Voe site there were several salmon cage farms in the area of the channel between Linga and Hevden Ness, their presence preventing full mapping of the area in this survey. It is interesting to note the presence of the dense mat of the filamentous red algae at the stations sampled in the shallow areas around Linga. This could be indicative of nutrient enrichment but it is probably unlikely since Howson (1999) reports similar observations from the MNCR Phase 2 studies carried out in 1986/87 before the salmon cages were in place. Earll (1982) also reports such loose lying mats of filamentous algae in this area of Shetland.

Apart from the potential of influence from the Busta Voe Salmon and shellfish farms there would appear to be no major contamination inputs at the three sites that affect the communities on the *Modiolus* beds surveyed. However, at the well-studied site in Sullom Voe the waste water effluent diffuser pipe from the Sullom Voe Oil Terminal discharges in the centre of an extensive *Modiolus* bed which ranges from around 20m to 30m water depth. Since the Terminal came on stream in 1979 there has been annual monitoring of the discharges and their effects on the surrounding sediments, biota and flora. Despite the expected slight elevations in contaminants measured in sediments and the flesh of *Modiolus* taken from the vicinity of the discharge, there have been no observable obvious changes to the *Modiolus* community (Davies & Matheson, 1995; ERT, 1995-2000). The diffuser pipeline is situated in a channel with very strong tidal currents and therefore the effluent tends to be diluted and dispersed very quickly. This site is of interest also because of the

physical destruction of a small part of the *Modiolus* bed caused by the original emplacement of the diffuser pipeline in a trench in the 1970s. In recent years, divers carrying out the annual monitoring surveys have observed small *Modiolus* growing in the gravel mound supporting the diffuser pipe (Mair, personal observation). Successful recruitment appears to have occurred here, not only on established *Modiolus* bed but also on artificial substrate.

The Busta Voe and Loch Alsh beds cover a greater area than the particular bed under study in upper Loch Creran. The bed in Loch Creran is also more isolated and possibly more sensitive to recruitment failure and/or physical damage (e.g. trawling).

Since *Modiolus* is regarded as mainly a northern species the influence of possible global warming on the displacement of some populations, although unlikely to have much of an effect, should be considered in the long-term view.

Methods used in monitoring studies for conservation management purposes should obviously be as non-destructive as possible and for long term and inter-site comparability methods should ideally be as standardised as possible (Hiscock, 1998a). Such non-destructive methods include quadrat counting (Murray, 1998), ACE type surveys (Hiscock, 1998b), photographic and video recordings, either on transects or as drop-down spot checks, and remote acoustic sensing methods (Davies, 1999). The only means of accurately measuring population structure, presence of spat, recruitment and the smaller associated fauna of a *Modiolus* community is by physical collection for subsequent detailed laboratory analysis. Fortunately, for such analysis only relatively small amounts of material need to be collected, e.g. by diving core methods (Brazier, 1998). Whilst it is vital that this type of analysis is done for verification purposes, perhaps it does not need to be carried out as frequently as the other methods, at least for the purposes of conservation management.

Use of experienced professional biologist divers is expensive although necessary. Methods used by divers that are accurate, but not excessively dive-time consuming, are preferable. Counting of fauna in quadrats can take a lot of time, especially if the *Modiolus* is dense. Therefore a method, such as was used in this study, which relates intersection counts to percentage coverage and density with a degree of statistical acceptability is of value. However, this method may underestimate abundance when the *Modiolus* is highly clumped.

The video mosaicing technique, also used in this study, has potential for providing a rapid means of covering a relatively large area of habitat and providing a permanent record that can be studied in more detail on the surface. The imaging software, data storage and the field methods employed to obtain useable material still need further development but the technique has the potential to provide high resolution detail as well as broad coverage of an area if the images are stored digitally. There is also rapid development of acoustic ground discrimination methods for broad scale mapping of habitats (Foster-Smith, Davies & Sotheran, 1999) and several studies have shown the use and potential of these methods (summarised in Davies, 1999). Although further development is necessary, and ground verification studies essential, there is no doubt that this method will be utilised extensively for broad scale survey and mapping. However, much work still needs to be done on the interpretability and repeatability of acoustic methods (Rees & Foster-Smith, 1998).

The 1999 surveys at the three study sites described here have provided results that indicate the similarities and differences in the biotopes and associated fauna at the different geographical locations. Each site is different in the environmental conditions that are prevalent and also in the associated fauna, some examples of which might be overlaps from adjoining other biotopes. In general however, the biotopes described here conform to the designations described in Connor *et al*. (1997). Conclusions and recommendations drawn from this study in 1999 are given in the following section 7.

7 RECOMMENDATIONS

More information is required on the modifying effects of different substrate types on the fauna associated with *Modiolus* clumps. On sedimentary beds this would require careful quantitative sampling of sediment biota on and off beds and also within a bed clump and non-*Modiolus* 'patch' to give an indication of which species are more associated with the shell/byssus thread matrix and which are associate directly with the underlying sediment. Quantitative coring techniques would be the best method for this type of study.

Further development and standardisation of methods for divers using quadrats for counting shells or assessing percentage of coverage would be beneficial. A rapid and easy to use method (such as the intersection method used in the present study) could be combined with on-site verification by an appropriate amount of sample removal (necessary for population structure and ageing analysis in any case).

At a localised sample site level video-mosaicing of larger areas of possibly $25m^2$ to $100m^2$ could provide both a digital permanent record and an illustrative 'overview' of bed structure. A permanent, fixed site could be monitored using this method by either leaving the quadrat marker grid in place or relaying the grid at each survey.

Further work should be done on broad scale survey and mapping by a combination of acoustic methods (which are rapidly developing in sensitivity and potential usefulness) backed up with adequate non-destructive ground verification, e.g. ROV video or drop down video/photography, etc.

Several different sample sites should be established for long term monitoring study to look at both natural ecological variations (e.g. possibly the *Ophiopholis* changes at Loch Creran) and potential anthropogenic factors.

It would be useful to have, for comparison, a study of *Modiolus* beds on Scotland's east coast (e.g. the bed reported in the Firth of Forth). It is understood that another major study of the benthos is to be carried out this year, just over 20 years after the last extensive study. A survey incorporating the *Modiolus* habitat should be encouraged as part of the overall programme.

There is valuable information to be obtained from more focused study at the *Modiolus* bed lying off the Sullom Voe effluent discharge site (monitored since 1979 and to be continued annually whilst the terminal is operational). For example there are fixed, marked sites where *Modiolus* recruitment can be monitored on a well-established bed as well as in trenched areas containing gravel acting as artificial substrates. The long-term recovery of a localised damaged area around the diffuser pipeline trench could be followed. The diffuser outfall is within a no-fishing zone so the bed should be free from fish gear damage.

Regular collaboration, co-ordination and exchange of information amongst groups working on *Modiolus* around the British Isles and other countries (such as the workshop held in 1999) should be encouraged and promoted.

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Fig. 5.1. The Loch Creran study site showing survey and sampling stations in 1999.

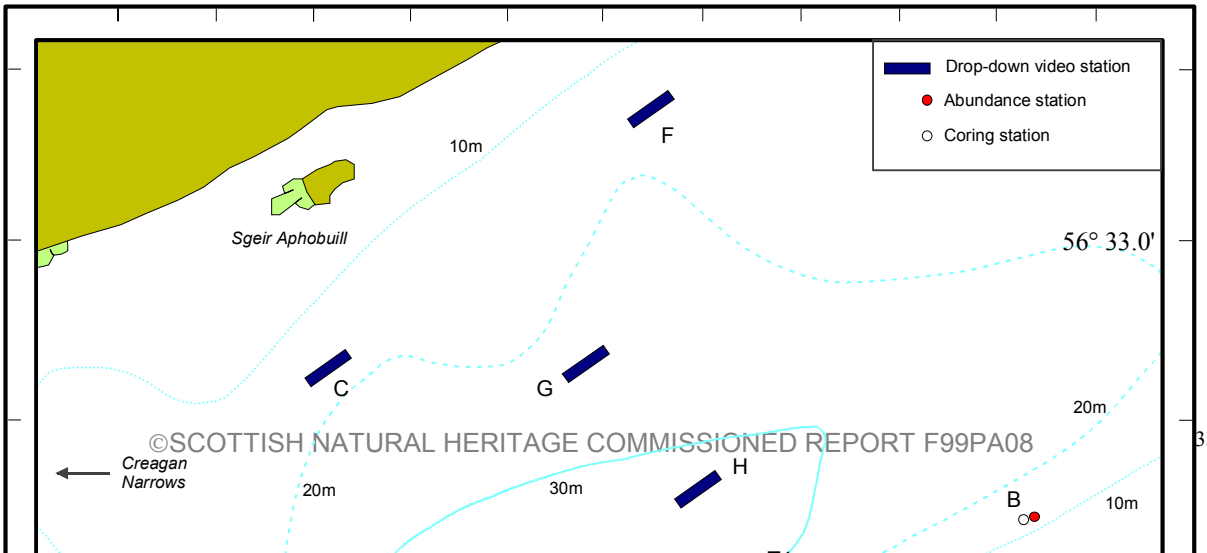

Fig. 5.2. Percentage cover of Modiolus modiolus *within the surveyed area of the upper basin of Loch Creran in the 1999 survey.*

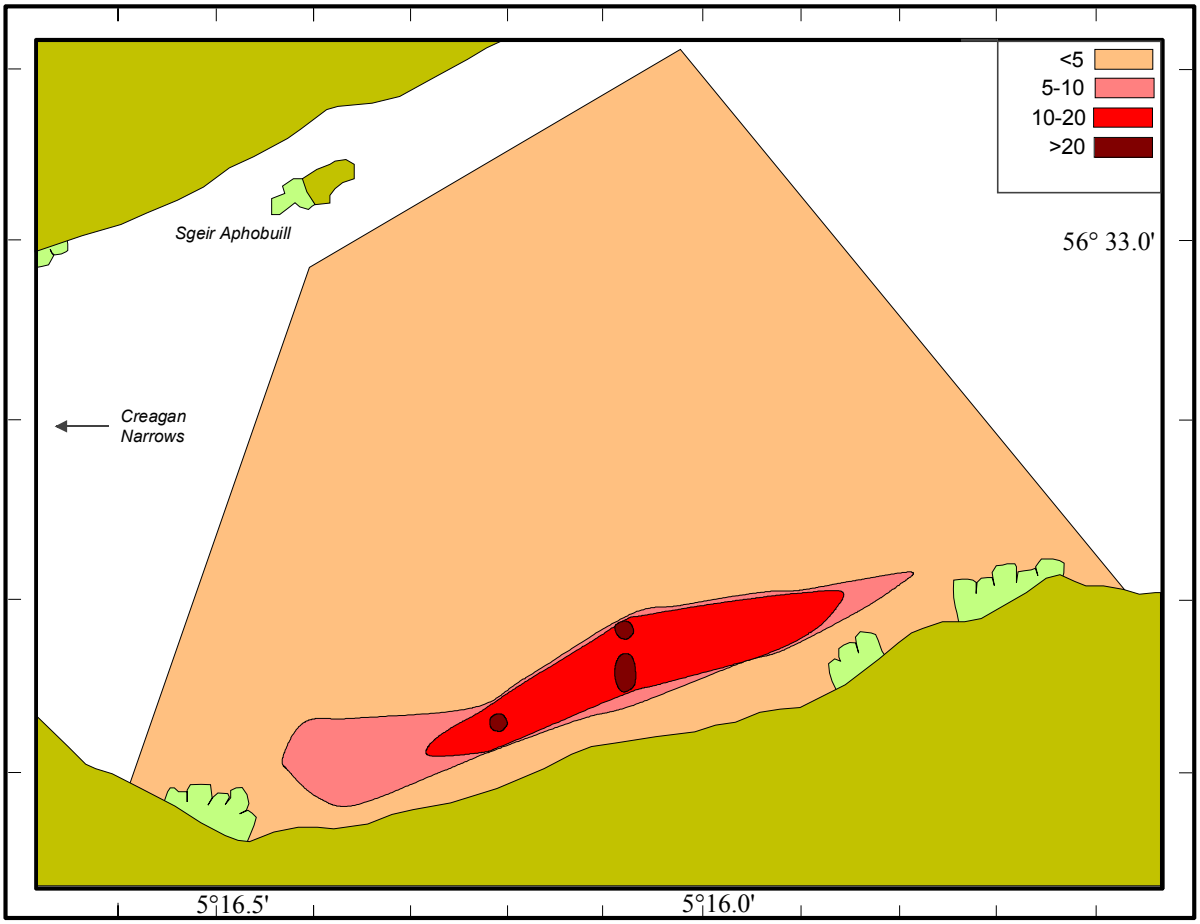

Fig. 5.3. Variation in particle size composition of the sediment along a depth transect running through the centre of the Modiolus *bed in Loch Creran, December 1999.*

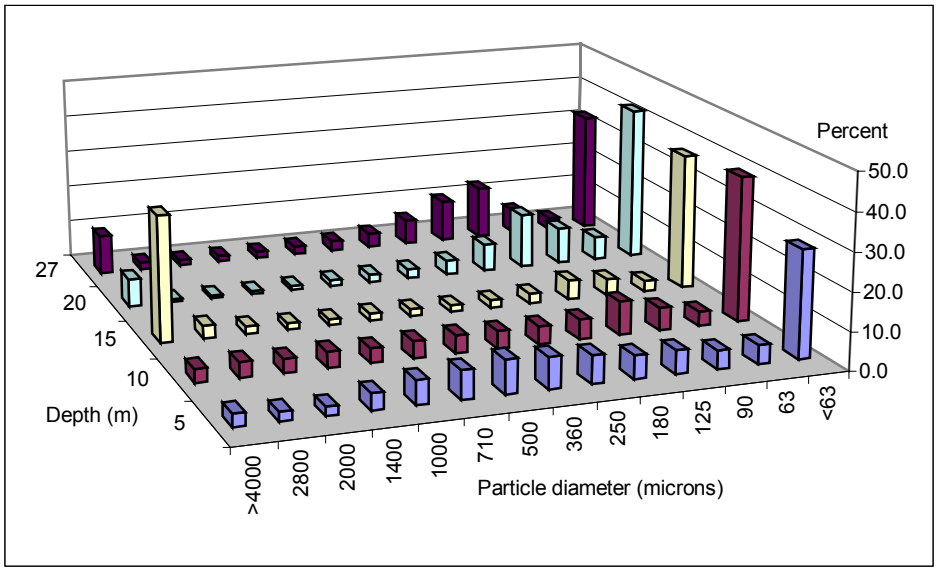

Fig. 5.4. Variation in particle size composition of the sediment along a transect parallel to the shore at about 15 m depth running through the centre of the Modiolus *bed in Loch Creran, December 1999.*

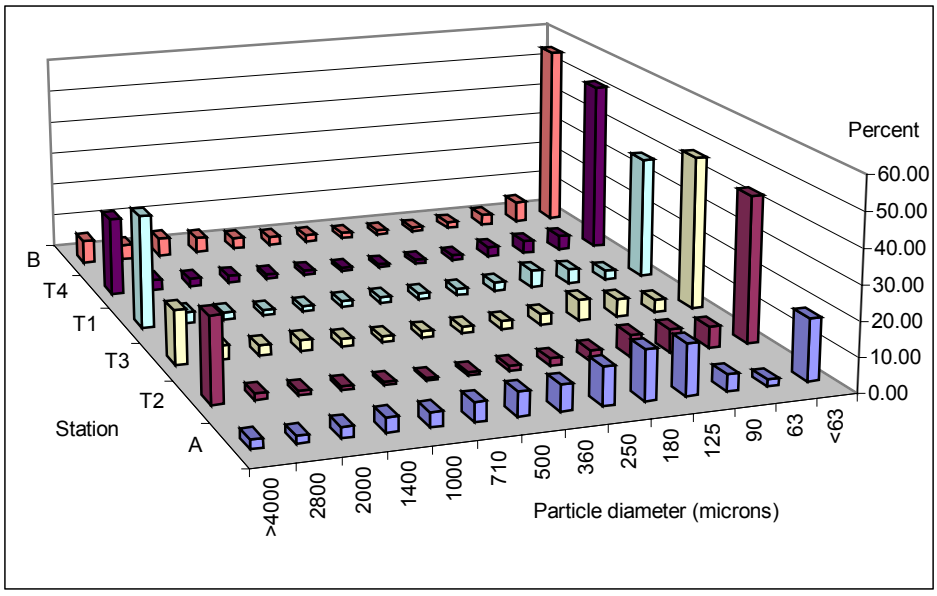

Fig. 5.5. Sedimentary organic carbon concentration (as percent dry weight of sediment) along a depth transect and longitudinal transect at 15 m running through the Modiolus *bed in Loch Creran, December 1999.*

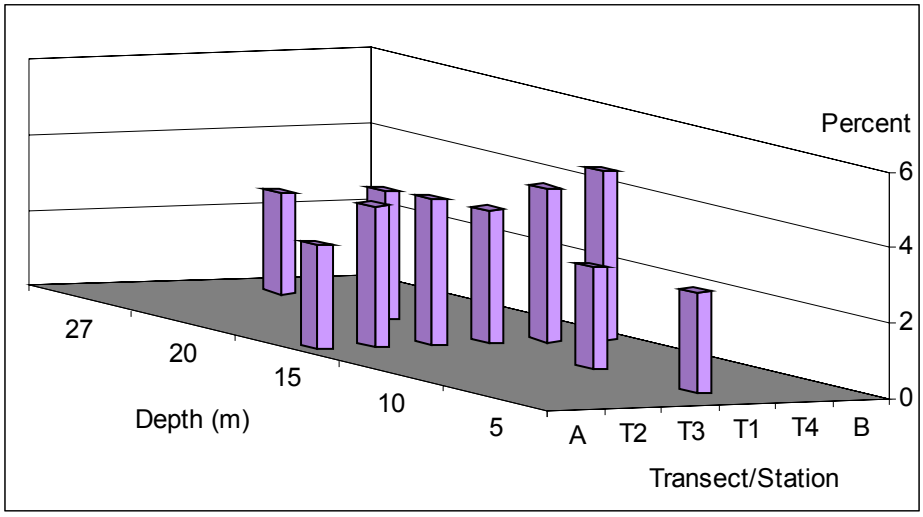

Fig. 5.6. Length/frequency distribution of Modiolus *from the three study sites in 1999.*

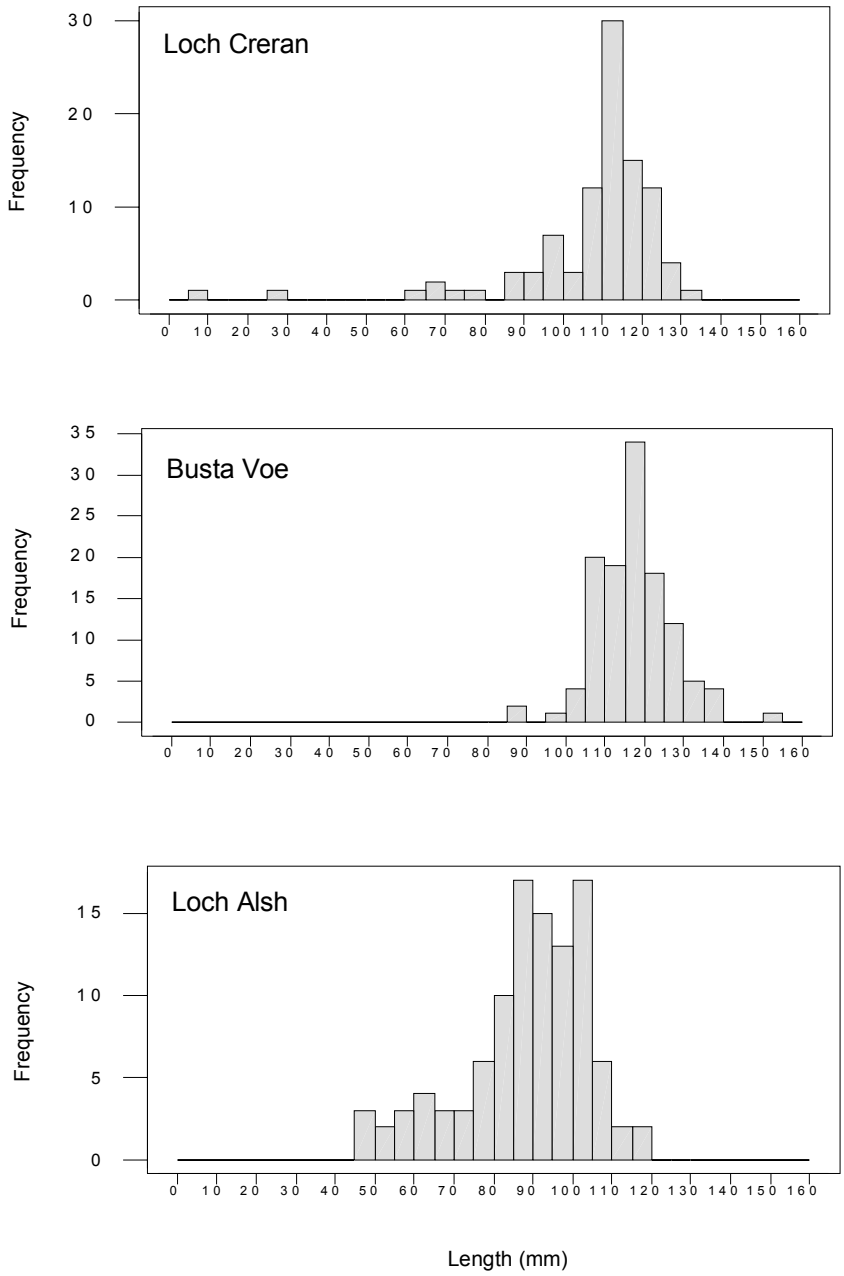

Fig. 5.7. Growth rates of Modiolus *collected from the three study sites in 1999. The raw data are plotted as symbols, while the curves represent fitted von Bertalanffy equations.*

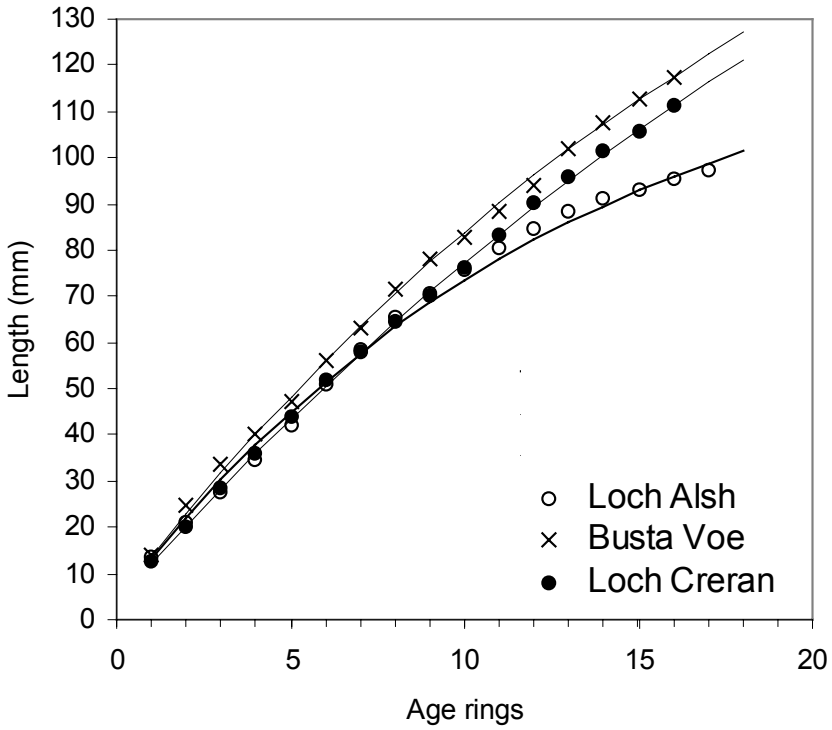

Fig. 5.8. The Busta Voe study site showing survey and sampling stations as well as percentage cover of Modiolus modiolus in the 1999 survey.

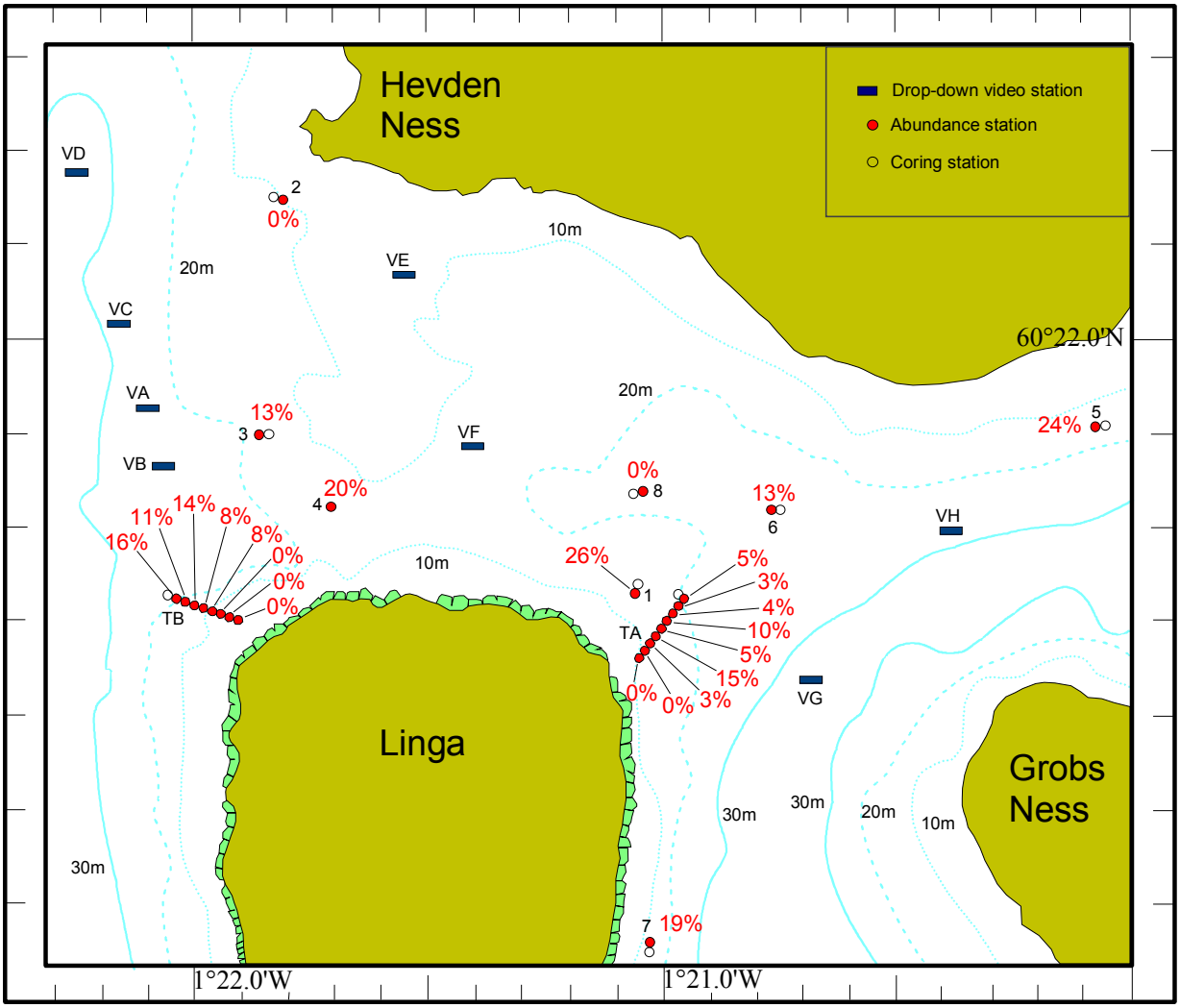

Fig. 5.9. *Video mosaic image of 5 x 5 m area of the seabed at station 1 in Busta Voe, August 1999. The rope grid is divided into ten 0.5 m wide lanes.*

Fig. 5.10. Particle size composition of the sediment at several stations at the Busta Voe study site in August 1999. Modiolus *was absent at stations 2 and 8, sparse at stations A and B but abundant at the other stations.*

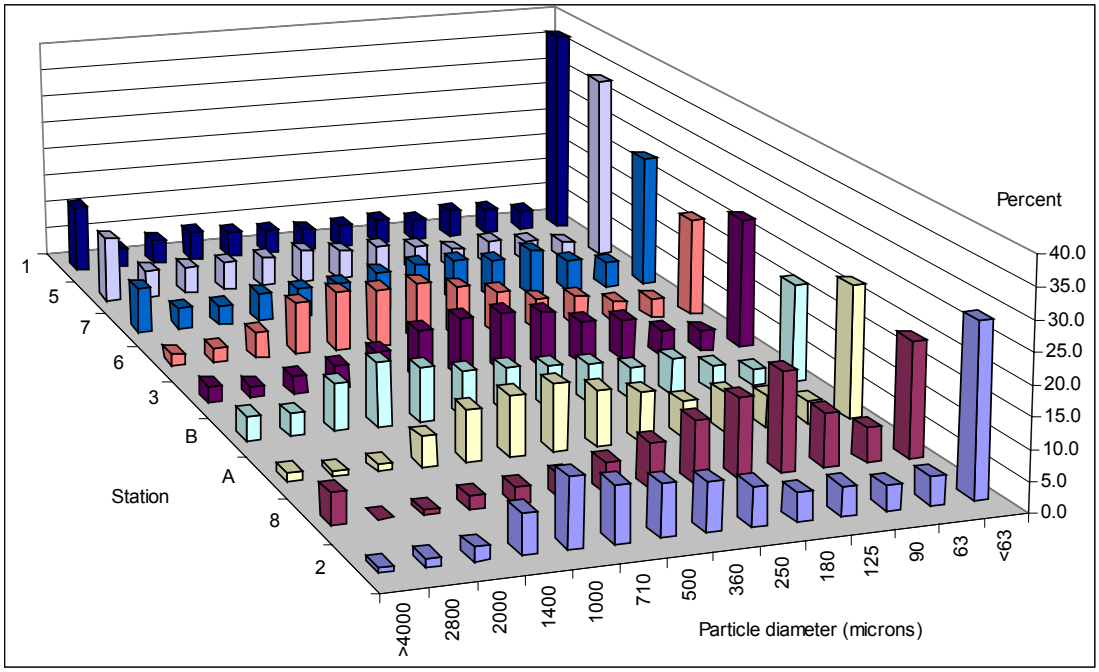

Fig. 5.11. The Loch Alsh study site showing survey and sampling stations as well as percentage cover of Modiolus modiolus *in the 1999 survey.*

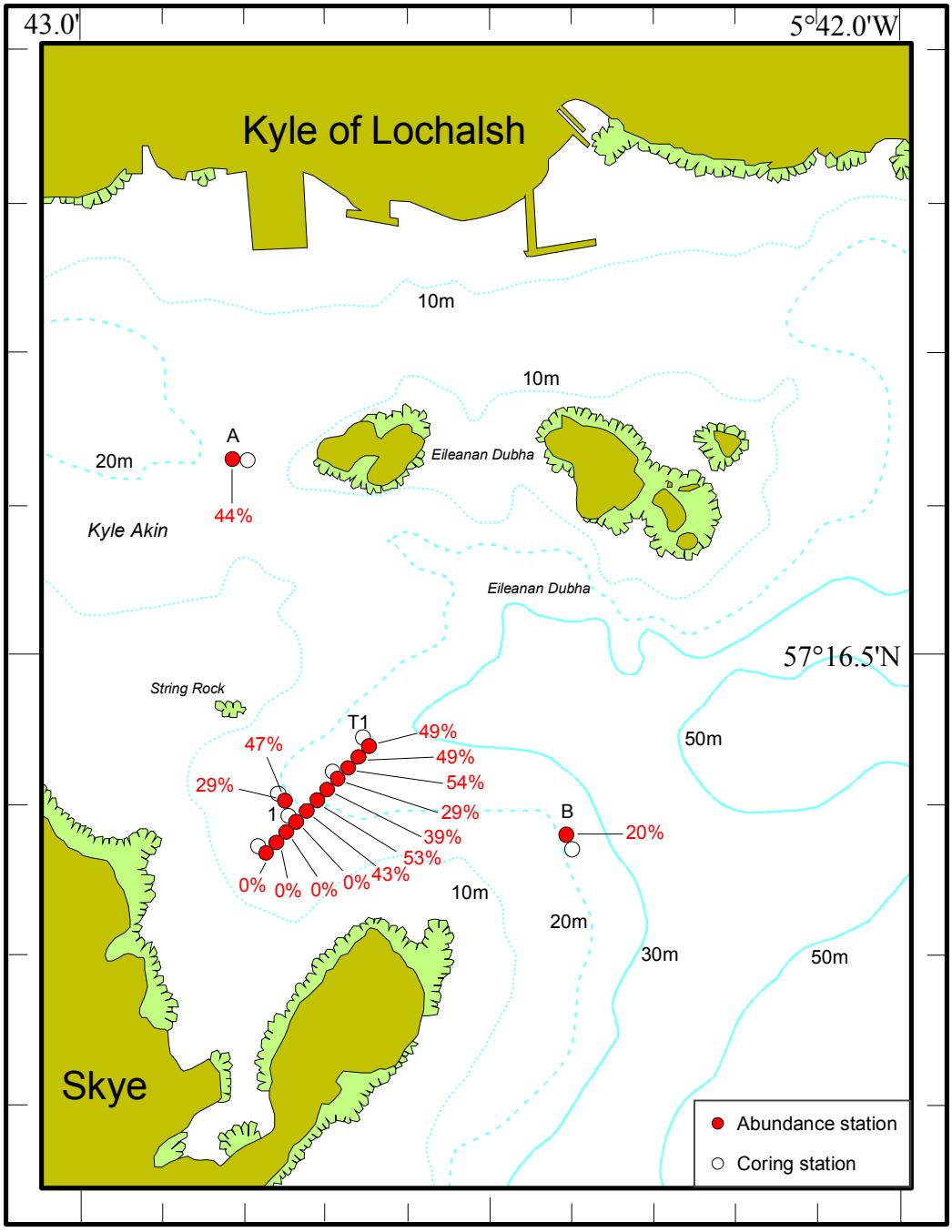

Fig. 5.12. Particle size composition of the sediment along a depth transect (T1) running through the Modiolus *bed and at other stations at the Loch Alsh study site* in 1999. Modiolus *was absent at stations T1/0 and T1/3 but present at all the other stations.*

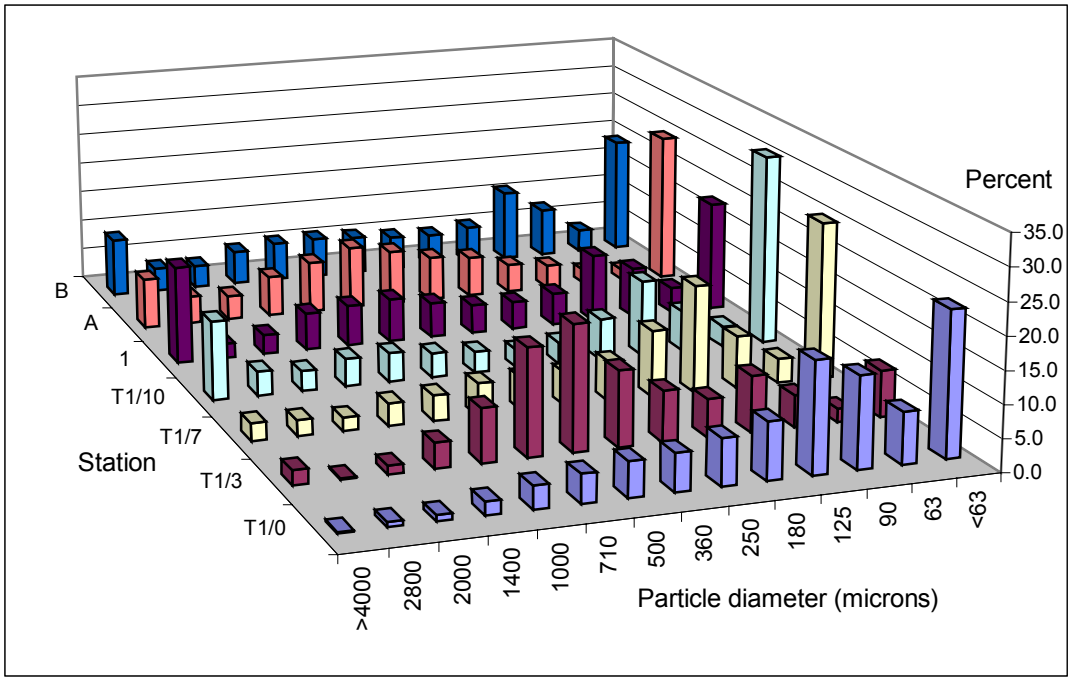

Fig. 5.13. Cluster analysis (Bray-Curtis similarity, group average sorting, log transformed data) of associated fauna and flora from 4 replicate Modiolus *clumps from Loch Creran (C1-C4), Busta Voe (B1-B4) and Loch Alsh (A1-A4) collected in 1999. For species recorded only in binary form (algae and colonial animals), presence was allocated an abundance of 1.*

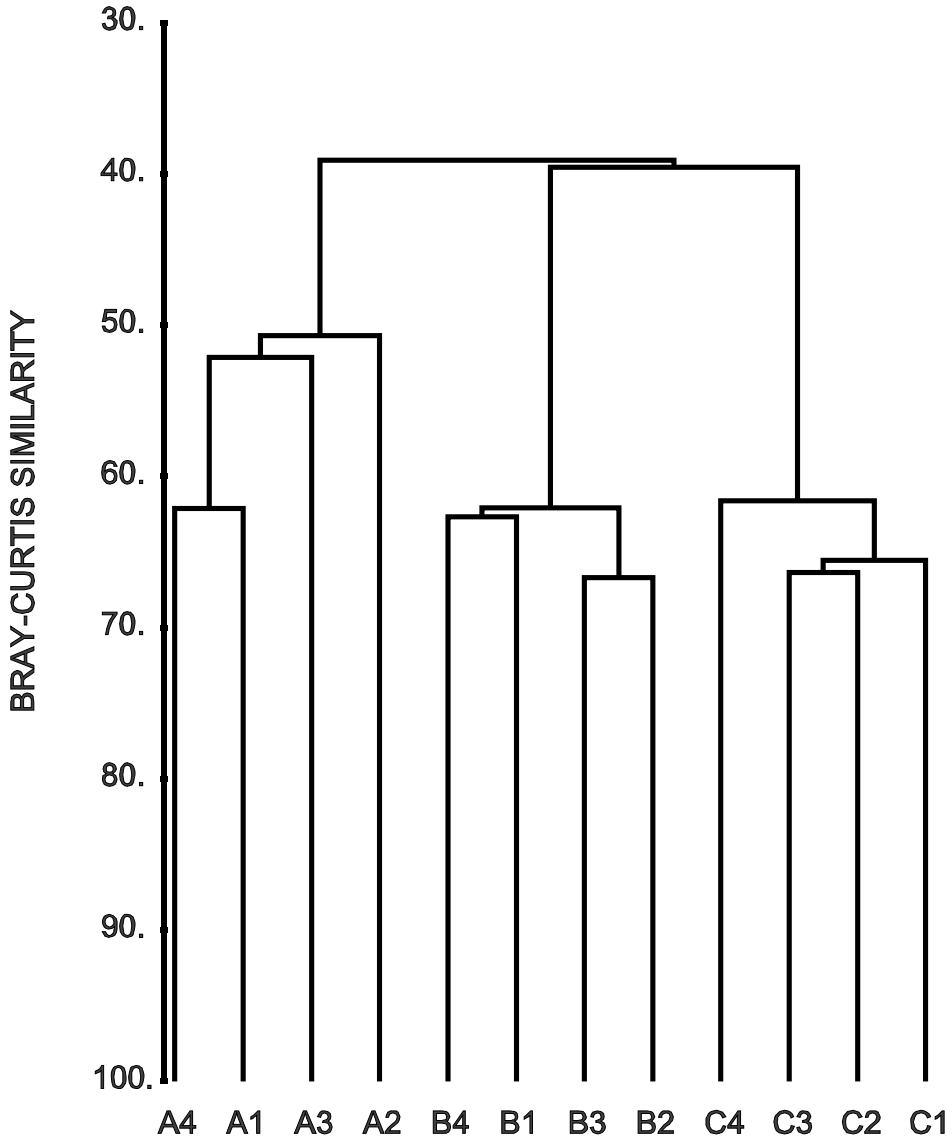

Fig. 5.14. Multidimensional scaling ordination (Bray-Curtis similarity, log transformed data) of associated fauna and flora from 4 replicate Modiolus *clumps from Loch Creran (C1-C4), Busta Voe (B1-B4) and Loch Alsh (A1-A4) collected in 1999. For species recorded only in binary form (algae and colonial animals), presence was allocated an abundance of 1.*

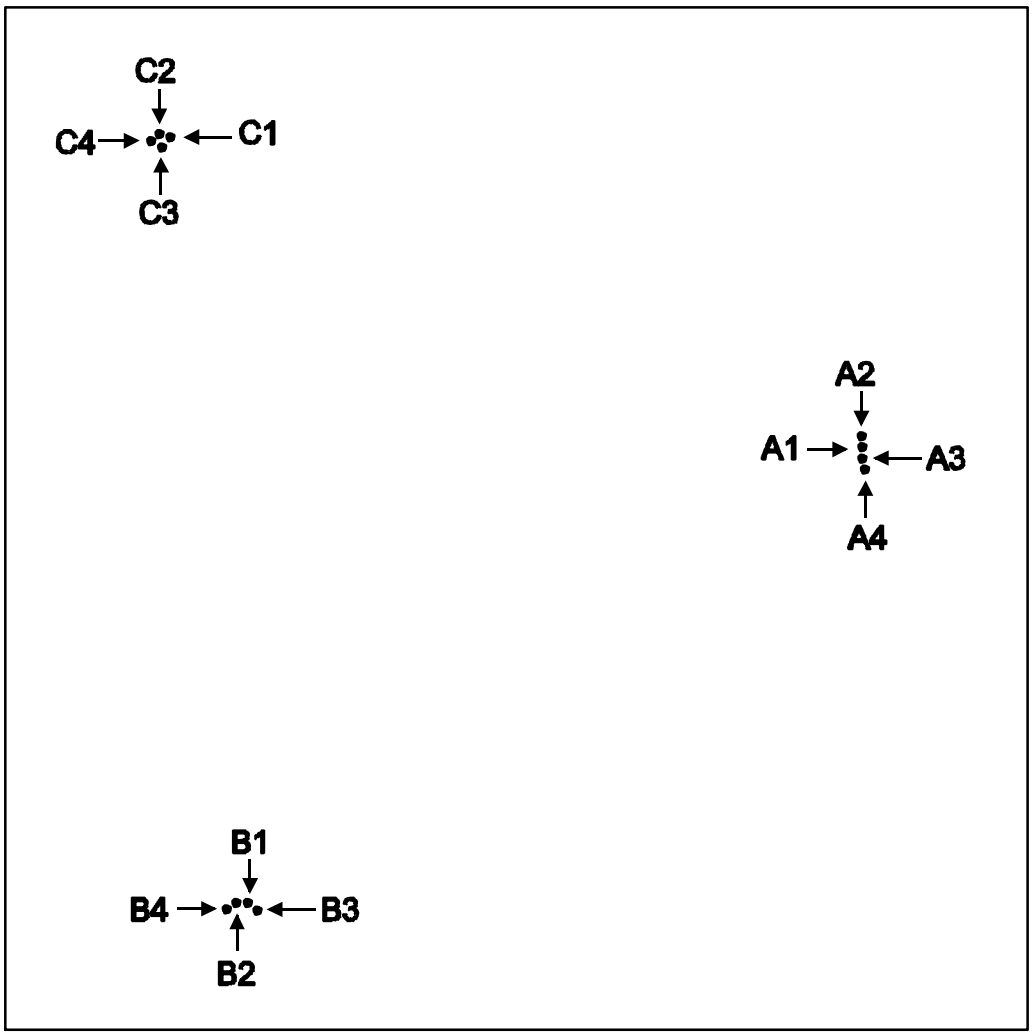

Table 5.1. Collection details, volume and size of the clumps of *Modiolus* sampled for identification of the associated fauna and flora.

Site	Station number	Location	Date	Depth (m)	Clump number	Number of *Modiolus*	Volume (ml)
Loch Creran	T1/3	56°32.77'N	14/08/99	15	1	5	192
		05°16.08'W			2	8	195
					3	9	257
					4	9	218
Busta Voe	1	60°21.73'N	22/08/99	14	1	5	279
		01°21.06'W			2	6	219
					3	7	242
					4	5	266
Loch Alsh	1	57°16.37'N	05/09/99	20	1	11	271
		05°42.78'W			2	14	224
					3	3	262
					4	3	216

Table 5.2. Particle size analysis of the sediment at the Loch Creran study site, December 1999. The table gives the percentage by weight of sediment retained on a series of sieves at 0.5 phi intervals.

Particle diameter (microns)	Station									
	A	B	T2	T3	T4	T1/0	T1/1	T1/3	T1/5	T1/6
>4000	2.5	6.9	24.6	15.6	23.0	3.3	3.6	33.1	7.5	10.4
2800	2.1	4.4	1.9	4.2	3.1	2.4	4.1	3.3	0.8	1.8
2000	3.0	5.5	1.2	3.0	2.4	2.3	3.6	2.0	0.8	1.5
1400	4.1	4.6	1.1	3.1	2.1	4.3	4.2	1.6	0.8	1.6
1000	4.1	3.3	0.9	2.3	1.3	6.2	3.8	1.5	1.1	1.7
710	5.4	2.5	0.7	1.8	1.3	7.4	4.5	1.9	1.6	2.2
500	6.9	2.1	0.9	1.9	1.0	8.8	4.8	1.8	2.0	2.7
355	7.4	1.6	1.3	2.0	1.0	8.1	4.6	1.8	2.4	3.9
250	11.0	1.4	2.2	2.4	1.2	7.3	4.7	2.0	3.7	6.7
180	14.4	1.2	3.2	3.2	1.5	6.0	5.3	2.6	7.3	11.2
125	14.7	1.8	6.4	6.2	3.0	6.1	8.8	5.2	14.6	14.2
90	4.8	3.2	6.7	5.2	3.8	4.8	6.0	4.4	9.8	6.5
63	1.9	6.3	6.2	3.8	4.3	4.9	3.9	2.8	6.2	3.2
<63	17.8	55.2	42.8	45.3	51.1	28.1	38.3	36.2	41.5	32.4

Table 5.3. Organic carbon (as a percentage of the dry weight of the sediment) and percentage cover of the seabed by *Modiolus* at the three study sites in 1999.

Site	Station	Carbon (%)	*Modiolus* cover (%)
Loch Creran	A	2.75	0
	B	4.47	1
	T2/2	3.74	8
	T3/2	3.87	20
	T4/2	4.06	11
	T1/0	2.68	0
	T1/1	2.68	5
	T1/3	3.53	24
	T1/5	3.37	24
	T1/6	2.68	0
Busta Voe	A	4.31	5
	B	1.67	6
	1	6.45	26
	2	4.03	0
	3	4.93	13
	5	6.31	24
	6	4.77	13
	7	3.16	19
	8	3.67	0
Loch Alsh	A	2.32	44
	B	2.37	20
	T1/0	2.06	0
	1	2.07	38
	T1/3	0.48	0
	T1/7	0.75	29
	T1/10	1.42	49

Table 5.4. Summary of MNCR Phase 2 survey for the Loch Creran site, 30 October 1999.

Survey	3	- 1999 Modiolus bed survey for SNH – Loch Creran		
Site number-	Report **T1/3**	Site name	E of Dallachulish	
	Field TC/3 1			
Habitat number				
Position	56°32.77'N 05°16.08'W			

SURVEY DETAILS

Surveyors	Colin Moore			
Height/Depth ranges		Height/Depth band	Biological subzone	Extent of record
Sea level	-14 to -17	10-20	Circalittoral - upper	Depth band
Chart datum	-12 to -15			

Survey quality	**Flora** Thorough **Fauna** Thorough	Biological assessment	Spp. richness Abundance **4**

SUBSTRATUM DETAILS

Substratum %	**Inclination** %	**Rock features** (1-5)	Sediment features **(1-5)**	Modifiers
	Upward			
Cobbles 10	100		**Surface relief 2**	
Pebbles 20			**Firmness 2**	
Gravel – stone 20			**Stability 2**	
Gravel – shell 20			**Sorting 5**	
Sand – med 10				
Mud 10				
Empty shells 10				

HABITAT NAME

Sheltered Modiolus bed

HABITAT DESCRIPTION

Modiolus clumps on seabed of muddy sand with many empty shells and small stones

SPECIES DATA

Species/Taxon name	Abundance
Suberites carnosus?	R
Halichondria bowerbankia?	R

Mycale sp.	O
Esperiopsis fucorum	F
Myxilla incrustans	R
Bougainvillia ramosa	O
Halecium halecinum	F
Kirchenpaueria pinnata	O
Hydrallmania falcata	R
Obelia sp.	O
Sarsia tubulosa	R
Alcyonium digitatum	O
Pachycerianthus multiplicatus	R
Sargartiogeton laceratus	R
Calliactis parasitica	R
Eupolymnia nebulosa	F
Myxicola infundibulum	O
Pomatoceros triqueter	C
Serpula vermicularis	C
Verruca stroemia	F
Balanus balanus	F
Balanus crenatus	F
Crangon crangon	R

continued…..

Table 5.4 continued.

Pagurus spp.	C
Munida rugosa	F
Hyas araneus	P
Inachus dorsettensis	R
Macropodia sp.	R
Liocarcinus depurator	C
Buccinum undatum	O
Modiolus modiolus	A
Chlamys distorta	P
Chlamys varia	C
Aequipecten opercularis	F
Mya truncata	R
Hiatella arctica	O
Disporella hispida	C
Antedon bifida	C
Crossaster papposus	R
Henricia sp.	O
Asterias rubens	C
Ophiothrix fragilis	C
Amphipholis squamata	O
Psammechinus miliaris	O
Echinus esculentus	O
Thyone fusus	R

Diplosoma listerianum	F
Ciona intestinalis	O
Corella parallelogramma	O
Asidiella aspersa	C
Ascidia mentula	F
Ascidia virginea	R
Dendrodoa grossularia	F
Botryllus schlosseri	R
Boltenia echinata	O
Pyura microcosmus	C
Syngnathus acus	R
Pomatoschistus pictus?	P
Pomatoschistus minutus?	P
Corallinaceae indet.	O
Lithothamnion glaciale	O
Laminaria saccharina	R
Number of species/taxa recorded	62

Table 5.5. Particle size analysis of the sediment at the Busta Voe study site. The table gives the percentage by weight of sediment retained on a series of sieves at 0.5 phi intervals.

Particle diameter	Station								
(microns)	2	8	A	B	3	6	7	5	1
>4000	0.9	5.3	1.5	4.1	2.8	2.1	7.9	11.4	11.9
2800	1.3	0.2	1.0	3.8	2.0	2.5	3.6	4.9	3.3
2000	2.1	0.9	1.4	7.9	2.9	4.6	3.5	4.8	4.4
1400	6.5	2.1	4.9	10.7	4.0	9.0	4.9	5.1	5.4
1000	11.2	2.9	8.5	9.1	5.7	10.2	5.1	5.3	4.6
710	9.2	3.5	10.1	7.8	8.6	9.9	5.3	5.8	4.4
500	8.4	5.0	11.1	7.7	10.0	10.4	6.7	5.2	3.8
355	7.8	7.2	9.4	7.3	10.3	9.1	7.4	5.3	4.1
250	6.4	10.2	8.2	6.7	9.7	7.5	7.5	4.6	4.4
180	4.6	12.8	6.0	5.3	7.2	5.5	6.8	3.6	3.7
125	4.7	16.3	6.6	6.2	6.8	5.3	8.0	4.4	4.9
90	4.1	9.0	5.4	4.1	4.4	3.6	5.6	3.7	4.5
63	4.6	5.8	3.8	2.7	3.5	3.4	4.6	2.9	3.6
<63	28.1	19.0	22.2	16.6	22.4	17.0	23.2	33.0	37.0

Table 5.6. Summary of MNCR Phase 2 survey for the Busta Voe site, 22 August 1999.

Survey	2	- 1999 Modiolus bed survey for SNH – Busta Voe/Olna Firth		
Site number-	Report **1**	Site name	NE of Linga	
Habitat number	**Field** 1 1			
Position	60°21.73'N 01°21.06'W			
SURVEY DETAILS				
Surveyors	Colin Moore, Hamish Mair			
Height/Depth ranges		Height/Depth band	Biological subzone	Extent of record
Sea level	-14 to -16	10-20	Circalittoral - upper	Depth band
Chart datum	-13 to -15			

Survey quality	**Flora** Thorough **Fauna** Thorough	Biological assessment	Spp. richness Abundance **4**

SUBSTRATUM DETAILS

Substratum %	**Inclination** %	**Rock features** (1-5)	Sediment features **(1-5)**	Modifiers
	Upward			
Gravel – shell 45	100		**Surface relief** **2**	
Sand – med 20			**Firmness** **2**	
Mud 20			**Stability** **2**	
Empty shells 15			**Sorting** **5**	

HABITAT NAME

Sheltered Modiolus bed

HABITAT DESCRIPTION

Modiolus bed with abundant Ophiothrix fragilis on muddy sand with much broken shell and empty shells

SPECIES DATA

Species/Taxon name	Abundance
Cliona ciliata	C
Bougainvillia ramosa	F
Kirchenpaueria pinnata	O
Obelia sp.	F

Sarsia sp.	R
Eupolymnia nebulosa	C
Myxicola infundibulum	F
Pomatoceros triqueter	A
Serpula vermicularis	O
Hydroides norvegica	R
Verruca stroemia	C
Balanus balanus	C
Balanus crenatus	O
Pagurus bernhardus	C
Munida rugosa	R
Hyas araneus	F
Inachus dorsettensis	P
Macropodia sp.	O
Liocarcinus depurator	F
Carcinus maenas	O
Lepidochiton asellus?	O
Tectura virginea	P
Gibbula cineraria	C
Buccinum undatum	F
Neptunea antiqua	O
Hinia incrassata	O

continued…..

Table 5.6 continued.

Modiolus modiolus	A
Aequipecten opercularis	O
Pecten maximus	R
Pododesmus patelliformis	P
Mya truncata	C
Hiatella arctica	P
Crisia eburnea	O
Electra pilosa	R
Scrupocellaria scruposa	F
Parasmittina trispinosa	R
Astropecten irregularis	R
Solaster endeca	R
Crossaster papposus	F
Henricia sanguinolenta	O
Asterias rubens	F
Ophiothrix fragilis	A
Ophiocomina nigra	O
Amphipholis squamata	O
Psammechinus miliaris	O
Echinus esculentus	C
Thyone fusus	O
Holothurian sp. A	R
Diplosoma listerianum	F

Corella parallelogramma	F
Asidiella aspersa	F
Asidiella scabra	F
Dendrodoa grossularia	C
Botryllus schlosseri	O
Diplecogaster bimaculata	R
Trisopterus minutus	C
Taurulus bubalis	R
Pholis gunnellus	R
Callionymus lyra	O
Pomatoschistus pictus?	O
Gobiidae indet.	C
Corallinaceae indet.	F
Lithothamnion glaciale	O
Callophyllis laciniata	R
Phycodrys rubens	O
Laminaria saccharina	R
Number of species/taxa recorded	66

Table 5.7. Particle size analysis of the sediment at the Loch Alsh study site. The table gives the percentage by weight of sediment retained on a series of sieves at 0.5 phi intervals.

Particle diameter	Station						
(microns)	T1/0	T1/3	T1/7	T1/10	1	A	B
>4000	0.2	2.2	2.7	12.3	15.3	8.0	9.4
2800	0.8	0.2	2.4	3.8	2.3	4.4	3.8
2000	0.9	1.3	2.1	3.1	3.1	3.9	3.6
1400	2.0	3.9	3.5	4.4	5.9	6.4	5.5
1000	3.5	8.3	4.0	4.6	6.4	8.2	6.2
710	4.4	16.5	5.1	3.8	6.8	10.1	6.5
500	5.4	19.3	5.1	3.3	5.5	8.8	6.1
355	5.8	11.7	5.1	2.8	4.5	7.2	5.5
250	7.1	7.9	6.3	3.4	4.4	6.5	5.3
180	8.8	5.9	10.4	6.5	5.1	4.6	6.0
125	17.0	8.7	16.7	12.0	10.9	3.8	11.6
90	14.0	4.9	8.1	6.4	8.0	2.2	7.9
63	7.9	2.1	3.9	3.2	4.1	1.7	3.7
<63	22.3	7.2	24.7	30.4	17.7	24.2	19.0

Table 5.8. Summary of MNCR Phase 2 survey for the Loch Alsh site, 6 September 1999.

Survey	1	- 1999 Modiolus bed survey for SNH – Loch Alsh		
Site number-	Report **1**	Site name	SE of String Rock, Loch Alsh	
Habitat number	**Field** 1 1			
Position	57°16.37'N 05°42.78'W			
SURVEY DETAILS				
Surveyors	Hamish Mair, Colin Moore			
Height/Depth ranges		Height/Depth band	Biological subzone	Extent of record
Sea level	-23 to -24	20-30	Circalittoral - upper	Depth band
Chart datum	-21 to -22			

Survey quality	**Flora** Thorough **Fauna** Thorough	Biological assessment	Spp. richness Abundance **4**

SUBSTRATUM DETAILS

Substratum %	**Inclination** %	**Rock features** (1-5)	Sediment features **(1-5)**	Modifiers
	Upward			
Pebbles 10	100		**Surface relief 2**	
Gravel – stone 20			**Firmness 1**	
Gravel – shell 10			**Stability 2**	
Sand – 40			**Sorting 5**	
Mud 5				
Empty shells 15				

HABITAT NAME

Current-swept Modiolus modiolus bed

HABITAT DESCRIPTION

Modiolus bed with dense cover of brittlestars and crinoids

SPECIES DATA

Species/Taxon name	Abundance
Cliona ciliata	C
Sponge unid.	R
Halecium halecinum	F

Nemertesia ramosa	P
Sertularia argentea	P
Obelia sp.	F
Alcyonium digitatum	R
Urticina eques	O
Lanice conchilega	R
Golfingia vulgaris	P
Pomatoceros triqueter	C
Hydroides elegans	R
Verruca stroemia	R
Balanus balanus	C
Pagurus spp.	C
Munida rugosa	F
Hyas sp.	O
Cancer pagurus	O
Liocarcinus depurator	C
Liocarcinus puber	F
Carcinus maenas	O
Lepidochiton asellus	C
Emarginula fissura	P
Gibbula cineraria	R
Calliostoma zizyphinum	P

continued…..

Table 5.8 continued.

Buccinum undatum	F
Neptunea antiqua	P
Hinia incrassata	P
Velutina velutina	P
Capulus ungaricus	R
Modiolus modiolus	A
Limaria hians	R
Chlamys distorta	P
Chlamys varia	R
Clausinella fasciata	P
Mya truncata	R
Pododesmus patelliformis	F
Hiatella arctica	O
Electra pilosa	R
Bugula avicularia	P
Scrupocellaria scruposa	O
Schizomavella linearis	O
Parasmittina trispinosa	R
Disporella hispida	C
Porella concinna	O
Antedon bifida	C
Luidia ciliaris	O
Solaster endeca	R

Crossaster papposus	F
Henricia sp.	R
Asterias rubens	C
Marthasterias glacialis	O
Ophiothrix fragilis	S
Ophiocomina nigra	S
Ophiopholis aculeata	S
Amphipholis squamata	O
Psammechinus miliaris	O
Echinus esculentus	A
Diplosoma listerianum	R
Ciona intestinalis	C
Corella parallelogramma	R
Ascidiella aspersa	O
Ascidiella scabra	O
Ascidia mentula	F
Ascidia virginea	R
Polycarpa pomaria	R
Gadus morhua	R
Trisopterus minutus	F
Pholis gunnellus	R
Phrynorhombus regius	R
Corallinaceae indet.	F

Lithothamnion glaciale	F
Plocamium cartilagineum	R
Chorda filum	R
Laminaria saccharina	R
Enteromorpha sp.	R
Ulva sp.	R
Number of species/taxa recorded	77

Table 5.9. Composition of the fauna and flora associated with 4 clumps of Modiolus modiolus *from the three study sites in 1999. For non-colonial animals the number of individuals is given. The presence of algae and colonial animals is indicated by +.*

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
ALGAE												
Aglaothamnion sp.					+		+					
Audouinella sp.					+							
Callophyllis laciniata						+	+					
Enteromorpha sp.										+		
Erythrotrichia carnea					+							
Goniotrichum elegans					+	+						
Griffithsia corallinaoides						+						
Lithothamnion glaciale		+			+							+
Ostreobium queketti	+		+		+	+	+	+			+	+
Phycodrys rubens					+	+	+	+	+	+		
Plocamium cartilagineum										+		
Polysiphonia stricta					+	+	+					
Pseudolithoderma extensum					+	+	+				+	+
Pterosiphonia parasitica							+	+				
Sphacelaria sp.					+							
PORIFERA												
Cliona celata					+	+	+	+	+			
CNIDARIA												
Alcyonium digitatum	4	4	11	4								
Clytia hemisphaerica	+	+	+		+	+	+	+	+	+	+	+
Cnidaria juv.			+	+	+		+	+				
Bougainvillia ramosa	+	+	+	+	+							
Halecium halecinum									+	+		
Hydrallmania falcata				+								
Kirchenpaueria pinnata		+										
Obelia sp.	+	+	+	+		+			+	+	+	+
Sarsia tubulosa				+								
Sarsia sp.						+						
PLATYHELMINTHES												
Stylostomum ellipse									2			1
Turbellaria indet										11	1	
NEMERTEA												
Nemertea sp. 1	1	2	1		5	9	3	1			2	1
Nemertea sp. 2			1	1								1
Nemertea sp. 3							1		1			1

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
ANNELIDA												
Polynoidae sp. 1	1	6										
Polynoidae sp. 2		1										
Polynoidae spp. indet.					24	7	7	1	4	70	15	8
Adyte pellucida	1		2									
Alentia gelatinosa			3									1
Gattyana cirrosa	2					1						
Antinoella sarsi							1		1			
Harmothoe extenuata									2			6
Harmothoe impar			6	22					1	10		
Harmothoe lunulata		1										
Harmothoe imbricata							1					
Harmothoe castanea							1					
Harmothoe marphysae												1
Lepidonotus clava										8		
Lepidonotus squamatus	10	17	20	5	1				6	4		7
Pholoe inornata	3	18	12	57	9	14	4	6	4	49	9	6
Sthenelais boa	1								1		2	2
Phyllodocidae spp. indet.					1					1	1	
Eteone sp.indet.											1	
Hypereteone lactea												1
Eteone longa			2									
Eulalia viridis			1									
Eumida sanguinea	1	3	1		1		2	1	3	3	9	4
Phyllodoce laminosa									1		1	
Pirakia punctifera											1	1
Phyllodoce sp. A										1		
Glycera spp. juv.					2							
Glycera alba										1		
Glycera tridactyla			1									
Glycera tesselata				1								
Glycera lapidum								1				
Glycinde nordmanni											1	
Sphaerodorum gracilis			2	1	3	1	1	1		2	2	3
Hesionidae sp. 1	1											
Gyptis rosea		1		2	2				1	20		
Kefersteinia cirrata	1	2	6			2	4			3	20	8
Nereimyra punctata	7	4	14	4	20	25	24	3	4	14	3	10
Ophiodromus flexuosus		6					1					
Podarke pallida			6	32	14	1				19		2
Gyptis capensis											4	

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
Syllidia armata	2											1
Syllidae sp. 1			1							3		
Syllis amica											1	
Typosyllis armillaris	2	2		1	1	1	1	1				1
Typosyllis brevipennis	1	3	3									
Eusyllis lamelligera				3								
Odontosyllis ctenostoma				1								
Exogone hebes				8	2					7		
Exogone naidina					2						1	
Sphaerosyllis bulbosa				3								
Sphaerosyllis hystrix										1		
Autolytus sp. 1			1						1	29		
Autolytus sp. 2												4
Nereis pelagica					1			1				
Nephtys sp. indet.		1										
Nephtys caeca	1				1	1	1					1
Nematoneris unicornis											3	1
Spinther arcticus			1									
Lumbrineriopsis paradoxa				5								
Lumbrineris tetraura		6	1		2			1		2	10	
Lumbrineris gracilis											1	
Ophryotrocha puerilis siberti				1								
Dorvillea rubrovittatus											1	
Protodorvillea kefersteini		5	6	4								
Levinsenia gracilis		1	1							1	3	
Aonides oxycephala										9		
Aonides paucibranchiata											3	
Spio filicornis					1	1						
Polydora caeca				2						1		
Polydora caulleryi										2		
Polydora sp. A		1										
Prionospio malmgreni		1	2							2		
Prionospio cirrifera										1	3	
Spiophanes kroyeri				1								
Cirratulidae sp. 1		3	4	9			6	2		1	3	
Cirratulidae sp. 2		2	5	4				1	2			
Cirratulidae sp. 3		1		2								
Chaetozone setosa					2	1	1					
Tharyx marioni					2					2		2
Flabelligera affinis		1	2	1		1	1				2	3

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
Pherusa plumosa			3	6	8		3			5		2
Heteromastus filiformis		5		7	10	5	1	4		3		8
Notomastus latericeus	2			1						1		
Euclymene oerstedi										2		
Scalibregma inflatum	3	4	2	3				1		4	2	6
Lagis koreni	2		1		4		1					
Amphicteis gunneri					1							
Amage adspersa	1		1									
Terebellides stroemi	1	4	4	3	1				1			3
Trichobranchus glacialis		5	5	5	4	3		1	5	5	4	8
Eupolymnia nebulosa	1	5	3	16	3	4	10	3		2		
Pista cristata						1						
Thelepus cincinnatus					3	1						
Polycirrus sp. 1	1								1	5		
Polycirrus sp. 2			1									
Polycirrus medusa							2					
Thelepus cincinnatus							2					
Branchiomma bombyx		2		6						2		
Jasmineira elegans									2	7	4	5
Chone duneri			1		1							
Myxicola infundibulum							2					
Hydroides elegans									1			1
Hydroides norvegica							1		1		3	1
Pomatoceros triqueter	18	10	31	21	24	21	27	14	20	96	28	24
Serpula vermicularis	1		1							1		
Salmacina dysteri		1										
Ologochaeta sp. 1				5								
Ologochaeta sp. 2										1		
SIPUNCULA												
Golfingia vulgaris											11	
ENTOPROCTA												
Barentsia gracilis	+			+						+		+
Pedicellina cernua		+		+	+			+	+	+		+
Pedicellinid sp.						+						
CHELICERATA												
Callipallene brevirostris	2		3	1						8	2	

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
CRUSTACEA												
Verruca stroemia	70	64	126	110	35	210	209	36	3	1	2	1
Balanus balanus	71	37	55	24	101	208	253	103	285	286	46	113
Balanus crenatus	22	4	7	35	5	5	3	3				
Barnacle spat	64	18	15	78	3	45	37	3	80		10	7
Ostracod A	8	5	1								23	2
Ostracod B	5	1	1								4	
Ostracod C	2											
Mysidacea	2	6	4	2								
Vaunthomsonia cristata										1	2	
Eudorella truncatula				2		2						
Nebalia bipes						12				2		
Pseudoparatanais batei	2			1					4	6		
Tanaopsis graciloides	2		1	4	2					2	5	
Gnathia sp.											1	
Anthura gracilis	1	1										
Janira maculosa	10	8		1								
Munna sp.	1	1		9								
Lysianassa ceratina	2								2			2
Orchomene humilis		2			4		6					
Perrierella audouianiana	11	1	5	7					5			2
Tryphosella sarsi												1
Ampelisca tenuicornis	1	1	1						2		2	
Gitana sarsi?										3	2	
Leucothoe spinicarpa	1	1										
Stenothoidae sp.				1								
Cheirocratus sp.				1								
Maera othonis												1
Urothoe elegans									1	1		
Perioculodes longimanus				1					1	1		1
Harpinia crenulata										2		
Metaphoxus fultoni					1		2			1	3	3
Liljeborgia kinahani	20	5	14	6								
Liljeborgia pallida	5	6	4									
Calliopius laeviusculus												2
Parapleustes bicuspis											1	
Stenopleustes nodifer											5	
Dexamine sp.	1											
Tritaeta gibbosa	1	58	6	19								
Aoridae sp.	33	4	67	38					4	17		3

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
Lembos websteri	9		6	4					1	1		
Gammaropsis maculata									1			
Corophium crassicorne	20	10	25	11					6	11	1	14
Jassa sp.											5	
Phtisica marina	47	13	10	24							2	
Pseudoprotella phasma	2	1		2						1	1	
Natantia sp.							1		1		1	1
Galathea sp.					9	4	3	4	4	2	2	1
Paguridae sp.					1							1
Pisidia longicornis	50	46	16	56					1		1	1
Hyas coarctatus									1	1		2
Inachus sp.						1						
Eurynome sp.											1	
MOLLUSCA												
Leptochiton asellus	1	1	1	2	11	3	5	3	4	11	13	11
Ischnochiton albus	1	1		1		1		1	1		1	
Callochiton septemvalvis						1					1	
Tonicella rubra							1					
Emarginula fissura						1				3	1	3
Gibbula cineraria				2		1				2		
Jujubinus miliaris											1	
Tectura virginea					8	1	4	8	1	3	5	2
Rissoa parva										1		
Alvania beanii?			1	2		2				6		
Onoba semicostata						7				13		
Setia pulcherrima										1		
Capulus ungaricus									1	1		
Buccinum undatum (juv)		2		1						1		
Hinia incrassata						3				1		
Odostomia unidentata?										5		
Brachystomia eulimoides?										1		
Partulida pellucida?										1		
Turbonilla jeffreysii				1								
Eulimella ventricosa						1						
Tritonia plebeia?	1											
Onchidoris sp.?										6		
Nucula nucleus				1	5		3	1	7	21	9	18
Arca tetragona										1		
Mytilus edulis	17	7	16	8	2	2	12	3				
Modiolus modiolus	5	8	10	12	5	6	7	5	11	14	3	3

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
Modiolula phaseolina						1	1	1	5	2	4	3
Crenella decussata											1	
Modiolarca tumida			1			4	5		1	1		
Mytilidae spat (Mytilus?)	20	16	22	54	5	13	23	3	7	27	5	
Limaria hians									1	2	2	1
Aequipecten opercularis (juv)		2			2	1	2		3	3	1	
Chlamys distorta	2	1	1						1			1
Chlamys varia											1	
Chlamys varia var.nivea	1	3							1			
Palliolum striatum			1	1							1	1
Palliolum tigerinum								1		1		
Pectinidae spat				21	3	1			4	19	4	3
Heteranomia squamula	17	11	6	3	18	15	28	5	7	10	9	4
Pododesmus patelliformis	15	27	44	18		2	3		18	26	9	10
Anomiidae spat			6	5		1	2	3	274	308	136	123
Lucinoma borealis							1					
Thyasira flexuosa						1		2	1		1	
Kellia suborbicularis					2						1	
Mysella bidentata		2	2	10	1	2				9	6	
Tridonta elliptica											2	
Parvicardium ovale			1						1	7	2	
Abra alba	8									3		
Chamelea gallina			1									
Timoclea ovata					3		4	4				2
Venerupis indet. (juv)											1	
Mya truncata	1	1	2	6			1	1		6	2	2
Corbula gibba			1									
Hiatella arctica	14	10	13	9	9	18	26	13	20	24	10	4
BRACHIOPODA												
Crania anomala									1			1
Terebratulina retusa		1										
BRYOZOA												
Aetea sica									+	+	+	+
Alderina imbellis										+	+	
Beania mirabilis									+	+	+	+
Bowerbankia sp.			+	+					+	+	+	+
Callopora dumerilii	+	+	+	+	+	+	+				+	
Cribrilina annulata										+		
Crisia eburnea?					+			+				
Diplosolen obelia											+	+

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
Disporella hispida	+	+	+	+					+	+	+	+
Electra pilosa					+					+		
Escharella imersa									+	+	+	
Escharella variolosa									+			
Escharella ventricosa									+			+
Escharina johnstoni??										+		
Fenestrulina malusii						+	+	+	+	+	+	+
Microporella ciliata					+				+	+	+	+
Nolela dilatata									+			
Parasmittina trispinosa?					+							+
Porella concinna									+			+
Schizomavella linearis									+		+	+
Schizoporella sp.?									+			
Scrupocellaria scruposa					+	+	+	+	+		+	+
Smittoidea reticulata									+	+		+
Tubulipora sp.					+					+		+
Tubuliporidae sp.												+
ECHINODERMATA												
Antedon bifida	1	1		1					6	1	1	3
Asterias rubens	2		1						1			1
Crossaster papposus					1							
Henricia sanguinolenta							1					
Asteroidea juv.					6	2					1	1
Amphipholis squamata	1	1		4		1		1				5
Ophiocomina nigra						1	1		2	23	8	17
Ophiopholis aculeata									21	38	18	13
Ophiothrix fragilis	35	23	52	23	4	13	17	2	18	16	7	12
Ophiuroidea juv.				14			1			39	5	
Echinus esculentus						1						1
Psammechinus miliaris	3	2	1				1		2	4	1	
P. miliaris juv.?				5						6	1	
Holothurian sp. A					1							
Thyone fusus	1						3					

Table 5.9 continued.

SITE	Loch Creran				Busta Voe				Loch Alsh			
CLUMP	1	2	3	4	1	2	3	4	1	2	3	4
TUNICATA												
Ascidia mentula		1	1						5	1		1
Ascidia virginea			1						1			
Ascidiella aspersa					8	2	5	6	2	1		
Ascidiella scabra									4			1
Boltenia echinata			2									
Botryllus schlosseri			+		+	+	+	+				
Ciona intestinalis	8		2	1					3	2		3
Corella paralellograma	1											
Dendrodoa grossularia	14	16	18	14	124	17	83	73				
Diplosoma listerianum			+	+	+	+	+	+	+	+	+	+
Polycarpa pomaria									2			
Pyura microcosmus	7	10	12	4								
PISCES												
Pomatoschistus pictus									1			
Diplecogaster bimaculata					1	1	1					

Table 5.10. Species richness, Shannon-Wiener diversity and Pielou evenness of the fauna and flora associated with Modiolus *clumps from the three study sites in 1999. The Shannon and Pielou indices are derived only from the species recorded quantitatively.*

Site	Clump	No. species	Shannon	Pielou
Loch Creran	1	80	4.882	0.791
	2	81	5.009	0.812
	3	88	4.800	0.764
	4	87	5.075	0.812
Busta Voe	1	74	4.081	0.716
	2	69	3.249	0.570
	3	69	3.382	0.585
	4	48	3.407	0.654
Loch Alsh	1	90	3.460	0.568
	2	116	4.652	0.710
	3	96	5.401	0.857
	4	98	4.809	0.772

Table 5.11. The main taxa and species characterising the differences in the associated fauna in Modiolus clump samples amongst the three study sites.

Species/Taxa	Loch Creran	Busta Voe	Loch Alsh
Number of algal species	2	13	6
Alcyonium digitatum	present	absent	absent
Phtisica marina	abundant	absent	present
Pisidia longicornis	abundant	absent	present
Verruca stroemia	abundant	abundant	sparse
Balanus crenatus	abundant	abundant	absent
Mytilus edulis	present	present	absent
Dendrodoa grossularia	present	abundant	absent
Limaria hians	absent	absent	present
Ophiopholis aculeata	absent	absent	abundant
Ophiocomina nigra	absent	sparse	abundant
Antedon bifida	sparse	absent	present
Pyura microcosmus	abundant	absent	absent
Number of bryozoan species	3	8	24

APPENDIX 1

Table 1. Details of 35 mm colour transparencies taken at the three study sites.

Table 2. Details of video footage taken at the three study sites. Video tapes are supplied in digital video format (original) and VHS format (copy). All video sequences are titled.

Table 1. Details of 35 mm colour transparencies taken at the three study sites. Photographer, Colin Moore.

Slide no.	Location	Latitude	Longitude	Depth (m)	Date	Equipment	Subject
LA1	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ciona, brittlestars
LA2	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ophiocomina
LA3	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ciona, Antedon
LA4	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Munida
LA5	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ascidea virginea
LA6	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Corella para..
LA7	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ascidea mentula
LA8	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ophiothrix mostly
LA9	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Antedon
LA10	Loch Alsh	57°16.37' N	05°42.78' W	23-24	05/09/99	Nik + C/U lens	Ophiopholis
LA11	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA12	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA13	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA14	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA15	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA16	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA17	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA18	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA19	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LA20	Loch Alsh	57°16.37' N	05°42.78' W	23-24	06/09/99	Nik + 15 mm	Habitat
LC1	Loch Creran	56°32.77' N	05°16.08' W	12-15	14/08/99	Nik + C/U lens	Ascidea mentula
LC2	Loch Creran	56°32.77' N	05°16.08' W	12-15	14/08/99	Nik + C/U lens	Modiolus
LC3	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	Aequipecten

	Creran	N	W		9	lens	
LC4	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	Munida
	Creran	N	W		9	lens	
LC5	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	Esperiopsis
	Creran	N	W		9	lens	
LC6	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	Ciona, Pyura,
	Creran	N	W		9	lens	Alcyonium
LC7	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	Ascidea
	Creran	N	W		9	lens	mentula
LC8	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	A. mentula,
	Creran	N	W		9	lens	Pyura, Mya
LC9	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + C/U	Pyura,
	Creran	N	W		9	lens	Antedon
LC1	Loch	56°32.77'	05°16.08'	12-15	29/07/9	Nik + C/U	Chlamys
0	Creran	N	W		9	lens	varia, Corella, Esperiopsis, A. mentula, Dendrodoa
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
1	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
2	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
3	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
4	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
5	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
6	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
7	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
8	Creran	N	W		9		
LC1	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
9	Creran	N	W		9		
LC2	Loch	56°32.77'	05°16.08'	12-15	14/08/9	Nik + 15 mm	Habitat
0	Creran	N	W		9		

Table 1 continued.

Slide no.	Location	Latitude	Longitude	Depth (m)	Date	Equipment	Subject
BV1	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Eupolymnia, Modiolus
BV2	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Modiolus
BV3	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Ascidiella scabra
BV4	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Hermit
BV5	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Ophiothrix
BV6	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Scallop
BV7	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Liocarcinus depurator
BV8	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Ascidiella scabra
BV9	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Liocarcinus depurator
BV10	Busta Voe	60°21.73' N	01°21.06' W	13-14	20/08/99	Nik + C/U lens	Ascidiella scabra
BV11	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV12	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV13	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV14	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV15	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV16	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV17	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV18	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV19	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat
BV20	Busta Voe	60°21.73' N	01°21.06' W	13-14	21/08/99	Nik + 15 mm	Habitat

Table 2. Details of video footage taken at the three study sites. Video tapes are supplied in digital video format (original) and VHS format (copy). All video sequences are titled.

Tape	Time (hr:min:sec)	Location	Subject	Date	Photographer
Loch Creran	00:00:00	Station T1/3	Close up	14/08/99	H. Mair
	00:15:14	Transect T4	Video transect	29/10/99	C. Moore
	00:26:45	Transect T1	Video transect	14/08/99	D. Harries
Busta Voe	00:00:00	Station 1	Close up	21/08/99	H. Mair
	00:13:57	Transect TB	Video transect	23/08/99	H. Mair
	00:32:53	Transect TA	Video transect	23/08/99	C. Moore
Loch Alsh	00:00:00	Station 1	Close up	04/09/99	H. Mair
	00:15:11	Transect T1	Video transect	07/09/99	H. Mair

APPENDIX 2

Table, adapted from the MNCR database, listing the species associated with *Modiolus* communities at sites in Scotland where *Modiolus* is recorded as Abundant and Superabundant

PORIFERA
Leucosolenia
Leucosolenia botryoides
Leucosolenia complicata
Scypha ciliata
Leuconia
Grantia compressa
Oscarella lobularis
Suberites carnosus
Suberites domuncula
Cliona celata
Halichondria
Halichondria bowerbanki
Halichondria panicea
Hymeniacidon perleve
Hymeniacidon sanguinea
Mycale
Mycale contarenii
Esperiopsis fucorum
Myxilla incrustans
Haliclona
Haliclona urceolus
Dysidea fragilis
Porifera indet crusts

Cyanea capillata
Aurelia aurita
HYDROZOA
Tubularia indivisa
Tubularia larynx
Sarsia eximia
Eudendrium
Eudendrium arbusculum
Eudendrium rameum
Eudendrium ramosum
Bougainvillia
Bougainvillia pyramidata
Bougainvillia ramosa
Hydractinia echinata
Clava multicornis
Halecium beanii
Halecium halecinum
Halecium muricatum
Halopteris catharina
Kirchenpaueria pinnata
Kirchenpaueria similis
Nemertesia antennina
Nemertesia ramosa
Plumularia setacea
Sertulariidae
Abietinaria abietina
Abietinaria filicula
Diphasia rosacea
Dynamena pumila
Hydrallmania falcata
Sertularella polyzonias
Sertularia argentea
Sertularia cupressina
Clytia hemisphaerica
Laomedea flexuosa

Obelia
Obelia geniculata
Rhizocaulus verticillatus

Alcyonium digitatum
Virgularia mirabilis
Pennatula phosphorea
Cerianthus lloydii
Protanthea simplex
Actinia equina
Anemonia viridis
Bolocera tuediae
Urticina
Urticina felina
Urticina eques
Anthopleura
Metridium senile
Sagartia elegans
Sagartia troglodytes
Cereus pedunculatus
Actinothoe sphyrodeta
Sagartiogeton laceratus
Adamsia carciniopados
Edwardsia
Caryophyllia smithii

PLATYHELMINTHES
TURBELLARIA
Uteriporus vulgaris

NEMERTEA
Tubulanus superbus
Cerebratulus
Cerebratulus fuscus
Lineus bilineatus
Lineus longissimus
Lineus viridis
Micrura aurantiaca
Amphiporus dissimulans
Emplectonema neesii
Oerstedia dorsalis

Priapulus caudatus

Golfingia
Golfingia margaritacea
margaritacea
Golfingia vulgaris vulgaris
Phascolion strombus
strombus
Phascolosoma granulatum

Chrysopetalum debile

Pisione remota
Aphrodita aculeata
Alentia gelatinosa
Eunoe nodosa
Harmothoe
Harmothoe extenuata
Harmothoe imbricata
Harmothoe impar
Harmothoe lunulata
Lepidonotus
Lepidonotus clava
Lepidonotus
squamatusPholoe inornata
Sthenelais boa
Eteoninae
Eteone
Eteone flava
Eteone longa
Eteone suecica
Pseudomystides limbata
Phyllodocinae
Anaitides
Anaitides groenlandica
Anaitides mucosa
Eulalia bilineata
Eulalia viridis
Eulalia mustela
Eumida
Eumida sanguinea
Phyllodoce
Phyllodoce lamelligera
Glycera
Glycera alba
Glycera lapidum
Glycinde nordmanni
Goniada maculata
Goniadella ?gracilis
Ephesiella abyssorum
Sphaerodoridium claparedii
Commensodorum
commensalis
Sphaerodoropsis minuta
Sphaerodorum gracilis
Hesionidae
Podarkeopsis capensis
Kefersteinia cirrata
Nereimyra punctata
Ophiodromus flexuosus
Podarke pallida
Syllidia armata
Microphthalmus listensis
Eurysyllis tuberculata
Syllis
Trypanosyllis coeliaca
Typosyllis
Typosyllis armillaris
Typosyllis hyalina
Typosyllis prolifera
Typosyllis variegata
Eusyllis blomstrandi
Odontosyllis gibba

Streptosyllis websteri
Syllides longocirrata
Exogone hebes
Exogone naidina
Exogone verugera
Sphaerosyllis bulbosa
Sphaerosyllis hystrix
Sphaerosyllis tetralix
Autolytus
Proceraea
Nereididae
Nereis
Nereis pelagica
Perinereis
Nephtys
Nephtys caeca
Nephtys hombergii
Nephtys kersivalensis
Pareurythoe
borealisEuphrosine foliosa
Nothria conchylega
Eunice pennata
Lumbrineris aniara
Lumbrineris gracilis
Lumbrineris tetraura
Notocirrus scoticus
Ophryotrocha
Ougia subaequalis
Parougia eliasoni
Schistomeringos neglecta
Orbinia sertulata
Scoloplos armiger
Aricidea
Aricidea catherinae
Aricidea cerrutii
Paradoneis lyra
Paraonis fulgens
Apistobranchus tenuis
Apistobranchus tullbergi
Poecilochaetus serpens
Aonides paucibranchiata
Laonice bahusiensis
Laonice cirrata
Minuspio cirrifera
Polydora caeca
Polydora caulleryi
Polydora ciliata
Polydora flava
Polydora quadrilobata
Prionospio
Prionospio fallax
Pseudopolydora antennata
Pseudopolydora pulchra
Scolelepis squamata
Scolelepis tridentata
Spio
Spio armata
Spio filicornis
Spio martinensis
Spiophanes bombyx
Spiophanes kroeyeri
Magelona alleni
Chaetopterus variopedatus
Cirratulidae
Caulleriella
Caulleriella alata
Tharyx killariensis
Chaetozone setosa
Cirratulus
Cirratulus cirratus
Cirriformia tentaculata
Dodecaceria concharum
Aphelochaeta marioni
Diplocirrus glaucus
Flabelligera affinis
Pherusa plumosa
Macrochaeta clavicornis
Capitella capitata
Capitomastus minimus
Heteromastus filiformis
Mediomastus fragilis
Notomastus latericeus
Peresiella clymenoides
Arenicola marina
Maldanidae
Praxillura
longissimaEuclymeninae
Euclymene
Praxillella affinis
Praxillella praetermissa
Nicomache
Rhodine gracilior
Ophelina acuminata
Ophelina modesta
Scalibregma inflatum
Polygordius appendiculatus
Myriochele
Owenia fusiformis
Amphictene auricoma
Lagis koreni
Ampharete
Ampharete baltica
Ampharete falcata
Ampharete finmarchica
Ampharete lindstroemi
Amphicteis gunneri
Anobothrus gracilis
Sosane sulcata
Terebellides stroemi
Trichobranchus glacialis
Trichobranchus roseus
Terebellidae
Amphitrite
Amphitrite cirrata
Axionice maculata
Eupolymnia nebulosa
Lanice conchilega
Neoamphitrite affinis
Neoamphitrite figulus
Nicolea
Pista cristata
Lysilla loveni
Polycirrus
Polycirrus plumosus
Thelepodinae
Streblosoma bairdi
Streblosoma intestinalis
Bispira volutacornis
Chone duneri
Chone filicaudata
Chone infundibuliformis
Euchone rubrocincta
Fabricia sabella
Jasmineira caudata
Myxicola aesthetica
Myxicola infundibulum
Sabella pavonina
Serpulidae
Hydroides norvegica
Pomatoceros
Pomatoceros triqueter
Serpula vermicularis
Filograna implexa
Protula tubularia
Spirorbidae
Circeis spirillum
Janua pagenstecheri
Paradexiospira vitrea
Spirorbis
Spirorbis corallinae
Spirorbis rupestris
Spirorbis spirorbis
Spirorbis tridentatus
OLIGOCHAETA
Grania

Nymphon
Nymphon brevirostre
Achelia
Endeis
Anoplodactylus petiolatus
Pycnogonum littorale
Halacaridae

CIRRIPEDIA
Verruca stroemia
Chthamalus
Chthamalus stellatus
Balanus
Semibalanus balanoides
Balanus balanus
Balanus crenatus
Sacculina carcini
COPEPODA
CYPRIDINOIDEA
Asterope norvegica
Cylindroleberis mariae
Philomedes lilljeborgii
Cytheridae

Nebalia bipes
AMPHIPODA
GAMMARIDEA
Apherusa bispinosa
Eusirus longipes
Perioculodes longimanus
Pontocrates arenarius
Synchelidium haplocheles
Synchelidium maculatum
Westwoodilla caecula
Parapleustes bicuspis
Amphilochoides serratipes
Amphilochus neapolitanus
Gitana sarsi
Paramphilochoides odontonyx
Leucothoe lilljeborgi
Metopa
Metopa propinqua
Stenothoe marina
Orchestia
Urothoe elegans
Urothoe marina
Harpinia antennaria
Harpinia crenulata
Parametaphoxus fultoni
Phoxocephalus holbolli
Acidostoma nodiferum
Hippomedon denticulatus
Lysianassa plumosa
Socarnes crenulatus
Socarnes erythrophthalmus
Tmetonyx similis
Austrosyrrhoe fimbriatus
Argissa hamatipes
Iphimedia obesa
Atylus vedlomensis
Dexamine spinosaDexamine thea
Guernea coalita
Ampelisca brevicornis
Ampelisca diadema
Ampelisca spinipes
Ampelisca tenuicornis
Ampelisca typica
Bathyporeia
Bathyporeia elegans
Gammaridae
Megaluropus agilis
Cheirocratus
Cheirocratus assimilis
Cheirocratus sundevallii
Maera othonis
Gammaropsis maculata
Gammaropsis palmata
Isaea
Gammaropsis cornuta
Photis longicaudata
Ericthonius rubricornis
Ischyrocerus anguipes
Aoridae
Aora
Leptocheirus hirsutimanus
Leptocheirus pectinatus
Corophium
Corophium bonnellii
Corophium crassicorne
Dyopedos porrectus
Caprellidae
Caprella linearis
Caprella septentrionalis
Pariambus typicus
Parvipalpus
Phtisica marina
Pseudoprotella phasma
Hyperiidae
Gnathia
Gnathia oxyuraea
Anthura gracilis
Limnoria (Limnoria) lignorum
Dynamene bidentata
Jaera albifrons
Janira maculosa
Paramunna bilobata
Pleurogonium rubicundum
Pseudarachna hirsuta
Idotea baltica
Idotea granulosa
Idotea neglecta
Idotea pelagica
Arcturella dilatata
Athelges paguri
Ligia oceanica
TANAIDACEA
Tanais
Tanais dulongii
Araphura brevimana
Leptognathia
Leptognathia gracilis
Tanaopsis graciloides
Iphinoe serrata
Eudorella truncatula
Campylaspis glabra
Diastylis laevis
Palaemon serratusEualus pusiolus
Hippolyte
Hippolyte varians
Pandalidae
Pandalus montagui
Crangon crangon
Paguridae
Anapagurus hyndmanni
Pagurus
Pagurus bernhardus
Pagurus cuanensis
Pagurus prideaux
Pagurus pubescens
Galathea
Galathea dispersa
Galathea intermedia
Galathea squamifera
Galathea strigosa
Munida rugosa
Pisidia longicornis
Porcellana platycheles
Ebalia tuberosa
Hyas
Hyas araneus
Hyas coarctatus
Inachus dorsettensis
Inachus phalangium
Macropodia rostrata
Corystes cassivelaunus
Cancer pagurus
Liocarcinus
Liocarcinus depurator
Necora puber
Liocarcinus pusillus
Carcinus maenas
Monodaeus couchi

Anurida maritima

Chaetoderma nitidulum
POLYPLACOPHORA
Leptochiton asellus
Ischnochiton albus
Lepidochitona cinerea
Tonicella marmorea
Tonicella rubra
Acanthochitona crinitus
Emarginula fissura
Tectura testudinalis
Tectura virginea
Patella ulyssiponensis
Patella vulgata
Helcion pellucidum
Margarites helicinus
Jujubinus clelandi
Gibbula
Gibbula magus
Gibbula tumida
Gibbula cineraria
Gibbula umbilicalis
Calliostoma zizyphinum
Skenea ossiansarsi
Tricolia pullus
Lacuna pallidula
Lacuna vinctaLittorina littorea
Littorina neritoides
Littorina mariae
Littorina obtusata
Littorina neglecta
Littorina nigrolineata
Littorina saxatilis
Hydrobia ulvae
Rissoa
Rissoa lilacina rufilabrum

Rissoa interrupta
Rissoa parva
Pusillina inconspicua
Pusillina sarsi
Alvania punctura
Cingula cingillus
Onoba aculeus
Onoba semicostata
Skeneopsis planorbis
Omalogyra atomus
Rissoella diaphana
Rissoella globularis
Rissoella opalina
Turritella communis
Bittium reticulatum
Chrysallida obtusa
Chrysallida spiralis
Odostomia
Odostomia turrita
Odostomia unidentata
Brachystomia carrozzai
Brachystomia eulimoides
Aporrhais pespelecani
Capulus ungaricus
Trivia arctica
Trivia monacha
Velutina velutina
Polinices montagui
Polinices pulchellus
Nucella lapillus
Ocenebra erinacea
Buccinum undatum
Neptunea
Neptunea antiqua
Colus gracilis
Hinia incrassata
Hinia pygmaea
Hinia reticulata
Mangelia
Mangelia brachystoma
Cylichna cylindracea
Philine
Philine punctata
Retusa
Retusa truncatula
Runcina coronata
Elysia viridis
Limapontia capitata
Aplysia punctata
Tritonia hombergii
Dendronotus frondosus
Doto
Doto coronata
Doto eireana
Goniodoris nodosa
Acanthodoris pilosa
Adalaria proximaOnchidoris depressa
Onchidoris muricata
Aegires punctilucens
Limacia clavigera
Polycera quadrilineata
DORIDACEA
Cadlina laevis
Archidoris pseudoargus
Janolus cristatus
AEOLIDIACEA
Coryphella
Coryphella browni
Coryphella gracilis
Flabellina pellucida
Cuthona rubescens
Tergipes tergipes
Eubranchus farrani
Eubranchus vittatus
Facelina bostoniensis
Favorinus branchialis
Aeolidia papillosa
Dentaliidae
PELECYPODA
Nucula
Nucula nitidosa
Nucula nucleus
MYTILACEA
Mytilus edulis
Crenella decussata
Musculus costulatus
Musculus discors
Modiolarca tumida
Modiolus
Modiolus modiolus
Modiolula phaseolina
Glycymeris glycymeris
Limaria hians
Limatula subauriculata
Ostrea edulis
Similipecten similis
Pseudamussium septemradiatum
Chlamys
Chlamys distorta
Chlamys varia
Chlamys varia nivea
Aequipecten opercularis
Pecten maximus
Anomiidae
Anomia ephippium
Pododesmus patelliformis
Pododesmus squamula
Myrtea spinifera
Lucinoma borealis
Thyasira flexuosa
Thyasira gouldi
Lasaeidae
Lasaea adansoni
Kellia suborbicularis
Devonia perrieri
Mysella bidentata
Lepton squamosum
Goodallia triangularis
Tridonta elliptica
Acanthocardia echinata
Parvicardium
Parvicardium exiguum
Parvicardium ovaleParvicardium scabrum
Laevicardium crassum
Cerastoderma edule
Spisula elliptica
Spisula solida
Ensis
Ensis arcuatus
Phaxas pellucidus
Angulus tenuis
Moerella pygmaea
Macoma balthica
Gari fervensis
Gari tellinella
Abra
Abra alba
Abra nitida
Abra prismatica
Arctica islandica
Circomphalus casina
Dosinia lupinus
Dosinia exoleta
Tapes rhomboides
Venerupis senegalensis
Chamelea gallina
Clausinella fasciata
Timoclea ovata
Mysia undata
Turtonia minuta
Mya
Mya truncata
Mya arenaria
Corbula gibba
Hiatella arctica
Thracia convexa
Thracia phaseolina
Cochlodesma praetenue
Rossia macrosoma
Eledone cirrhosa

Neocrania anomala

BRYOZOA
Crisiidae
Crisia denticulata
Oncousoecia diastoporides
Oncousoecia dilatans
Tubulipora phalangea
Alcyonidium
Alcyonidium diaphanum
Alcyonidium gelatinosum
Alcyonidium hirsutum
Flustrellidra hispida
Cribrilina annulata
Cribrilina punctata
Puellina venusta
Umbonula littoralis

Escharoides coccinea
Cryptosula pallasiana
Hippoporina pertusa
Smittoidea reticulata
Parasmittina trispinosa
Porella compressa
Porella concinna
Porella minuta
Escharella immersaEscharella ventricosa
Phylactella labrosa
Neolagenipora collaris
Schizoporella unicornis
Schizomavella linearis
Microporella ciliata
Fenestrulina malusii
Haplopoma graniferum
Chorizopora brongniartii
Cylindroporella tubulosa
Cellepora pumicosa
Celleporina hassallii
Omalosecosa ramulosa
Aetea sica
Eucratea loricata
Membranipora membranacea
Electra pilosa
Pyripora catenularia
Callopora aurita
Callopora craticula
Callopora dumerilii
Callopora lineata
Crassimarginatella solidula
Tegella unicornis
Amphiblestrum flemingii
Ramphonotus minax
Amphiblestrum solidum
Cellaria
Cellaria sinuosa
Scrupocellaria
Scrupocellaria reptans
Bugula
Bugula fulva
Bryozoa indet crusts

PHORONIDA
Phoronis
Phoronis muelleri

Antedon bifida
Antedon petasus
Astropecten irregularis
Luidia ciliaris
Porania pulvillus
Asterina gibbosa
Solaster endeca
Crossaster papposus
Henricia
Henricia oculata
Henricia sanguinolenta
Asterias rubens
Leptasterias muelleri
Marthasterias glacialis
Ophiothrix fragilis
Ophiocomina nigra
Ophiopholis aculeata
Amphiura
Amphiura brachiata
Amphiura filiformis
Amphiura securigera
Amphipholis squamata
Ophiura
Ophiura affinis
Ophiura albida
Ophiura ophiuraECHINOIDEA
Psammechinus miliaris
Echinus esculentus
Strongylocentrotus droebachiensis
Echinocyamus pusillus
SPATANGOIDA
Echinocardium cordatum
Echinocardium pennatifidum
Cucumaria
Cucumaria frondosa
Trachythyone elongata
Pawsonia saxicola
Ocnus lacteus
Thyone fusus
Neopentadactyla mixta
Thyonidium drummondii
Psolus phantapus
Leptosynapta inhaerens

Clavelina lepadiformis
Polyclinidae
Polyclinum aurantium
Sidnyum turbinatum
Didemnidae
Trididemnum cereum
Diplosoma listerianum
Lissoclinum perforatum
Ciona intestinalis
Corella parallelogramma
Ascidiella aspersa
Ascidiella scabra
Ascidiella
Ascidia conchilega
Ascidia mentula
Ascidia virginea
PLEUROGONA
Polycarpa
Polycarpa pomaria
Dendrodoa
Dendrodoa grossularia
Botryllus schlosseri
Botrylloides leachi
Pyura
Pyura microcosmus
Molgula complanata

Scyliorhinus canicula

Salmo trutta
Diplecogaster bimaculata
Gadidae
Merlangius merlangus
Molva molva
Pollachius pollachius
Pollachius virens
Trisopterus minutus
Spinachia spinachia
Scorpaena scrofa
Myxocephalus scorpius
Taurulus bubalis
Agonus cataphractus
Cyclopterus lumpus
Centrolabrus exoletus
Ctenolabrus rupestrisLabrus bergylta
Labrus mixtus
Lipophrys pholis
Leptoclinus maculatus
Lumpenus lampretaeformis
Pholis gunnellus
Callionymus lyra
Gobiidae
Gobius paganellus
Gobiusculus flavescens
Lesueurigobius friesii
Pomatoschistus
Pomatoschistus minutus
Pomatoschistus pictus
Zeugopterus punctatus
Pleuronectidae

Halichoerus grypus

CYANOPHYCOTA

RHODOPHYCOTA
Porphyropsis coccinea
Porphyra
Porphyra purpurea
Porphyra umbilicalis
Audouinella
Scinaia trigona
Bonnemaisonia asparagoides
Bonnemaisonia hamifera
Trailliella intricata
Gelidium
Gelidium latifolium

Gelidium pusillum
Palmaria palmata
Dilsea carnosa
Dumontia contorta
Callophyllis cristata
Callophyllis laciniata
Kallymenia reniformis
Peyssonnelia
Hildenbrandia
Corallinaceae
Corallina officinalis
Dermatolithon
Lithophyllum
Lithothamnion
Lithothamnion glaciale
Phymatolithon calcareum
Maerl indet
Ahnfeltia plicata
Phyllophora crispa
Phyllophora pseudoceranoides
Coccotylus truncata
Mastocarpus stellatus
Chondrus crispus
Polyides rotundus
Plocamium cartilagineum
Furcellaria lumbricalis
Halarachnion ligulatum
Cystoclonium purpureum
Rhodophyllis
Rhodophyllis divaricata
Rhodophyllis divaricata var. werneriChylocladia verticillata
Lomentaria articulata
Lomentaria clavellosa
Callithamnion
Callithamnion tetricum
Ceramium
Ceramium nodulosum
Ceramium shuttleworthianum
Compsothamnion thuyoides
Griffithsia corallinoides
Halurus flosculosus
Plumaria elegans
Pterothamnion plumula
Ptilota plumosa
Acrosorium venulosum
Cryptopleura ramosa
Delesseria sanguinea
Hypoglossum hypoglossoides
Membranoptera alata
Haraldiophyllum bonnemaisonii
Nitophyllum punctatum
Phycodrys rubens
Heterosiphonia plumosa
Brongniartella byssoides
Osmundea hybrida
Laurencia obtusa
Laurencia pinnatifida
Odonthalia dentata
Polysiphonia
Polysiphonia brodiei
Polysiphonia elongata
Polysiphonia lanosa
Polysiphonia fucoides
Polysiphonia stricta
Pterosiphonia
Pterosiphonia parasitica
Rhodomela lycopodioides
Rhodophycota indet.(non-calc.crusts)

CHRYSOPHYCOTA

CHROMOPHYCOTA
Ectocarpaceae
Pilayella littoralis
Spongonema tomentosum
Pseudolithoderma extensum
Elachista fucicola
Leathesia difformis
Spermatochnus paradoxus
Acrothrix gracilis
Chordaria flagelliformis
Eudesme virescens
Mesogloia vermiculata
Cutleria multifida
Aglaozonia (Asexual Cutleria)
Sphacelaria
Cladostephus spongiosus
Dictyota dichotoma
Desmarestia aculeata
Desmarestia viridis
Asperococcus fistulosus
Asperococcus bullosus
Dictyosiphon
Dictyosiphon foeniculaceus
Colpomenia peregrinaScytosiphon lomentaria
Chorda filum
Laminaria
Laminaria digitata
Laminaria hyperborea
Laminaria saccharina
Alaria esculenta
Ascophyllum nodosum
Ascophyllum nodosum mackaii
Fucus
Fucus ceranoides
Fucus serratus
Fucus spiralis
Fucus vesiculosus
Pelvetia canaliculata
Himanthalia elongata
Halidrys siliquosa
Chromophycota indet.(crusts)

Enteromorpha
Enteromorpha intestinalis
Ulva
Ulva lactuca
Chaetomorpha melagonium
Cladophora
Cladophora rupestris
Bryopsis hypnoides
Derbesia

Zostera marina

Lichina pygmaea