Natural England Commissioned Report NECR043

Meeting the MPA Network Principle of Viability

Feature specific recommendations for species and habitats of conservation importance

First published 11 June 2010

www.naturalengland.org.uk

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

© **www.seasurvey.co.uk**

Blue mussels *Mytilus edulis*

Background

This report was commissioned in September 2009 to provide advice on viability, one of the seven Marine Protected Area (MPA) network design principles. This research used existing literature to provide evidence on the viable area required to conserve habitats and species of conservation importance.

The findings are being used by Natural England and JNCC to inform the Ecological Network Guidance for the Marine Conservation Zone Project. The Ecological Network Guidance will guide stakeholders in identifying Marine Conservation Zones to contribute to the ecologically coherent MPA network. The report has been subjected to an international peer review exercise by Defra nominated marine scientists.

This report should be cited as:

HILL, J., PEARCE, B., GEORGIOU, L., PINNION, J., GALLYOT, J. 2010. *Meeting the MPA Network Principle of Viability: Feature specific recommendations for species and habitats of conservation importance*. Natural England Commissioned Reports, Number 043.

Natural England Project Manager - Dr Jen Ashworth, Senior Specialist Marine, Evidence, Northminster House, Peterborough PE1 1UA **Jen.Ashworth@naturalengland.org.uk**

Contractor - Marine Ecological Surveys Limited, 24a Monmouth Place, Bath, BA1 2AY **www.seasurvey.co.uk**

Keywords - Marine Protected Area (MPA), Marine Conservation Zone (MCZ), network, ecological coherence, viability

ISSN 2040-5545

Jacqueline Hill, Bryony Pearce, Lucy Georgiou, Jennifer Pinnion & Jennifer Gallyot

April 2010

Marine Ecological Surveys Limited

Summary

The Marine and Coastal Access Act 2009 created a new type of Marine Protected Area (MPA), called a Marine Conservation Zone (MCZ). MCZs, together with other types of existing MPAs, will deliver the Government's aim for the formation of an 'ecologically coherent network of well managed Marine Protected Areas'.

Through stakeholder engagement and consultation the Department for Food and Rural Affairs (Defra) has developed seven design principles which are to be applied to the UK network of MPAs;

- **Representativity**
- **Replication**
- **Viability**
- **Adequacy**
- **Connectivity**
- **Protection**
- **Best available evidence**

The objective of this study is to address the design principle of viability through the assessment of 37 species and 25 habitats which are likely to be protected by the MPA network (known as features of conservation importance – FOCI).

A viable MPA has been defined within the scope of this study as being an area large enough to encompass most naturally occurring ecological processes and the home ranges of the species or groups of species characteristic of habitat communities which are the target for protection.

The specific objectives of this viability assessment were to review existing literature to identify adult home ranges for species of conservation importance and to identify the minimum site area required for each habitat of conservation importance. This review focused on published peer-reviewed journal articles but where gaps exist, was supplemented with data and reports produced by Marine Ecological Surveys Ltd as well as other grey literature.

As most species in this review are sessile or sedentary the reviews consider several factors other than home range, important to the ecology, and hence viability of species and habitats. The resulting viability assessments, for species and habitats of conservation interest, are based on the following factors:

Home range of adults – migrations, foraging and normal patterns of movement to meet the biological needs for shelter and reproduction were researched for the species of conservation interest as well as species deemed to be ‘characteristic’ residents of the habitats of conservation interest. The vast majority of species were found either to be entirely sessile or to undertake only very limited movements. Home range is therefore not considered to be a useful indicator of the area required to ensure the persistent viability of marine species or habitats.

Minimum Viable Population (MVP) – ensuring that a population has a reasonable chance of survival is considered to be a critical element of viability. A reduction of genetic fitness can reduce the ability of a species or group of species to survive environmental change, since inbreeding can introduce unfavourable mutations as well as reducing evolutionary potential. Published studies on the viable population sizes i.e. the size required to ensure the persistence of populations and protect against in-breeding and genetic mutations, were reviewed. Although studies relating specifically to marine invertebrates were few in number a viable population size of 5000 individuals has been estimated for a wide range of taxa. Species densities reported in the literature and/or derived from the MESL database were used to calculate the effective population size into the MPA size required to support a viable population. The use of population densities in viability assessments is thought to be a useful indicator of the minimum viable MPA area, although the precise values derived in this assessment should be used with caution given the absence of targeted genetic viability studies.

Dispersal and Self-Seeding – the continued viability of an MPA can only be achieved if it is self perpetuating, and hence it should be large enough to encompass dispersal and recruitment. Review of the literature revealed sparse and often contradictory information regarding the dispersal of marine species. The majority of species in this study have a planktonic phase in their development and research suggests that dispersal commonly occurs over large distances (often exceeding 50 km). However, the uncertainties which surround the dispersion models, and the contradictory evidence reported by some genetic studies, make it difficult to ascribe high confidence levels to these dispersal measures. Most invertebrate marine species exhibit larval dispersal and where this is to be protected, very large (>1000 km^2) MPAs would be necessary. The results of this investigation indicate that self-seeding is only appropriate for species that do not have a widely dispersing larvae or where they occur in enclosed areas such as bays, lochs and estuaries. For the majority of species with widely dispersing larvae connectivity is more important for protecting recruitment and dispersal distances are provided here for guidance.

Spatial and temporal dynamics - when considering the size and design of marine MPAs the area protected should be based on what Pickett and Thompson refer to as the ‘minimum dynamic area’. This is the smallest area with a natural disturbance regime that allows for the normal processes of local extinction, re-colonisation and succession and hence the preservation of species. The determination of a minimum dynamic area is based on knowledge of disturbance-generated patch size, frequency, and longevity, and the mobility of the preserved species. Thus, in order to capture biodiversity patterns and processes in MPA network design, a clear **understanding of their spatial and temporal variability** is required. Very little **quantitative** research has been undertaken on the dynamics of marine ecosystems but nevertheless where information was available, the spatial and temporal variability of species and habitats have been discussed in the relevant habitats sections in the report.

This review has revealed considerable gaps in our understanding of marine species and habitats. Significant resources would be required to secure the data necessary to undertake robust viability assessments for MPA design and until such a time as these data become available a precautionary approach, based on the best currently available evidence, to viability is recommended.

The use of home ranges was found to be of limited use in MPA design for many of the species and habitats reviewed here. The vast majority of species covered in this report are sessile or not wide ranging and so the area required to conserve the movements of individuals was often markedly smaller than the area estimated to contain a genetically viable population. This may not be the case however, where more mobile species are the focus of conservation efforts.

The use of dispersal distances in determining MPA size has also proven to be problematic since the size of MPA required for self-seeding populations was found to be prohibitively large where species have a planktonic phase in their development. Furthermore, the extents identified using this information far exceeded the extent of MPAs in other parts of the world which have been proven to be viable over a number of years (see *Mitella* and *Palinurus* examples). Designating a series of smaller MPAs with appropriate spacing to maximise connectivity is considered to be a more effective way of protecting these species and habitats.

Where species undergo direct development, dispersal would be encompassed in an MPA area which protects genetic diversity. Establishing the area required to support the minimal viable population is therefore considered to be the most useful component of viability assessments and more focused research in this area would be very beneficial to the design of the UK's MPA network.

The variability and dynamics of the species and habitats studied here was found to be an important component in assessing the requirements of a viable MPA, despite the lack of quantitative data. Where variability is important to the persistence of a habitat or species, this should be encompassed in the MPA design.

Acknowledgements

We are grateful to the contributions of several people in the course of the research carried out for this project. Dr Christine Maggs (Queens University Belfast) and Dr Darrell Birkett provided invaluable help and advice on the life-history characteristics of the rare algal species. Dr Gerd Könnecker, a consultant based in the Republic of Ireland (previously of the Martin Ryan Institute in Galway), assisted with discussions on the biology and ecology of deep sea sponges. We would also like to thank Dr Jason Hall-Spencer of Plymouth University for the provision of useful literature on maerl beds. Our thanks also go to the staff at the National Marine Biological Library in Plymouth for their patience! Jen Ashworth and Robert Enever at Natural England provided helpful feedback during the research and writing stages of the report. We are also grateful for the useful comments and guidance from the Defra-nominated scientists on the International Peer Review panel.

Contents

List of tables

Appendix 1:

List of figures

1 Introduction

The Marine and Coastal Access Act 2009 creates a new type of Marine Protected Area (MPA), called a Marine Conservation Zone (MCZ). MCZs, together with other types of existing MPAs, will deliver the Government's aim for the formation of an 'ecologically coherent network of well managed Marine Protected Areas'. This network will conserve rare, threatened, and representative species and habitats to conserve or enhance biodiversity and ecosystems [1].

Ecological coherence is still an evolving concept in the scientific community and there is no universally accepted definition. However the UK has worked closely with other countries to develop a working understanding of an ecologically coherent network through the OSPAR process.

The principles which will underpin the design of the MPA Network of sites are:

- **Representativity** – the MPA network should represent the range of marine habitats and species through protecting all major habitat types and associated biological communities present in each of the seas in our marine area.
- **Replication** – all major habitats should be replicated in each regional sea and distributed throughout the network. The amount of replication will depend on the extent and distribution of features within regional seas.
- **Viability** – the MPA network should incorporate self-sustaining, geographically dispersed component sites of sufficient size to ensure species and habitats persistence through natural cycles of variation.
- **Adequacy** – the MPA network should be of adequate size to deliver its ecological objectives and ensure the ecological viability and integrity of populations, species and communities (the proportion of each feature included within the MPA network should be sufficient to enable its long-term protection and/or recovery).
- **Connectivity** – the MPA network should seek to maximise and enhance the linkages among individual MPAs and between regional networks of MPAs using the best current science. For certain species this will mean that sites should be distributed in a manner to ensure protection at different stages in their life cycles.
- **Protection** – the MPA network is likely to include a range of protection levels. Ranging from highly protected sites or parts of sites where no extractive, depositional or other damaging activities are allowed, to areas with only minimal restrictions on activities that are needed to protect the features.
- **Best available evidence** – network design should be based on the best information currently available. Lack of full scientific certainty should not be a reason for postponing decisions on site selection.

A series of research initiatives on these design principles have now been commissioned by Natural England and The Joint Nature Conservation Committee (JNCC) which will, in combination, inform the design of the UK's MPA network. This study deals with one component of this, the design principle of viability.

Aims & Objectives

The aim of the current project is to address the MPA design principle of **VIABILITY**.

Marine Ecological Surveys Limited was commissioned by Natural England to build on the work of Roberts *et al.,* [2] and to provide viability assessments for 37 species and 25 habitats of conservation importance. These species and habitats are listed under one or more of the following conservation designations: the Wildlife and Countryside Act (1981), UK Biodiversity Action Plans (BAP), the OSPAR convention (Threatened or Declining), the IUCN 'Red List' and Annex I of the EU Habitats Directive (1992).

The specific objectives of this viability assessment are as follows:

- To review existing literature to identify mature adult species home ranges for the **species** of conservation importance (Table 1-1).

- To review existing literature to identify the minimum site area required for each **habitat** of conservation importance (Table 1-2) in order to maintain the integrity of the habitat.

Assessing viability

A viable MPA is defined as an area that should be large enough that most ecological processes are able to operate within it and is sufficient to encompass the home ranges of the species or groups of species (referred to here as habitats) which are the target for protection.

As most species in this review are sessile or sedentary the reviews consider several factors other than home range, important to the ecology, and hence viability of species and habitats. The resulting viability assessments, for species and habitats of conservation interest, will therefore, need to consider broader ecological factors. It is beyond the scope of this research to investigate all of the ecological processes and functions which contribute to the viability of individual species and habitats in the marine environment and so we have identified four core aspects of viability on which this study will focus:

Home range of adults – migrations, foraging and normal patterns of movement represent an essential component of MPA design. Thus, as a bare minimum the area protected should encompass the home range of the resident species. The home range of a species or group of species can also be considered as a proxy for a number of other ecosystem functions since the home range of a species will encompass the area required for the provision of adequate food and shelter. Where species have a dispersal stage the home range will not encompass the whole life cycle.

Minimum Viable Population – ensuring that a population has a reasonable chance of survival is considered to be a critical element of viability. A reduction of genetic fitness can reduce the ability of a species or group of species to survive environmental change, since inbreeding can introduce unfavourable mutations as well as reducing evolutionary potential.

Dispersal and Self-Seeding – in order to ensure true viability of a species or a group of species the area of protection needs to contain a self perpetuating population. However, this is often not practical in the marine environment where many species have a planktonic stage in their development that allows dispersal on a massive scale. To ensure the self-seeding an MPA would need to be as large as the mean larval dispersal distance of the target species, which in many instances would mean that very large MPAs (>1000 km^2) would be necessary. An alternative, therefore, lies in the creation of a series of spatially distinct, yet ecologically connected MPAs.

Spatial and temporal dynamics - when considering the size and design of marine MPAs the area protected should be based on what Pickett and Thompson refer to as the ‘minimum dynamic area’. This is the smallest area with a natural disturbance regime that allows for the normal processes of local extinction, re-colonisation and succession and hence the preservation of species. The determination of a minimum dynamic area is based on knowledge of disturbance-generated patch size, frequency, and longevity, and the mobility of the preserved species. Thus, in order to capture biodiversity patterns and processes in MPA network design, a clear **understanding of their spatial and temporal variability** is required.

Table 1-1 List of the species for which a viability assessment has been undertaken and the conservation listings in which they appear

SPECIES	COMMON NAME	CONSERVATION LISTING			
		WILDLIFE & COUNRYSIDE ACT (1981)	BIODIVERSITY ACTION PLAN (BAP)	OSPAR (THREATENED OR DECLINING)	OTHER
Anotrichium barbatum	Bearded red seaweed		×		
Cruoria cruoriaeformis	A red seaweed		×		
Dermocorynus montagnei	A red seaweed		×		
Lithothamnion corallioides	Coral Maerl		×		
Padina pavonica	Peacock’s tail		×		**Nationally scarce**
Phymatolithon calcareum	Common Maerl		×		
Alkmaria romijni	Tentacled lagoon-worm	×			**Nationally scarce**
Armandia cirrhosa	Lagoon sandworm	×	×		**Nationally rare**
Gobius cobitis	Giant goby	×			
Gobius couchi	Couch’s goby	×			
Hippocampus guttulatus	Long snouted seahorse	×	×	×	
Hippocampus hippocampus	Short snouted seahorse	×	×	×	**CITES/ Bern Convention**
Victorella pavida	Seamat	×	×		**Nationally rare**
Amphianthus dohrnii	Sea-fan anemone		×		**Nationally rare**
Edwardsia ivelli	Ivel’s sea anemone	×	×		**IUCN (data deficient)**
Edwardsia timida	Timid burrowing anemone		×		**Nationally scarce**
Eunicella verrucosa	Pink sea-fan	×	×		**IUCN vulnerable**
Funiculina quadrangularis	Tall sea pen		×		

Table Error! No text of specified style in document.**-2** List of the species for which a viability assessment has been undertaken and the conservation listings in which they appear

SPECIES	COMMON NAME	CONSERVATION LISTING			
		WILDLIFE & COUNRYSIDE ACT (1981)	BIODIVERSITY ACTION PLAN (BAP)	OSPAR (THREATENED OR DECLINING)	OTHER
Haliclystus auricula	A stalked jellyfish		×		
Leptopsammia pruvoti	Sunset cup coral		×		
Lucernariopsis campanulata	A stalked jellyfish		×		
Lucernariopsis cruxmelitensis	A stalked jellyfish		×		
Nematostella vectensis	Starlet sea anemone	×	×		**IUCN vulnerable**
Pachycerianthus multiplicatus	Fireworks anemone		×		
Swiftia pallida	Northern sea fan		×		
Arrhis phyllonyx	A deep-sea shrimp		×		
Gammarus insensibilis	Lagoon sand shrimp	×	×		
Gitanopsis bispinosa	An amphipod shrimp		×		
Mitella pollicipes	Gooseneck barnacle		×		
Palinurus elephas	Crayfish		×		
Arctica islandica	Ocean quahog			×	
Atrina pectinata	Fan mussel	×	×		
Caecum armoricum	Defolin's lagoon snail	×			**Nationally rare**
Nucella lapillus	Dog whelk			×	
Ostrea edulis	Native Oyster		×	×	
Paludinella littorina	Sea snail	×			**Nationally rare**
Tenellia adspersa	Lagoon sea slug	×	×		**Nationally rare**

Table Error! No text of specified style in document.**-3** List of the habitats for which a viability assessment has been undertaken and the conservation listings in which they appear

HABITATS	EU HABITATS DIRECTIVE (ANNEX I)	CONSERVATION LISTING	
		BIODIVERSITY ACTION PLAN (BAP)	OSPAR (THREATENED OR DECLINING)
Intertidal *Mytilus edulis* beds on mixed and sandy sediments	Biogenic reef	✕	✕
Carbonate mounds		✕	✕
Coastal saltmarsh	Estuaries *Salicornia* and other annuals colonising mud and sand *Spartina* salt meadows and Mediterranean and thermo-Atlantic halophilous scrubs	✕	
Cold-water coral reefs	Reefs	✕	✕
Deep-sea sponge aggregations		✕	✕
Estuarine rocky habitats	Estuaries	✕	
File shell beds		✕	
Fragile sponge & anthozoan communities on subtidal rocky habitats		✕	
Intertidal underboulder communities		✕	
Intertidal mudflats	Mudflats and sandflats not covered by seawater at low tide	✕	✕
Littoral chalk communities		✕	✕
Maerl beds		✕	✕
Modiolus modiolus beds	Biogenic reefs Large shallow inlets and bays	✕	✕
Mud habitats in deep waters: Sea-pen and burrowing megafauna communities		✕	✕
Ostrea edulis beds			✕
Peat and clay exposures		✕	
Sabellaria alveolata reefs	Biogenic reefs	✕	
Sabellaria spinulosa reefs	Biogenic reefs	✕	✕
Saline lagoons	Coastal lagoons	✕	
Seagrass beds		✕	✕
Sheltered muddy gravels		✕	
Subtidal chalk	Reefs	✕	
Subtidal sands and gravels		✕	
Tide-swept channels		✕	

2 Methodology

Literature review

The primary objectives of this assessment were met through thorough review and analysis of the peer-reviewed literature. Where possible the review has been based on primary literature and a total of 650 articles were reviewed. For some species and habitats this has not been possible due to the lack of relevant research. In these instances grey literature, where available, has been used to provide supplementary evidence.

For six species of conservation importance the biological and ecological information was not adequate to undertake a viability assessment. Some of the rare and scarce species that have restricted distributions have been the subject of little, if any, academic research. Where knowledge of the biology, especially the mode of reproduction, of a species is limited or even completely lacking it has been necessary to select a proxy species, as defined below, to inform the analysis.

Proxy species

A proxy species is defined as **a species with similar life history characteristics and/or** occupying the same or similar ecological niche as the species of interest.

The process for the selection of proxy species was initially based on a search of the taxonomic hierarchy (Genus:Family:Order) until a species that fulfilled the above criterion was identified. The list of proxy species was circulated to Natural England and JNCC for approval before use.

The life-history and ecological niche of closely related species or groups were reviewed in order to select the proxy species most likely to be representative of the species of interest. Where a proxy species has been used for part of all of a viability assessment the data are denoted with a * and the proxy species is clearly identified within the text.

Characteristic Species

Acknowledging that a viability assessment of all species associated with the habitats of conservation interest would be a prohibitively time consuming exercise it is necessary to select the most appropriate species for each habitat.

The criteria that have been used to select the species which are characteristic of the habitats of conservation importance are:

- those species which have a strong influence on the ecology of that community and
- those species that are ‘characteristic’ of the habitat in question and are part of the signature assemblage

Species that have a strong influence on the ecology of the community include habitat engineers, such as the biogenic reef builders. These species significantly enhance structural complexity and thereby support an associated community that may otherwise not be present. Other ecologically important species include those, whose interactions, such as predation, grazing or competition, maintain community structure and function.

Characteristic species have been defined as those that are ‘faithful and frequent’ in the habitat [3]. However, the abundance, frequency or faithfulness of a species within a habitat is not necessarily a good indicator of the contribution of a species to the viability of a habitat. We have therefore, used the following qualifications to the selection of characteristic species:

Ecologically important: those characteristic species that play important functional roles, such as elemental and energy cycling, contribution to overall productivity and propagule and larval supply.

Functional group: where we identified several species from the same functional group (e.g. interstitial predatory polychaetes) the most ‘faithful and frequent’ species was selected following a review of the peer-reviewed literature. In some cases the only information available regarding the component species within habitats of conservation importance was from the Marine Habitat Classification [4].

Ecological dependence: Some species may be considered characteristic of particular habitats but will have a low level of ecological dependence on that habitat. For example, species such as the common starfish *Asterias rubens* and the common shore crab *Carcinus maenas* were found to be ‘faithful and frequent’ in a high proportion of the habitats. These species are ‘ubiquitous’, highly mobile and in the absence of any evidence to suggest a specific affinity with a particular habitat of conservation interest have low ecological dependence on the habitat and have, therefore, been excluded from the viability analysis.

Conversely, the habitat may or may not be where a particular species spends most of its life, but if it cannot complete the life cycle without the habitat, dependence is high. For example, seasonal or intermittent visitors, in particular fish and birds, that visit particular habitats for spawning or nursery grounds will have a high level of ecological dependence on those habitats. Such visitors can influence the abundance and biomass of organisms in a community over time [5, 6]. However, the suitability of MPAs as a conservation tool for large and highly mobile components of the marine ecosystem such as fish and birds is questionable since they cover extremely large distances in their lifetimes often using resources from different regions or even continents. The conservation and management of marine fisheries are being addressed elsewhere within the context of the Marine and Coastal Access Act (2009) and the European Common Fisheries Policy.

Over 210 marine species were selected as characteristic species for the habitats of conservation importance. The life-history traits including home range, reproductive strategy and dispersal distance, were researched for all characteristic species. This exercise required an extensive search of electronic databases, journals, books and reports. There was very little information on the life history characteristics of species in faunal groups such as hydroids and bryozoans and in these instances it was only possible to derive life history traits at a lower taxonomic resolution. These coarse life-history assessments should be treated with some caution since there is often considerable variability in life history traits within a family or genus. Where more than one measure (for example larval dispersal distance or time in the plankton) was reported in the literature we have adopted a precautionary approach and given a range of values.

There is a high level of variability in both the quality and quantity of life history data available for the species and habitats of interest. To this end, confidence levels have been assigned to individual data items included in the assessments based on the rationale detailed in Table . Colour coding has been used in each cell of the viability assessment summary boxes in the species and habitat reviews to indicate the confidence in individual data items.

The full list of characteristic species used in the viability assessments is given in Appendix Table 6-4.

Table 2-1 Confidence levels applied to the viability assessments

CONFIDENCE LEVEL	EXPLANATION
High	Confidence is high where the information presented has been derived from primary peer-reviewed literature sources that make specific reference to the biological characteristic presented.
Moderate	Confidence is moderate where data has been derived from grey literature without reference to primary research or inferences from a mixture of primary sources and informed judgements.
Low	Confidence is low where analysis has been derived by "informed judgement" where very little or no information is present or where a proxy species has been used.

Viability Assessments

Viability assessments for the species and habitats of conservation interest listed in Table 1-1 and Table Error! No text of specified style in document.**-3** have been made using the following information:

Home range of adults

A literature review was undertaken in order to ascertain the area used by species and groups of species for migrations, foraging and reproduction. Most species (87 %) in this review, however, are sessile and therefore, do not have a home range greater than the size of the individual.

Population size and density

The minimum viable population (MVP) is an estimate of the number of individuals required for a high probability of survival of a population over a given time [7]. A commonly used but somewhat arbitrary definition is >95% probability of persistence over 100 years [8]. Unfortunately, marine invertebrates are poorly investigated taxa in terms of viable population studies. Traill *et al*., [7] found only three studies which assessed the MVP for marine invertebrates in a review of over 2000 peer reviewed articles. Although studies relating specifically to marine invertebrates were few in number a viable population size of 5000 individuals has been estimated for a wide range of taxa This effective population size is in good agreement with the median MVP identified by Traill *et al.,* [7] in their review of 212 species as well as the recommendations of Frankham [9] based on genetic information.

In order to convert the effective population size into an estimate of the area required to support it, population densities were sought from the peer-reviewed literature; unfortunately these were found to be entirely lacking. This element of the viability assessment therefore draws strongly upon MESL reports from surveys around the UK coastline. The data from these studies have been collected for research studies and environmental impact assessments for a range of clients and funding bodies, reports which are publicly available. All of the species identification and sample analysis has been carried out by the MESL Laboratory which participates in the

NMBAQC (National Marine Biological Analytical Quality Control) scheme. Abundance data recorded in quantitative grab samples were extracted, where available, and these data are summarised in Appendix Table 6-1. The published MESL reports that relate to the data used are listed in Appendix Table 6-2.

Species were present in the MESL database in variable numbers of samples and abundances and so an indication of the level of data, and therefore the level of confidence, in the estimates of Minimum Viable Population (MVP) numbers have been provided. Where only a small number of records (<10) were present only a low confidence can be ascribed to the resulting density estimates. Where between 10 and 50 records were identified the confidence level ascribed to the density estimates was moderate and where greater than 50 records were identified the confidence level was deemed to be high. The colour coding for confidence levels, as shown in Table 2-1, has been applied.

Dispersal and Self-Seeding

The mode of reproduction including dispersal modes and distances were sought for both the species of conservation interest and the characteristic species within the habitats as part of this study. The reproductive and dispersal modes were recorded using the standard abbreviations listed in Table 2-2 below.

Table 2-2 Codes used to describe reproductive and dispersal modes used by marine species

CODE	DESCRIPTION
A	Asexual reproduction
AB	Asexual budding
AV	Asexual with vegetative
BR	Brooding
DIR	Direct development (i.e. no larval stage)
E	Eggs or egg capsule
FS	Free spawning, normally with external fertilization
J	Dispersing juvenile stage
L	Pelagic larval stage
LEC	Lecithotrophic (non-feeding) larva
PLK	Planktotrophic (feeding) larva
S	Spores (algal)

Much of the literature on larval dispersal provided data on the larval period (i.e. number of days in the plankton) rather than an actual dispersal distance. In the absence of information available on dispersal distance this has been estimated on the basis of data obtained from a dispersal and drift modelling exercise carried out by Roberts and others [2]. In general, the swimming ability of invertebrate larvae is weak (and they are very small) and is totally overwhelmed by water movements and so is not considered important in the estimation of dispersal distances.

The conversion factor we have used to convert dispersal periods into distances is based on dispersal by tidal currents plus, since wind driven water movement is important in UK waters, added wind-generated dispersal. In all the cases where the distance has been estimated in this way the confidence level has been reported as low. A summary of the conversions used is presented in Table 2-3.

Where there was no information available on larval period or dispersal distance, but evidence of larval type was available we have used the following estimate: lecithotrophic larval period 1 – 10 days and planktotrophic larval period 11 – 30 days. The dispersal distance data that has been estimated using this approach has been given a low confidence (coloured red) and has been denoted with a # symbol and noted at the foot of the table. The influence of actual location and the prevailing local conditions will need to be considered at the MPA planning phase.

Table 2-3 Conversion factors used to derive larval dispersal distances based on the work of Roberts and others [2]

DAYS IN PLANKTON	**< 1**	**1 - 10**	**11 - 30**	**31 - 50**	**> 50**
DISPERSAL DISTANCE (km)	**< 4**	**4 - 10**	**11 - 40**	**41 - 49**	**> 49**

To ensure that an MPA is self-seeding it needs to cover an area that will retain a significant proportion of the offspring produced by the target population. The area required will be determined by the mode of reproduction, the larval period and the distance travelled in that period. However, knowledge of larval dispersal is still uncertain. Not only is there a lack of accurate data on dispersal potential for most species, but also the complexities and uncertainties of the hydrodynamic processes affecting larval transport mean that local processes may be very important. Larvae will be dispersed by the prevailing water currents, caused by tidal motions, wind stress, atmospheric pressure gradients, wave motions, river out-flows and large scale oceanographic circulations. Water movements are therefore highly complex and site-specific and dispersal distances may need to be modified for individual locations as part of the MPA planning process.

In order to use dispersal as a principle in MPA design a precautionary approach has been adopted which assumes that larvae have an equal chance of being carried in any given direction. In most instances this distribution will be elliptical since reciprocal tides are usually the dominant force behind water movements. We have, however, for the purposes of this study used the dispersal distance to calculate the area, as a circle, that would encompass all larval dispersal. Since the majority of data that exists for marine species are given in ranges it would be impossible to ascertain the true mean and so the maximum distance given for larval dispersal potential has been used in this study. We have assumed the dispersal distance to be the diameter of the circle of dispersion (Figure 1).

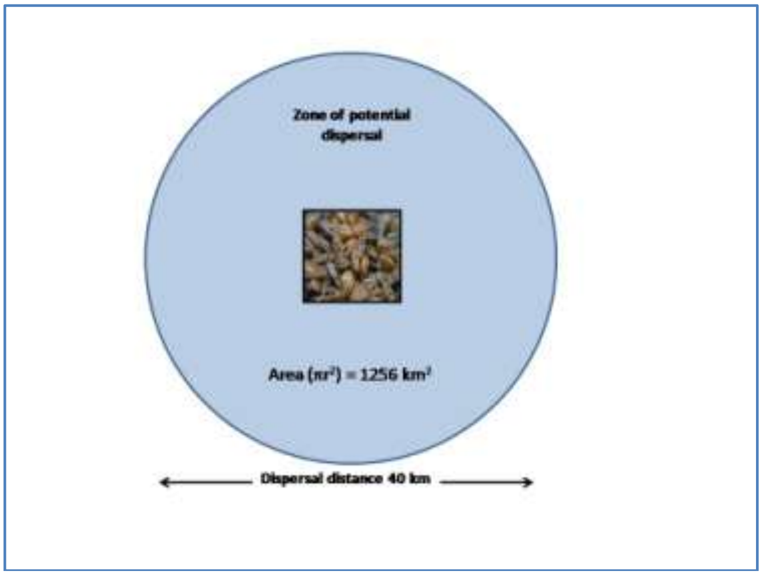

Figure 2-1 Calculation of MPA size based on self-seeding populations from dispersal distance

Spatial and temporal dynamics

The spatial and temporal dynamics of the species and habitats of conservation interest listed in Tables 1 and 2 have been reviewed as far as possible within the scope of this investigation. Unfortunately quantitative data on the spatial and temporal variability of species and communities was largely lacking from the literature but nevertheless, qualitative information has been included in the assessments whenever it was available.

3 Results

Species of conservation importance

Anotrichium barbatum (Bearded red seaweed)

The rhodophyte algae *Anotrichium barbatum* has rose-pink thalli that form tufts up to 60 mm high; the dichotomously branched filaments are flaccid and delicate. The distinguishing feature of this plant is the reproductive structures borne on whorls of trichoblasts (hair-like projections). *A. barbatum* is currently only known from one location in Cardigan Bay, Wales (Oyster Bank) where it attaches to gravel-pebble sized rocks and shells or is epiphytic on algae to a depth of 10 m [10, 11]. Recent observations of this alga in areas other than Cardigan Bay have been due to misidentification of the introduced species *A. furcellatum* [11]. Oyster Bank is a sheltered area with mud and sandy sediments, that is stabilized by pebbles and shells and is also home to other rare red algae including *Dermocorynus montagnei* and *Polysiphonia sanguinea* [10].

Anotrichium barbatum appears to have been subject to intense collection for the preparation of herbariums during the 19th century when it was found at several locations in the English Channel. Records of it in the last 20 years, however, are very sparse and it is therefore classed as nationally rare and thought to be in decline [12]. Oyster Bank is an SAC but the area is used by boat traffic and dredgers and the development of a harbour and water sports centre is planned for this site [10]. *A. barbatum* is thought to be at the most northerly limit of its distribution in Cardigan Bay and, as an isolated population that may have limited reproductive capability, it may not recover from environmental or anthropogenic impacts [10].

Anotrichium barbatum life history traits

- <u>Adult home range</u> - *A. barbatum* is a sessile alga [11].
- <u>Mode of reproduction</u> - the gametophytes (reproducing organs) of *A. barbatum* are dioecious or monoecious producing spermatangia, cystocarps or both. The tetrasporongia (meiospores) produce four spores by meiosis which are released from the cystocarp and settle to produce haploid plants. Spermatangia have been observed in August and cystocarps in May-October, while the tetrasporangia have been observed in June-October [10]. See Figure 3-1.

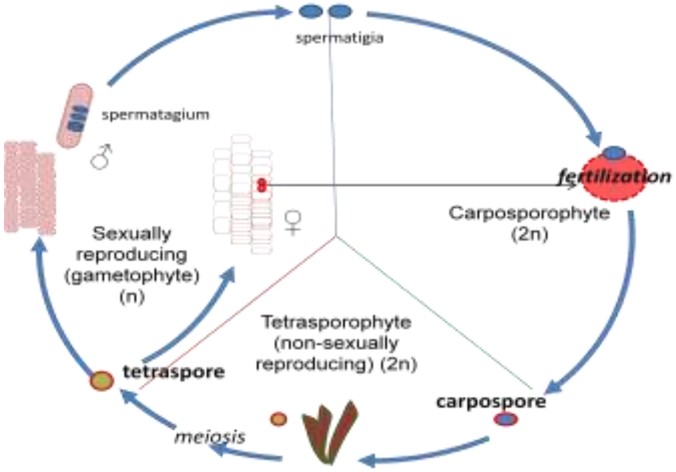

Figure Error! No text of specified style in document.**-2** Schematic of the generalised triphasic reproductive cycle of the red algae (Rhodophyta)

- Fecundity - not known.
- Dispersal - no direct observations on dispersal distance or information on the duration that propagules stay in the plankton have been recorded for this species.
- Recruitment - no information found.

Table 3-4 Summary of the viability assessment for *Anotrichium barbatum*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	AV and S	-	< 10	[11, 13]

Viability of *Anotrichum barbatum*

A. barbatum is a sessile alga and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this localised species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. With a maximum dispersal distance of 10 km an area **less than 79 km^2** has been estimated to be adequate for the protection of a self-seeding population of *A. barbatum.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. In addition, current knowledge indicates that the distribution of this species is restricted to a single location, protection of a large area would not be necessary. Until further research is carried out the best option would appear to be site specific management of the extent of this species in Cardigan Bay.

Cruoria cruoreaeformis (Crustose red seaweed)

Cruoria cruoreaeformis is a perennial non-calcareous encrusting alga that forms crusts about 200 µm thick on live maerl [14, 15]. Live crusts are bright red and appear velvety in texture [16]. Culture studies and observations indicate *C. cruoreaeformis* only grows on live maerl [17, 18]. It often occurs where other crustose red algae, such as *Peyssonnelia* spp., are also growing [15, 16].

Cruoria cruoreaeformis is classified as rare, although it can be locally abundant in suitable habitats [19-21]. *C. cruoraeformis* has only been recorded from maerl beds in the UK and, less frequently from gravel beds elsewhere [17, 19].

Cruoria cruoreaeformis life history traits

- Adult home range - *C. cruoreaeformis* is a sessile, photosynthetic alga [15].
- Mode of reproduction - reproduction in *C. cruoreaeformis* can be tetrasporophyte (haploid reproducing phase) or gametophyte (diploid reproducing phase), which are isomorphic [15]. Gametophytes are monoecious and bear carposporophytes [15]. Tetraspores (meiospores) are produced in the tetrasprorangium by meiosis and are released continuously; they will settle and grow close to the mature crusts [15]. See Figure 3-1.
- Fecundity - no information found.
- Dispersal - dispersal is limited as spores settle close to the parent plant [15].
- Recruitment - no information found.

Table 3-5 Summary of the viability assessment for *Cruoria cruoreaeformis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	AV and S	-	< 1	[13, 20-22]

Viability of *Cruoria cruoreaeformis*

C. cruoreaeformis is a sessile alga and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. With a dispersal distance less than 1 km an area **less than 0.8 km^2** has been estimated to be adequate for the protection of a self-seeding population of *C. cruoreaeformis.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. Since *C. cruoreaeformis* is thought to only grow on live maerl the protection of maerl habitats will be central to the conservation of this species.

Dermocorynus montagnei (Red seaweed)

Synonym: *Grateloupia montagnei* [23]

Dermocorynus montagnei is an encrusting non-calcareous rhodophyte, which displays small (2mm) papillae. The crusts are brownish-red and the papillae have a purple tinge to them [15, 24]. *Dermocorynus* crusts often cover small stones and have an irregular outline.

D. montagnei is found exclusively on small (5-10 mm) mobile pebbles and fragments of maerl in subtidal, shallow inlets and bays [23, 25, 26]. *D. montagnei* is considered rare and probably under-recorded mainly due to its size and restricted habitat [20]. *D. montagnei* is strongly associated with maerl beds and is often found attached to maerl fragments [24].

Dermocorynus montagnei life history traits

- Adult home range - *D. montagnei* is a non-migratory, crustose seaweed [24].
- Mode of reproduction - The gametophyte can be tetrasporangial (haploid reproducing phase) or gametangial (diploid reproducing phase) [23, 27]. Small erect papilli arise from the crust and reproductive organs (spermatangia and carposporangial) develop when the papilli are around 500 µm long. Fertilization occurs once the functioning male and female gamete fuse and enter the carpogonium. Carpospores germinate and spores are released to settle on suitable substrata where cells divide to form a growing disc. Culture experiments by Guiry and Maggs [24] found papilli started to form at 104 days post-settlement. At around 180 days post-settlement papilli reached 1mm long and started to release tetraspores (meiospores). See Figure 3-1..
- Fecundity - no information
- Dispersal - Spores are non flagellate and dispersal is thought to be limited [24] but no direct measurements are available.
- Recruitment - no information.

Table 3-6 Summary of the viability assessment for *Dermocorynus montagnei*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (DAYS)	(km)	REFERENCES
0	-	AV and S	-	< 1	[13, 20, 26]

Viability of *Dermocorynus montagnei*

D. montagnei is a sessile alga and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. With a dispersal distance less than 1 km an area **less than 0.8 km^2** has been estimated to be adequate for the protection of a self-seeding population of *D. montagnei.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. Since *D. montagnei* is associated with live maerl the protection of maerl habitats will be central to the conservation of this species.

Lithothamnion corallioides (Coral maerl)

Lithothamnion corallioides is a non-jointed coralline red algae known to exist in two forms; a crustose form that attaches to substrata such as pebbles, and as free-living rhodoliths, which can form extensive maerl beds. In the UK *Lithothamnion corallioides* is predominantly found in its free-living form [19, 28]. Maerl are slow-growing (0.4-1mm/yr) and some beds in Europe are thought to be over 8000 years old [19, 29]. *L. corallioides* exhibits a more limited range than another important UK species, *Phymatolithon calcareum* which is able to grow in more sheltered environments [19]. *L. corallioides* can be epilithic growing on the surfaces of pebbles and rocks. *L. corallioides* may also form beds of live and dead calcareous thalli (individual branches), which interlock creating their own complex habitats (maerl beds). These beds support high functional and taxonomic diversity [19, 30].

Lithothamnion corallioides, in its free-living form, is present on sandy-mud or silty sediments in sheltered bays and estuaries. Extensive maerl beds are only found in areas with moderate to strong bottom-currents but where there is little wave action [19, 28, 31]. This species is capable of photosynthesis in relatively low light conditions, although turbidity remains a limiting factor controlling its distribution. In the UK *L. corallioides* is found at a range of depths up to 30 m, but is found in greater density at depths of 5-10 m, although it has been recorded at depths exceeding 200 m in the Azores where light is able to penetrate [32, 33].

The BIOMAERL project [34] found maerl beds support a wide range of other marine species including some that are seemingly obligate to the maerl habitat, such as the red algae *Cruoria cruoreaeformis* [17] that are considered rare.

The habitat provided by maerl constitutes important nursery and feeding grounds for fish species (including cod, *Gadhus morhua,* and pollock, *Pollachius pollachius*) [35] and there is evidence that they provide important refugia for bivalve brood stocks and can improve productivity [35-37].

L. corallioides is sensitive to anthropogenic stressors, such as dredging and pollution. Recovery in this species is low due to its slow growth and low recruitment rates [38]. Maerl is a slow growing, long lived algae that is considered a non-renewable resource in areas where it is extracted [39]. Experiments have shown flumes of dredge spoil can reduce primary productivity by up to 70% [33, 40], severely damaging maerl communities. Experimental dredging in an area of the Clyde Sea revealed recovery was minimal, even in the fourth year of post-impact monitoring [37].

Lithothamnion corallioides life history traits

- Home range of adult - sessile in the UK [19, 41].
- Mode of reproduction - crustose algae form erect branches, which break off and grow as free-living maerl thalli. In the UK crustose forms of *L. corallioides* are extremely rare and vegetative reproduction is therefore the main or only form of reproduction [19, 42, 43].
- Fecundity - no information found but assumed to be low as sexual reproduction rare.
- Dispersal - vegetative reproduction restricts the ability of maerl to re-colonise and disperse [19].
- Recruitment - thought to be low [38]. Populations are self-sustaining, therefore removing and damaging areas of maerl can lead to unviable populations [37].

Table 3-7 Summary of the viability assessment for *Lithothamnion corallioides*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	AV	0	< 1	[19, 43, 44]

Viability of *Lithothamnion corallioides*

L. corallioides is a sessile alga and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. With a dispersal distance less than 1 km, an area **less than 0.8 km^2** has been estimated to be adequate for the protection of a self-seeding population of *L. corallioides.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. In addition, for such heavily exploited and vulnerable habitats the minimum viable area may be more realistically defined as the extent of habitat remaining plus adjacent areas of suitable habitat to allow for recovery.

Padina pavonica (Peacock's tail)

Padina pavonica is a lightly-calcareous brown algae that has a distinctive fan-shaped frond, which grows into a funnel. Green and brown bands are conspicuous on the outside of the frond, while the inner frond is green [45]. Hair-like projections are found on the surface of the thallus, which grows in concentric bands from superficial cells [46]. Liddle [47] described a high degree of plasticity in the morphology and growth of *P. pavonica*. The presence of encrusting coralline algae has been suggested to enhance colonization of *P. pavonica* [48].

P. pavonica is considered nationally rare/scarce and may be sensitive to climate change [49]. However increased temperatures may initiate gametophyte production and help distribute the species more widely in the UK [50].

Padina pavonica life history traits

- Adult home range - *P. pavonica* is a sessile, photosynthetic alga [45].
- Mode of reproduction - *P. pavonica* exhibits alternating haploid and diploid generations. Sexually reproducing plants are rarer than their tetrasprongial counterparts, especially in UK waters [47, 51]. It is uncertain what conditions would induce gametogenesis (sexual reproduction) although temperature may be of some importance as sexually reproducing plants have been observed in the Mediterranean. It is also unclear if this species is dioecious or monoecious [51]. Tetrasporangial sori (reproductive structures) divide by meiosis into four spores, which are released, settle and divide by meiosis [52].
- Fecundity - unknown
- Dispersal - unknown
- Recruitment - no information found

Table 3-8 Summary of the viability assessment for *Padina pavonica*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	S	-	< 10	[47, 51, 53]

Viability of *Padina pavonica*

P. pavonica is a sessile alga and therefore home range does not need to be considered in the design of a viable MPA for this species. There is still much uncertainty regarding the life history traits of this species, particularly with regard to the frequency of sexual reproduction and the dispersal of spores. Data pertaining to the minimum viable population are also completely lacking. With a dispersal distance up to 10 km an area **less than 79 km^2** has been estimated to be adequate for the protection of a self-seeding population of *P. pavonica.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. In the absence of adequate information a precautionary approach should be taken to protect this species at a range of MPA sizes and connectivity. Long-term monitoring of protected sites would be necessary to evaluate the appropriateness of the management strategy employed.

Phymatolithon calcareum (Common maerl)

Phymatolithon calcareum is a non-jointed coralline red algae. It can occur attached to pebbles and other substrata in its crustose form, or as free-living rhodoliths which form maerl beds and provide their own complex habitat for other organisms. These beds can consist of live rhodoliths, dead maerl or a mixture of the two. *P. calcareum* is most likely encountered in its free-living form in the UK [19, 28, 38, 41]. Maerl are slow-growing (0.4-1mm/yr) and some beds in Europe are thought to be over 8000 years old [19, 29].

P. calcareum is found on clean gravel or coarse sand substrata and extensive maerl beds are found in areas where moderate to strong bottom-currents reduce siltation. *P. calcareum* is often found together with *Lithothamnion corallioides* but is found on more wave exposed areas [31, 38].

Maerl beds in general are found at a range of depths to 30 m in the UK, but are more commonly found between 5 and 10 m. In areas such as the Azores maerl species have been recorded to depths exceeding 200 m, where light can penetrate to these depths [33, 38].

Maerl beds support high functional and taxonomic diversity [17, 19] and many species, are thought to be endemic to the maerl bed habitat [15], several which are protected under the Bern Convention [28, 38]. Kamanos [54] found maerl beds form important habitats for commercially important fish species such as cod in terms of feeding and nursery areas and work by Hall-Spencer and Moore [37] showed maerl habitats increased the productivity of shellfish.

P. calcareum is considered a non - renewable resource as it is a slow growing, long lived species [39] and its reproductive strategy means it has low dispersal potential and recovery is inhibited [38].

***Phymatolithon calcareum* life history traits**

- Adult home range - *P. calcareum* is a sessile and photosynthetic organism [19].
- Mode of reproduction - No gametophytes of this species have been observed in UK waters so they are thought to only reproduce vegetatively [42].
- Fecundity - no information found.
- Dispersal - vegetative propagation means dispersal is very limited [44].
- Recruitment - no information found.

Table 3-9 Summary of the viability assessment for *Phymatolithon calcareum*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	V	0	0	[19, 43, 44]

Viability of *Phymatolithon calcareum*

P. calcareum is a sessile alga and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. The limited literature on this species suggests that dispersal only occurs through vegetative propagation and in the absence of adequate information a **precautionary approach** should be taken to protect this species.

***Armandia cirrhosa* (Lagoon sandworm)**

Armandia cirrhosa is a small (< 8mm long) burrowing saline lagoon polychaete worm that is known largely from the Mediterranean. Very little is known about its biology [55] and so the wider *Armandia* genus has been used to represent this species.

Armandia cirrhosa has only been recorded in a few lagoonal habitats in the UK, including Small Mouth Spit and East Fleet Sandbank in Portland Harbour, Dorset [56] Individuals acquired from the Dorset lagoons were found to inhabit muddy/sandy substrates although a preference for shingle-rich and gravelly substrates were described from Hampshire sites [57]. *A. cirrhosa* is thought to have disappeared from the Keyhaven-Lymington Lagoon in Hampshire due to habitat degradation [58].

***Armandia cirrhosa* life history traits**

- Adult home range - sedentary, burrow dwelling.
- Mode of reproduction - *Armandia* spp. are free spawning and exhibit high mortality after the spawning season [59].
- Fecundity - no information.
- Dispersal - species of the genus *Armandia*, including *A. brevis,* exhibit planktotrophic [60] larvae that have the potential to stay in the water column from three weeks to several months. During this time they go through a series of metamorphic (setiger) stages before settling and recruiting to the adult population [61]. They are thought to have a high dispersal potential of up to 1000 km [62, 63].
- Recruitment - not known.

Table 3-10 Summary of the viability assessment for *Armandia cirrhosa*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
< 1	47	*FS-L -PLK	*21 – up to several months	*15 -1000	[62, 63]

***Armandia** spp. as a proxy

Viability of *Armandia cirrhosa*

Armandia cirrhosa is a burrow dwelling polychaete and an MPA area of **less than 1 km^2** would be required to encompass its home range. There is very little reliable information on the dispersal potential of this species with estimates of dispersal potential between 15 and 1000 km and so estimates of the area required for a self-seeding population should be treated with caution. This species is only found in lagoons and since water movements are usually restricted in these environments it is likely the lagoon system itself would provide adequate protection for the persistence of this species. The area required to ensure the continued genetic viability of an *A. cirrhosa* population is estimated to be **47 m^2** and so it is possible that only part of a lagoon would be required for a viable *A. cirrhosa* MPA.

Alkmaria romijni (Tentacled lagoon worm)

Alkmaria romijni is a small (< 5 mm long) tube dwelling polychaete worm found in areas of sheltered muddy-mixed sediments, fine sand and soft substrate to depths of a few meters in brackish water and coastal lagoons. The tube, which lies within the top 1-2 cm of the sediment [55] is constructed of mud, faecal pellets and a thin transparent film encrusted with quartz grains and clay particles [64]. *A. romijni* is thought to have a wide salinity tolerance (4‰ - >25‰) [55, 65, 66]. *A. romijni* has been recorded at twenty-seven sites in the UK and is now thought to be more widespread than originally described [66]. JNCC have recommended a reduction in protection status under the Wildlife and Countryside Act (1981), whilst maintaining protection of the lagoon habitat [67].

Cardose et al. [68] found that an increase in *Enteromorpha spp*. caused by eutrophication can significantly reduce the biomass of *A. romijni*. Recovery of the *A. romijni* population was seen after management of the Portuguese lagoon [69].

Alkmaria romijni life history traits

- <u>Adult home range</u> - sessile tube dwelling deposit feeder [65].
- <u>Mode of reproduction</u> - the larvae of *A. romijni* is incubated in the maternal tube for 12 days before release as a juvenile. Total larval development lasts 3 months [70].
- <u>Fecundity</u> - unknown.
- <u>Dispersal</u> - the juvenile is free living and non-feeding on the surface of the sediment and will develop its own tube within 20 days. During this time the juveniles may disperse widely [70, 71].
- <u>Recruitment</u> - not known.

Table 3-11 Summary of the viability assessment for *Alkmaria romijni*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	BR–DIR-J	20	10-100	[70-72]

Viability of *Alkmaria romijni*

As a sessile tube dweller the home range does not need to be considered in the design of a viable MPA for *A. romijni*. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. With a maximum dispersal distance of 100 km an area of **7854 km^2** has been estimated to be adequate for the protection of a self-seeding population of *A. romijni*. However, since the distribution of this species is restricted to lagoons systems it is likely that a significant proportion of the larvae would be retained and that a self-seeding population will be adequately protected by the lagoon itself.

Gobius cobitis (Giant goby)

The Giant goby *Gobius cobitis* has a deep body with a short tail stalk and can reach a total length of 27 cm [45]. It has a speckled appearance that is pale to olive brown with darker patches on the lower half of the body although males will appear darker during the breeding season. *G. cobitis* is found in channels and rock pools within sheltered intertidal shores, particularly in areas of mixed substrata, often with a freshwater input [73-76]. They have a bottom-dwelling habit and can be gregarious [77].

G. cobitis feeds on small amphipods, insects and their larvae and a high proportion of green algae (*Ulva* spp.) [75]. Other intertidal fish assemblages (such as blenniidae) will have a profound effect on the distribution of Gobiidae across their local habitat [78, 79]. Due to its residency in the intertidal area it is thought to be under pressure from coastal development [73].

Gobius cobitis life history traits

- <u>Adult home range</u> - this species is mobile and will utilize different microhabitats in the intertidal area at low and high tide [78].
- <u>Mode of reproduction</u> - the breeding season is between May - June in the British Isles and earlier in Europe [74]. Males show territorial behaviour at nest sites prior to and during nesting when they will fan eggs [73, 74, 76]. Male and female courtship behaviour precedes spawning and fertilization of eggs at the nest site, a process which can take up to 10 hrs. Fertilized eggs are attached to the underside of rocks and boulders in channels and tide pools by threads [73].
- <u>Fecundity</u> - sexual maturity is reached within 2-3 years and females lay two clutches per year [74].
- <u>Dispersal</u> - eggs hatch 22-24 days after spawning releasing a planktonic larvae that gradually settles on the substrate as a fully benthic juvenile around 35 days after hatching. They are thought to remain in the intertidal area thereafter [74, 76] and it takes a further 9 days for the juvenile to develop into the adult stage.
- <u>Recruitment</u> - juveniles move out of the smaller high intertidal pools to larger more complex habitats at the end of recruitment [80] while adults move to deep channels that are permanently linked with the sea [78].

Table 3-12 Summary of the viability assessment for *Gobius cobitis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
1-10 km	-	Spawn (Embryos attached at nest site)-J	35	40-49	[74, 76]

Viability of *Gobius cobitis*

An area of **1 km^2- 10 km^2** would be required to protect the home range of *G. cobitis* although it is not currently known if an area of this size would contain adequate genetic variability to ensure the persistence of this species. *G. cobitis* is reported to have a dispersal potential between 40 and 49 km and so a much larger MPA, **1257-1886 km^2** would be necessary to protect a self-seeding population. It is likely that a series of connected MPAs would be more appropriate for the conservation of this species. Since *G. cobitis* occurs in only restricted habitats some consideration should be given to the protection of sheltered intertidal shores with mixed substrata, in areas where the species is known to occur.

Gobius couchi (Couch's goby)

Gobius couchi is typically brown with darker brown patches along the lateral line and one positioned on the pectoral fins [81]. This species is thought to have longevity of up to 10 years [82]s. There is a lack of information on the status and reproduction of this species [83]. *Gobious couchi* is an intertidal epibenthic member of the Gobiidae that lives in rockpools and crevices with a complex habitat of rocks and boulders, with some degree of algal cover and sand/broken shell substrate and a depth range of 2.5-14 meters [84, 85]. They exhibit a preference for pools with *Enteromorpha* and other filamentous green algae and are often found on the high shore [82]. *G. couchi* have been associated with a range of microhabitats including sand, rock, mud and shell substrates in the Mediterranean [86].

G. couchi utilizes various algal species including *Ulva* spp. for food and vegetative cover which is particularly important during the breeding season [82]. They feed on a variety of small amphipods, gastropods, bivalves, Protozoa, polycheates, oligocheates as well as insects and their larvae [82, 87]. *G. couchi* is considered one of the rarer gobies and has a localised distribution in the UK, although this may be due to misidentification [86, 88]. As a resident of the intertidal area, which is vulnerable to anthropogenic and natural changes, this species is sensitive and thought to be in decline. It is considered to be of global importance due to its vulnerability, but this is mainly due to lack of information [83].

Gobius couchi life history traits

- Adult home range - *G. couchi* is a mobile (swimming) species that is not known to migrate [84, 87].
- Mode of reproduction - as with other Gobiidae, males entice females to spawn on male nest and then fertilize eggs. Territorial males guard nest sites and fan eggs once fertilized [73, 87]. Broods are laid on the underside of rocks and guarded by the male. These may include two broods possibly from different females [82]. *G. couchi* is thought to spawn in the spring [89].
- Fecundity - no information found.
- Dispersal - once hatched the juveniles are planktonic before recruiting to the benthos. Juveniles will stay within the intertidal zone and there is probably a degree of partitioning

on the shore between adults and juveniles as with other Gobiidae [74, 80]. There is no information on the larval period and so the value for the congener *G. cobitis* is used.
- Recruitment - no information found.

Table 3-13 Summary of the viability assessment for *Gobius couchi*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
1-10 km	-	Spawn (Embryos attached at nest site)-J	35*	40-49	[74, 76]

Gobius cobitis

Viability of *Gobius couchi*

An area of **1 km^2- 10 km^2** would be required to protect the home range of *G. couchi* although it is not currently known if an area of this size would contain adequate genetic variability to ensure the persistence of this species. The dispersal potential of *G. couchi* is not reported in the literature but assuming it is similar to that of *G. cobitis* MPA, **1257-1886 km^2** would be necessary to protect a self-seeding population. It is likely that a series of connected MPAs would be more appropriate for the conservation of this species.

Hippocampus guttulatus (Long-snouted seahorse)

Hippocampus guttulatus are distinct from other seahorse species by way of a 'mane' of fleshy appendages that run from the head to the dorsal fin. Adults can reach heights of 150 mm and they live for 4.5 – 5.5 years [45, 90]. *H. guttulatus* is found in shallow inshore waters and littoral lagoons, associated with algae and seagrass beds (*Zostera* and *Posidonia*) but not exclusively [91]. This species prefers complex habitats with dense vegetation [92].

Hippocampus spp. exhibit monogamous mating, small brood size, narrow range, limited dispersal, a high degree of parental care and low population densities (0 – 0.7m^{-2}), suggesting that they are sensitive to disturbance [90, 93]. However they also exhibit short generation times and an early age of sexual maturity (120-129mm/0.85-0.95 years), implying rapid recovery under optimal conditions [90].

This species is habitat specific to beds of the eelgrass *Zostera* spp., which are declining and considered rare in European waters [92]. They are often caught as a by-catch by fishing vessels [94, 95] but are not usually traded [96].

Hippocampus guttulatus life history traits

- Adult home range - the home range of adults is between 0.005 – 67 m^2 (mean 12.1 m^2) and overlap [90, 93]. Site fidelity is thought to be higher in breeding pairs compared to juveniles and single animals [90].
- Mode of reproduction - sexes are separate and fertilization is internal. Females place eggs in the male's pouch where they are fertilized and brooded for 3-5 weeks [93]. Mating pairs are monogamous during breeding season, although instances of polygamy have been noted [93, 97].
- Fecundity - no information found.

- Dispersal - following development in the brood pouch, juveniles are planktonic immediately after birth for 6-8 weeks. They are fully recruited to the seagrass habitat at approximately 3 months [90, 93].
- Recruitment - no information found.

Table 3-14 Summary of the viability assessment for *Hippocampus guttulatus*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0.005 - 67 m^2	-	BR-J-PLK	42 - 56	>49	[90, 93]

Viability of *Hippocampus guttulatus*

An area of **0.005 m^2- 67 m^2** would be required to protect the home range of *H. guttulatus* although it is not currently known if an area of this size would contain adequate genetic variability to ensure the persistence of this species. The larvae of *H. guttulatus* are reported to have a long planktonic period and hence an MPA area **greater than 1886 km^2** would be necessary to protect a self-seeding population. However, this species is highly habitat specific, to eelgrass and dense aquatic vegetation, and so conservation of those specific habitats known to currently support seahorses should be considered. It is likely that a series of connected MPAs would be more appropriate for the conservation of this species.

Hippocampus hippocampus (Short-snouted seahorse)

Hippocampus hippocampus has the distinctive seahorse posture, with its head set at a right angle to the body. It exhibits a short (one third less then head length) up-turned snout and adults can reach 150 mm in height. Colouration can be brown, orange, purple or black, sometimes with small white spots [45]. *H. hippocampus* feeds on zooplankton and small crustaceans [98]. This species is found in shallow inshore waters and littoral lagoons often in *Zostera* and *Posidonia* beds. Curtis and Vincent [92] found *H. hippocampus* to be located in sparsely vegetated areas near seagrass beds. This acts to partition this species from *H. guttulatus* which have a common geographic range.

Hippocampus hippocampus shows life history characteristics (monogamous mating, small brood size, narrow range and limited dispersal, parental care, low density populations), that make it vulnerable to extinction.

Hippocampus hippocampus life history traits

- Adult home range - *H. hippocampus* has a home range of 0.7 – 18.1 m^2 (mean 7.8 m^2) and a high site fidelity [93]. Records of it in deeper water suggest it migrates to stable environments during the winter months [99] [99].
- Mode of reproduction - This species is gonochoristic and females place eggs in the male’s pouch where they are fertilized [93]. Mating pairs are monogamous during the breeding season, although instances of polygamy have been noted. The breeding season is April – October [93, 97].
- Fecundity - no information found.
- Dispersal - After release from the male brood pouch, juveniles stay in the plankton for 6-8 weeks before being recruited to the adult population [93].
- Recruitment - no information found.

Table 3-15 Summary of the viability assessment for *Hippocampus hippocampus*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0.7 – 18.1 m^2	-	BR-J-PLK	42 – 56	>49	[90, 94]

Viability of *Hippocampus hippocampus*

An area of **0.7 m^2- 18.1m^2** would be required to protect the home range of *H. hippocampus* although it is not currently known if an area of this size would contain adequate genetic variability to ensure the persistence of this species. The larvae of *H. hippocampus* are reported to have a long planktonic period and hence an MPA area **greater than 1886 km^2** would be necessary to protect a self-seeding population. However, this species is highly habitat specific, to eelgrass and dense aquatic vegetation, and so conservation of those specific habitats known to currently support seahorses should be considered. It is likely that a series of connected MPAs would be more appropriate for the conservation of this species.

Victorella pavida (Trembling sea mat)

Victorella pavida is a colonial bryozoan that forms a mat on submerged substrata such as stones and vegetation. Erect cylindrical zooids arise from a chitinous stolen and display a lophophore (feeding appendage) with eight tentacles [100].

V. pavida is currently only known to be present at one location in the UK; at Swanpool in Falmouth [101]. Swanpool is a dynamic brackish lagoon system, 8 ha in size that is isolated from the sea by a sand and shingle bar [102]. Salt water incursion is maintained by an outlet culvert [103] and during high water at spring tides may enter the lagoon over the top of the bar or may percolate through the bar. Freshwater input is via a seepage stream and through storm and roadside drains during heavy rainfall. Swanpool's salinity ranges from 3.1 ‰ to 26 ‰ and *V. pavida* is found throughout the pool [102]. *V. pavida* attaches to submerged stones, plants and artificial substrata [100, 104, 105]. *V. pavida* is often found on the submerged stems of the common reed *Phragmites australis*. This reed has declined in Swanpool due to spraying to control reed growth and encroachment of wet woodland, in particular Willow Carr [101].

The populations of *V. pavida* in Swanpool are isolated and limited dispersal occurs between colonies. Pollution, siltation, disturbance to the current salinity regime and the decline of *Phagmites australis* may all contribute to threaten this species [101].

Victorella pavida life history traits

- Adult home range - *V. pavida* is a sessile, filter feeder [100].
- Mode of reproduction - *V. pavida* produce hibernacula (resistant dormant propagules) in the autumn before the parent colony dies over the winter. The hibernacula are produced by zooids and germinate into new colonies under favourable conditions [104]. Dormancy may be triggered by a variety of abiotic and biotic factors [106], also see [100, 103] for reviews. Hibernacula are only viable short term (5 months in laboratory conditions) [104]. There is no evidence of sexual reproduction in the UK.
- Fecundity - no information found.
- Dispersal - the propagules of *V. pavida* stay attached to the parent colony so dispersal is limited. Longer distance dispersal will only arise if fragmentation occurs [104].
- Recruitment - no information found.

Table 3-16 Summary of the viability assessment for *Victorella pavida*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (DAYS)	LARVAL DISPERSAL (km)	REFERENCES
0	-	S	0	0	[103, 104]

Viability of *Victorella pavida*

V. pavida is a sessile bryozoan and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this localised species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. The literature on this species suggests that propagules stay attached to the parent colony so that dispersal is very limited. Since this species is endemic to only one location in the UK any conservation measures will need to be site based. In particular, the ecology of Swanpool should be maintained to protect the habitat and encourage reed growth which has declined due to spraying to control reed growth and encroachment of willow car.

Amphianthus dohrnii (Sea fan anemone)

Amphianthus dohrnii is a small anemone which grows up to 50 mm in diameter, but more usually 10 mm, and is adapted to living on gorgonians by wrapping its base around the branches. The tentacles are arranged in four or five cycles and the base is short [107]. It is often cream, pink, orange or red. *A. dohrnii* is often seen in dense aggregations [108]. It is found in sublittoral habitats below 15 m, where it attaches to the branches of organisms such as the seafans *Eunicella verrucosa* and *Swiftia pallida* (in Scotland) [108-110].

This species is considered rare and appears to be declining, and the anemone's preferred attachment site, the sea fans *E. verrucosa* and *S. pallida*, are also threatened [111, 112].

Amphianthus dohrnii life history traits

- Adult home range - *A. dohrnii* is a sedentary and non-migratory anemone [108].
- Mode of reproduction - the reproduction of *A. dohrnii* is thought to occur asexually by basal laceration, where the adult shuffles along the substrate leaving fragments of itself behind, which develop into new anemones [108]. There are no observations or reports of sexual reproduction for this species in the UK but when it does occur a planula larva, capable of dispersing, would be produced.
- Fecundity - no information.
- Dispersal - the dispersal potential of *A. dohrnii* is limited due to its method of reproduction [108].
- Recruitment - no information.

Table 3-17 Summary of the viability assessment for *Amphianthus dohrnii*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (DAYS)	LARVAL DISPERSAL (km)	REFERENCES
0	-	A	0	0	[108]

Viability of *Amphianthus dohrnii*

Amphianthus dohrnii is a sessile animal and therefore home range does not need to be considered in the design of a viable MPA for this species. Literature on this species suggests that its dispersal is very limited due to its mode of reproduction. There are large gaps in our knowledge of the biology and ecology of this localised species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking, without this information **a precautionary approach** to the protection of this species is recommended. *Amphianthus dohrnii's* preferred habitat is the seafans *Eunicella verrucosa* and *Swiftia pallida* although it is also known to attach to other rod-shaped substrata. Since these seafan species are also conservation priority species measures to protect them will also help to protect *A. dohrnii*.

Edwardsia ivelli (Ivell's sea anemone)

Edwardsia ivelli is a non-migratory burrowing anemone that has only been described from one location in West Sussex in 1975 [113]. Since then it has not been recorded and may be extinct [114]. Due to the lack of information on the habits and characteristics of this species, *E. timida,* another conservation priority species, has been allocated as a proxy species.

Manuel [113] described Widewater Lagoon in Sussex as a shallow (<1m), mixopolyhaline (15-30 ‰) lagoon with no seawater input. A dense algal mat covers the lagoon in summer and the sediment is soft mud with an organic content of 5-15% [113].

See *Edwardsia timida* for further information

Edwardsia timida (Timid burrowing anemone)

Edwardsia timida is a slender burrowing anemone that can reach 70 mm long and 5 mm in diameter. The tentacles (16-32) are arranged in three cycles [108]. The scapulus (column), disc and tentacles are translucent, often orange-pink, yellow or sometimes buff. The scapulus, and sometimes the tips of the tentacles, are ornamented with white streaks or spots [108, 115]. *E. timida* lives in intertidal to subtidal habitats [116] where there is clean stone, sand and gravel [49]. They can occur in abundance under certain conditions [108].

Edwardsia timida life history traits

- Adult home range - sessile
- Mode of reproduction - both viviparity and oviparity have been observed in this species. Eggs masses are brooded at the entrance of the anemone's burrow and hatch into ciliated planula larvae [108, 117].
- Fecundity - no information found.
- Dispersal - the larvae are lecithotrophic and will swim for approximately two months before settling and metamorphosing into the adult form [108].
- Recruitment - no information found.

Table 3-18 Summary of the viability assessment for *Edwardsia timida*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	BR-L-LEC	60	> 49	[49, 108, 113]

Viability of *Edwardsia timida*

E. timida is a sessile burrowing anemone and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **greater than 1886 km^2** has been estimated to be necessary for the protection of a self-seeding population of *E. timida.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. In addition, since the distribution of *Edwardsia* species is

Eunicella verrucosa (Pink sea fan)

Eunicella verrucosa is a branching gorgonian whose colonies are usually around 25 cm high, although colonies reaching 50 cm high have been recorded. Branches are white or pink and have a 'warty' appearance when the polyps are retracted [118]. *Eunicella verrucosa* is found in subtidal areas where it can attach to bedrock, large boulders and artificial substrata and also to rocky outcrops associated with coarse sediment [119]. It is most commonly found at depths of 10 – 100 m, though sightings in shallower areas have been recorded around Plymouth Sound [112]. This filter feeder prefers areas with light currents to which the colonies align themselves perpendicularly [108].

E. verrucosa increases habitat complexity, and acts as an attachment site for a small number of other organisms including the rare sea fan anemone, *Amphianthus dohrnii* [50]. The seafan nudibranch, *Tritonia nilsodhneri,* also has a close association with the seafan where it feeds and lays its egg coils. Dogfish and cuttlefish egg cases are sometimes seen attached to the pink sea fan by their tendrils [112, 120]. *E. verrucosa* is a slow growing, sensitive organism, that is nationally scarce and susceptible to damage and disease. It is also reported to have low recoverability from damage and disturbance [121].

Eunicella verrucosa life history traits

- Adult home range - sessile.
- Mode of reproduction - *E. verrucosa* is a gonochoristic species and an annual broadcast spawner [122] which has relatively large oocytes and spermeries that occur in large numbers, which indicates high reproductive energy expenditure. Reproductive success is dependent on several factors including water temperature, lunar phase, habitat availability and pre/post settlement mortality [123].
- Fecundity - no information found.
- Dispersal - a study of *E. verrucosa* populations in East Tennents Reef (Lyme Bay) and Skomer Bay MNR found gametes were released into the water column during Aug/Sep and fertilized externally. Larvae are thought to be short lived and to settle near the natal site. However, some colonization of sites several hundreds of meters from parent colonies, appear to have occurred and this will be dependent on favourable currents [121, 124] and some populations may be reproductively interdependent so isolating populations will reduce recruitment and suitable habitats over sufficient distances [123].
- Recruitment - over a five year study period at East Tennents Reef between 7 to 18 individuals recruited to the population a year in an area of 4 m^2 [123]. However, Hiscock [125] found that recruitment to the HMS *Scylla* in Plymouth took four years to recruit after the wreck was sunk despite individuals residing on rocky reefs only 50 m away.

Table 3-19 Summary of the viability assessment for *Eunicella verrucosa*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L-LEC	3 – 5	4 - 10	[121, 123]

Viability of *Eunicella verrucosa*

E. verrucosa is a sessile animal and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. With a dispersal distance up to 10 km an area **less than 79 km^2** has been estimated to be necessary for the protection of a self-seeding population of *E. verrucosa.* However, since the dispersal is reported to be important over different spatial scale this estimate should be treated with caution. More research (i.e. genetic studies) may help to identify the role and importance of interbreeding populations and may also help identify the areas where interbreeding populations (and favourable currents) occur to enable proper management and connectivity of these sites. Protection measures also need to consider the life-history traits of the rare species associated with it (such as *Amphianthus dohrnii*).

Funiculina quadrangularis (Tall sea pen)

Funiculina quadrangularis is a large elongate sea pen that can reach over 2 m in length [118]. *F. quadrangularis* is found in areas of fine muds from depths of, 20 m to over 2000 m [108] in sheltered, low energy environments such as sea lochs [126, 127]. *Asteronyx loveni*, a deep water brittle-star, often occurs in association with *F. quadrangularis*, which may be obligate. *Astacilla longicornis* (specialised crustacea) is also often found clinging to this species [128].

Eno [129] found that *F. quadrangularis* was disturbed from their attachment sites by fishing activity, especially trawlers for Norwegian lobsters (*Nephrops norvegicus*), although most individuals were able to reattach if the brittle stems were not broken [127, 130, 131].

Funiculina quadrangularis life history traits

- Adult home range - *F. quadrangularis* is non-migratory and it exhibits temporary attachment, if dislodged it can reattach itself to suitable substrate [128, 129].
- Mode of reproduction - *F. quadragularis* is a gonochristic species and a broadcast spawner. The oocytes and spermatocytes are expelled through the mouth of the polyp, mainly between October - January.
- Fecundity - high fecundity with around 50-2000 oocytes per 1 cm midsection. Oocytes are present all year in females with around 10% maturing for spawning [126].
- Dispersal - populations are thought to be self-sustaining [128] so dispersal is limited but no evidence of propagule dispersal period or distance is available for this species. In general sea pens have lecithotrophic larvae. The larval duration of the sea pen *Ptilosarcus guerneyi* is between 7 – 30 days, depending on the environmental conditions [132]. As local populations are probably self-seeding they will be vulnerable to local extinctions [126, 128].
- Recruitment - no information found.

Table 3-20 Summary of the viability assessment for *Funiculina quadrangularis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L-LEC	7-14*	4 - 40	[126, 132]

**Ptilosarcus guerneyi*

Viability of *Funiculina quadrangularis*

F. quadrangularis is a sessile animal and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **less than 1256 km^2** has been estimated to be necessary for the protection of a self-seeding population of *F. quadrangularis.* However, there is evidence that populations can be self-sustaining and so it is possible that this is an over-estimate of the area required.

Haliclystus auricula (a stalked jellyfish)

Haliclystus auricula is a funnel shaped stalked jellyfish, which attaches to algae and other substrates by an adhesive disk. It can reach heights of 60 mm and shows variable colouration from green to reddish-brown [45, 133]. *H. auricula* attaches to algae such as *Ulva* spp., *Ceramium fornicata* and *Cymogongrus fourcellatus* and is also found on gravel and sandy substrates [134]. In Chile the seasonality of abundance of *H. auricula* was positively correlated with algal availability [135]. This species feeds on a range of invertebrates and larvae including copepods, amphipods, fly larvae and ostracods [134].

Haliclystus auricula life history traits

- Adult home range - stalked jellyfish are sedentary and non migratory [133].
- Mode of reproduction - *H. auricula* are gonochoristic, gametes are expelled through the mouth and fertilization is external [136]. All stauromedusae are thought to be annuals [118].
- Fecundity - no information found.
- Dispersal - The planula larvae *Haliclystus* spp. hatch around 24 hours after fertilization and start to creep along the substrate by extension and retraction, one movement cycle takes about two minutes so dispersal is thought to be limited [136, 137]. The planula will continue creeping for 1-3 days before settling and metamorphosing into the adult form. Larvae will often settle in groups [136].
- Recruitment - no information found.

Table 3-21 Summary of the viability assessment for *Haliclystus auricula*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L (Crawling stage)	1-3 days*	< 0.5 km	[136-138]

**H.salpinx* and *H. stejnegeri*

Viablity of *Haliclystus auricular*

Haliclystus auricula is a sedentary animal and therefore home range does not need to be considered in the design of a viable MPA for this species. Literature on this species suggests that its dispersal is very limited since the larval phase only lasts for 24 hours. With a dispersal distance less than 0.5 km an MPA area of **less than 0.2 km^2** is therefore required to support a self-seeding population. There are large gaps in our knowledge of the biology and ecology of this localised species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking and so **a precautionary approach** to the protection of this species is recommended. The distribution appears to be fairly restricted with records from Pembrokeshire in Wales, the south-west coast, Northern Ireland, isolated records from Northumberland and the Shetland Isles and Orkney further north in Scotland.

Leptopsammia pruvoti (Sunset cup coral)

Leptopsammia pruvoti is a slow growing, long lived (40 -100 years) Mediterranean-Atlantic scleractinian (stony) coral that often lives in small groups of 10 to over 200 or as solitary individuals [139-141]. The polyps are bright yellow and often conceal the calcareous skeleton and may attain a height of 60 mm tall [108]. This anemone attaches to rock in caves, gullies and overhangs in the shallow sublittoral, to a depth of 40 m, where there are light water currents [108, 142].

Irving [140] lists several species that may negatively impact *L. pruvoti.* These include organisms such as the boring organisms *Phoronis hippocrepia* (horseshoe worm), the polychaete *Psuedopotamilla reniformis* and the burrowing bivalve *Hiatella arctica*, which may detach the cup coral from its attachment site. Once detached from their site *L. pruvoti* will eventually die. The epizooic barnacle, *Boscia anglica* is known to attach to the column and calyx of several coral species and increase feeding competition. There may also be incidental damage by grazers such as topshells and the wrasse *Labrus bergylta*.

Leptopsammia pruvoti life history traits

- Adult home range - sessile
- Mode of reproduction - *L. pruvoti* has gonochoristic polyps that reach sexual maturity at a size of around 3 mm. Spermeries and oocytes mature in around 24 months. The rate of gonad development increases from November - January and fertilization takes place in January - April, when the embryos are brooded in the female polyp's coelentric cavity. The planula larvae are released between May-June (in the Mediterranean) [139].
- Dispersal - the planula larvae of *Leptopsammia pruvoti* settle within 24 hours close to the natal coral [140, 143].
- Fecundity - *L. pruvoti* is thought to reproduce infrequently and shows low levels of recruitment in areas of the UK [140]. In the Mediterranean this species exhibits high fecundity and a short incubation period compared to other Dendrophylliid corals [139, 144, 145].
- Recruitment - populations from Lundy and the Isles of Scilly have been monitored over several years and recruitment to these populations in the 1980s and 1990s was reported to be minimal [140]. The northern extreme of *L. pruvoti's* range is Lundy Island and recruitment may be hindered by environmental conditions encumbering synchronous gamete production and release. In recent years however, this situation appears to have changed with good recruitment of new individuals observed at some monitoring sites at Lundy [146]. Initial genetic studies (Dr P. Watts et al. unpublished and work in progress) suggest that individuals in a colony are clones of each other and, together with the isolated nature of colonies of several hundred, suggest very localized recruitment so that

a viable colony size may be as small as 2-3 m^2 (personal communication K. Hiscock). It has been suggested that recruitment to these isolated populations in the south west of the UK may be reliant on periodic arrival of larvae from more southerly sites recruitment [50, 140, 147].

Table 3-22 Summary of the viability assessment for *Leptopsammia pruvoti*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	BR-L-LEC	1	<4	[140]

Viability of *Leptopsammia pruvoti*

Leptopsammia pruvoti is a sessile animal and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking and reproduction in the UK is poorly understood. With a dispersal distance less than 4 km an area **less than 13 km^2** has been estimated to be necessary for the protection of a self-seeding population of *L. pruvoti* although more recent research on recruitment suggests that this area may be considerably smaller. The dispersal distance has been given a low confidence this estimate should be treated with caution. The reproductive output of *Leptopsammia* in the UK appears to be poor because the species is at the northern limit of its distribution and long-term survival may be reliant on highly infrequent transport of larvae from southern populations in the Mediterranean.

Lucernariopis campanulata (a stalked jellyfish)

The stalked jellyfish *Lucernariopis campanulata* has a funnel-shaped bell that can reach 20 mm in height. This species exhibits a range of colouration including translucent, green, brown or red with 1-4 turquoise spots at the base of the funnel on the oral surface [118]. *L. campanulata* appears to have an annual life-cycle [148]. It can be found attached to algae and *Zostera* plants from the low intertidal and shallow sublittoral [118]. *L. campanulata* is often recorded attached to *Zostera* and the decline of this species in areas like Salcombe has been linked to the decline of the *Zostera* bed [149].

Lucernariopis campanulata life history traits

- Home range of adult -The stauromedusae are sedentary and non-migratory [133].
- Mode of reproduction - *L. campanulata* is gonochoristic and free spawning, sexual maturity is reached at half maximum size [149].
- Fecundity - no information found.
- Dispersal - The larvae of *Lucernariopsis* hatch approximately 24 hours after fertilization and start to creep along the substrate by extension and retraction, so dispersal is limited [136, 137]. The planula will continue creeping for 1-3 days before settling and metamorphosing into the adult form.
- Recruitment - no information found.

Table 3-23 Summary of the viability assessment for *Lucernariopis campanulata*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L (Crawling stage)	1-3 days	< 4 km	[136-138, 149]

Viability of *Lucernariopis campanulata*

Lucernariopis campanulata is a sedentary animal and home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **less than 13 km^2** has been estimated to be necessary for the protection of a self-seeding population of *L. campanulata. L. campanulata* is often recorded attached to *Zostera* and the decline of this species has been linked to the decline of seagrass beds, therefore incorporating the viability assessment of *Zostera* beds into any management strategy of *L. campanulata* is essential to the maintenance of this species.

Lucernariopis cruxmelitensis (a stalked jellyfish)

L. cruxmelitensis exhibits the typical umbrella shape of the stalked jellyfish (stauromedusae) attaching to algae with its oral disc. The body colour varies from light to dark maroon and sometimes shades of grey or brown are also present. The primary tentacles have been described as dark black-maroon and the nematocysts are bright which and arranged in the pattern of a Maltese cross [149]. Greater densities of *L. cruxmelitensis* occur in winter. It is therefore thought to be an annual as it is often absent during the height of summer [148, 149].

This species is found in the low intertidal and shallow sublittoral [118] and is often recorded attached to the fronds of algae such as *Chondrus*, *Gigartia*, *Ulva*, *Gracilaria*, *Fucellaria* and *Corallina*. When attached to *Corallina* it is perfectly camouflaged [148].

Lucernariopsis cruxmelitensis life history traits

- Adult home range - stauromedusae are sedentary and non-migratory [133].
- Mode of reproduction - The sexes are separate in *L. cruxmelitensis* and adults broadcast spawn when they reach half their maximum height [136, 149].
- Fecundity - no information found.
- Dispersal - as with all stauromedusae, the planula larvae and medusa do not swim, the planula creep along the substrate after hatching (approximately 24 hours after fertilization). This movement is facilitated by extension and retraction and takes about 2 min for one cycle to complete [136, 137]. The planula will continue creeping for 1-3 days before settling, often in groups, and metamorphosing into the adult form [136].
- Recruitment - no information found.

Table 3-24 Summary of the viability assessment for *Lucernariopis cruxmelitensis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L (Crawling stage)	1-3 days*	< 4 km	[136, 138]

**L.campanulata*

Viability of *Lucernariopsis cruxmelitensis*

Lucernariopis cruxmelitensis is a sedentary animal and home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **less than 13 km^2** has been estimated to be necessary for the protection of a self-seeding population of *L. cruxmelitensis.* However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. This species is not associated with a particular type of substratum or algae but the inclusion of large shallow areas of coastal waters, where algae are able to grow (i.e. to a depth of approximately 25 m) would ensure protection of suitable habitat for this species.

Nematostella vectensis (Starlet sea anemone)

Nematostella vectensis is a burrowing anemone that lives in soft mud and amongst submerged vegetation it can be identified by 14 – 16 long white-banded tentacles [55]. *N. vectensis* is found in brackish and saline ponds, creeks and sheltered estuaries down to depths of around 1 m, where they burrow, within muddy-fine sand sediments with high organic content [150-153]. The salinity tolerance of *N. vectensis* is 10-37 ‰ but they are found in areas where freshwater input other than rainfall is absent or low relative to seawater and where near-bottom flow rates are low [151].

N. vectensis is a sedentary carnivore feeding on copepods, insects, midge larvae, ostracods, hydrobiid snails, copepod egg masses etc. *N. vectensis* is prey for large shrimps and nudibranchs [150, 154]. The presence of macrophytes such as *Cheatomorpha* spp and *Ruppia* spp seem important to this anemone’s distribution [151].

Recent genetic evidence indicates that *N. vectensis* was introduced to England from its presumed native range in the north western Atlantic Ocean [155], probably via shipping traffic [156]. In the UK *N. vectensis* has a limited distribution and is thought to be vulnerable [151], largely due to the lack of sexual reproduction because of the absence of males in the UK. Populations in the Western Atlantic and Pacific, where males are found and sexual reproduction does take place, are abundant and widespread [150].

Nematostella vectensis life history traits

- <u>Adult home range</u> - sessile and non migratory
- <u>Mode of reproduction</u> - in the UK *N. vectensis* is thought to only reproduce asexually by fission or cleavage and there are no recorded males [151, 156, 157]. In areas outside the UK fertilization is external through broadcast spawning. Planulae larvae emerge 36-48 hours after fertilization and will swim with intermittent resting phases for seven days before settling and metamorphosing into juveniles. There is a short phase where

juveniles will have limited movement by 'gliding' which usually ceases when they reach 1 mm [157, 158].

- Fecundity - no information found.
- Dispersal - in the UK dispersal is limited due to the asexual reproductive strategy [151].
- Recruitment - no information found.

Table 3-25 Summary of the viability assessment for *Nematostella vectensis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	A	0	0	[155, 156]

Viability of *Nematostella vectensis*

Nematostella vectensis is a sessile anemone and therefore home range does not need to be considered in the design of a viable MPA for this species. Literature on this species suggests that its dispersal in the UK is very limited due to its mode of reproduction. Conditions in the UK are probably not suited to sexual reproduction but protection of the habitat this species is found in, typically saline lagoons and sheltered brackish areas, would at least help to ensure the short term persistence of this species. In the longer term the lack of sexual reproduction and consequent lack of genetic variability may render these populations vulnerable to changes in environmental conditions. Long term monitoring is required to determine if any sexual reproduction is taking place in any UK populations.

Pachycerianthus multiplicatus (Fireworks sea anemone)

The fireworks sea anemone, *Pachycerianthus multiplicatus*, is a large (up to 300 mm) tube dwelling anemone. It displays spectacular long tentacles (up to 180) that are white, often with brown banding. The tube can be up to 1 m long and is constructed from mucus, discharged nematocyst threads and foreign material [108].

In UK waters *P. multiplicatus* is only found in sheltered areas of West Scotland's sea lochs and is only associated with specific biotopes (CMU.SpMeg). These biotopes are characterised by soft fine muds in depths of over 15 m, where bioturbation may be present and burrows and mounds are prominent features of the seascape [159]. *P. multiplicatus* is restricted to eating plankton due to its weak nematocysts [160]. This species creates attachment sites for other, non specified, organisms [159]. Often found in association with crustacea such as *Pandalus* spp., *Lebbeus polaris* and *Spirontocaris liljeborgii* [160]. *P. multiplicatus* is rare and has a localised distribution [161].

Pachycerianthus multiplicatus life history traits

- Adult home range - *P. multiplicatus* is a sedentary anemone [108].
- Mode of reproduction - *P. multiplicatus* broadcast spawns and males release gametes first which stimulate the release of the female eggs [162].
- Fecundity - no information found.
- Dispersal - The larvae of *P. multiplicatus* are thought to be short-lived and demersal [163] therefore spending a few hours to a few days in the plankton and therefore dispersal is thought to be limited [162].
- Recruitment - no information found.

Table 3-26 Summary of the viability assessment for *Pachycerianthus multiplicatus*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L-LEC	Few hours to few days	0-7	[162, 163]

Viability of *Pachycerianthus multiplicatus*

Pachycerianthus multiplicatus is a sedentary anemone and home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **less than 38 km^2** has been estimated to be necessary for the protection of a self-seeding population of *P. multiplicatus.* However, it is likely that a series of connected MPAs would be more appropriate for the conservation of this species. Since the distribution of *P. multiplicatus* is highly site specific, to Scottish sea lochs, conservation measures to protect these habitats should be considered.

Swiftia pallida (Northern seafan)

Swiftia pallida is a gorgonian sea fan found only in Scottish Lochs. It can attain a height of 200 mm, although specimens of around 100 mm are more usual [164]. *S. pallida* can be found attached to rocks, boulders, shell and bedrock, where silt deposits are noticeable, in depths of 15-60 meters [108, 164]. The anemone *Amphianthus dohrnii,* which is considered rare and in decline, has a strong association with *Swiftia palllida* in Scottish waters [124]. The anthozoans, *Alcyonium glomeratum* and *Caryophyllia smithii* are also frequently associated with this species [164].

There is concern that if the water temperatures increase by 2 ^{o}C, it may initiate the decline of *S. pallida* from Scottish waters. This would also impact the rare anemone *Amphianthus dohrnii,* unless *S. pallida* is replaced by *E. verrucosa* [50, 124].

Swiftia pallida life history traits

- Adult home range - Gorgonians are sedentary with limited movement [108].
- Mode of reproduction - *S. pallida* annually broadcast spawns, the spawning cycle is probably temperature dependent [124].
- Fecundity - no information found.
- Dispersal - The larvae of *S. pallida* are thought to be lecithotrophic and have limited dispersal potential as populations seem to be self sustaining [124]. Very little information is available on the dispersal and recruitment of this species.
- Recruitment - no information found.

Table 3-27 Summary of the viability assessment for *Swiftia pallida*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L-LEC	Few hours to a day	< 4	[121]

Viability of *Swiftia pallida*

Swiftia pallida is a sedentary animal and home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **less than 13 km^2** has been estimated to be necessary for the protection of a self-seeding population of *S. pallida.* However, the very limited and site specific distribution of *Swiftia pallida* suggests that site based conservation measures would be most appropriate. Long term monitoring is necessary to determine the impact of climate change on sea temperatures and the impact on its viability.

Arrhis phyllonyx (a deep-sea amphipod)

Arrhis phyllonyx is a deep water suprabenthic (living above the substratum) amphipod [165]. It is up to 20 mm long, white with a pinkish tinge [166]. This amphipod is found at depths ranging from 10 - 2,465 m in temperatures of no more than 6.6 ^{o}C and can tolerate waters down to zero degrees in winter. It exhibits a preference for soft mud sediments but is also known on coarser sandy sediments in the Gulf of St. Lawrence [165, 166].

Arrhis phyllonyx life history traits

- Adult home range - vertical migrations show a nocturnal pattern and can be as much as 3-4 meters from the benthos and so some individuals may be carried away by water currents. However, amphipods are generally resident to an area so the adult dispersal distance has been estimated at 1 km. The season and diurnal patterns are not fully understood [165].
- Mode of reproduction - Sainte-Marie and Brunel [165] study of *A. phyllonyx* in the Gulf of St. Lawrence found breeding occurred once a year during October – November and both sexes became sexually mature in their second to third year. Males are thought to die after copulation and females die after they brood their young. Development of the young lasts 7-8 months and they are released from the marsupium between April and June [165, 167].
- Fecundity - no information found.
- Dispersal - no dispersing larval stage. The juvenile amphipods recruit to the adult population after release from the marsupium [168].
- Recruitment - no information found.

Table 3-28 Summary of the viability assessment for *Arrhis phyllonyx*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
1	-	BR-DIR	0	0	[165, 168]

Viability of *Arrhis phyllonyx*

The home range of this *A. phyllonyx* is estimated to be **1 km^2** and because this species undergoes direct development an MPA of this size would encompass the complete life-cycle of this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking, without this information **a precautionary approach** to the protection of this species is recommended.

Gammarus insensibilis (Lagoon shrimp)

Gammarus insensibilis is an amphipod shrimp considered a stenohaline marine lagoonal specialist [169]. *G. insensibilis* is a resident of lagoons and sheltered brackish water to depths of 2-3 meters. In the Mediterranean they have been recorded in fully marine environments down to depths of 15 meters, where the morphologically similar species *G. locusta* is absent [170]. The alga *Cheatomorpha linum* forms dense mats to which *G. insensibilis* is often found attached. Stomach content analysis has shown this alga to be an important food source for this amphipod [171]. *G. insensibilis* grazes on a variety of algae including the rhodophyte, *Gracilaria verrucosa* [172]. Populations have also been reported to be highly abundant in *Zostera* beds of the Mediterranean [173].

G. insensibilis plays host to a variety of trematode parasites, such as *Microphallus papillorobustus,* during part of the parasites life-cycle. Parasites can often manipulate the responses of their host and make them more vulnerable to predation [174, 175].

A reduction in the protection status of *G. insensibilis* under Schedule 5 of the Wildlife and Countryside Act (1981) has been proposed, as this species may be more widespread then originally thought. Saline lagoons are protected under the EU habitats directive and are under threat from pollution, drainage and coastal development [67].

Gammarus insensibilis life history traits

- Adult home range - amphipods are mobile but generally resident to an area
- Mode of reproduction - the males guard the females just before the female moults and eggs are fertilized then brooded by the female in the marsupium, for around 9-11 days [175, 176] although the length of the incubation stages are temperature dependent [171].
- Fecundity - in one brood 25-50 embryos can be incubated. Development of the juvenile lasts 4-5 months and reproductive output is higher during the winter months [177].
- Dispersal - juveniles of Gammeridean amphipods are generally directly recruited to the adult population once released from the marsupium [168].
- Recruitment - no information found

Table 3-29 Summary of the viability assessment for *Gammarus insensibilis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
<1	316*	BR – DIR	0	0	[171, 175, 176]

**Gammurus* spp.

Viability of *Gammarus insensibilis*

The home range of this *G. insensibilis* is estimated to be **1 km^2** and because this species undergoes direct development an MPA of this size would encompass its complete life-cycle. It has been estimated that an area of **316 m^2** is required to protect a genetically viable population of this *Gammurus spp* but until species specific population viability data become available this estimated should be treated with some caution.

Mitella pollicipes (Gooseneck barnacle)

Synonym: *Pollicipes pollicipes*

Mitella pollicipes is a stalked barnacle, up to 30 mm in length; that uses its peduncle (fleshy stalk) to attach to the substratum. The body is broad and short and exhibits five large plates at the top followed by rows of successively smaller triangular plates [45]. In some regions of Europe it is targeted commercially and mainly harvested for the Spanish market [178, 179]. *M. pollicipes* is internationally threatened, and management strategies have been set up in parts of Spain and Portugal to protect commercial stocks [179-181]. UK populations are less frequent and are not commercially exploited [182].

M. pollicipes is found on the lower rocky shore and subtidally, where there is a suitable hard substratum [45]. Aggregations of the gooseneck barnacle can also be found on the underside of boats and ships or attached to floating debris and marine turtles. The biomass and density of goose barnacles are considerably higher in areas of high wave energy [181]. Adults are often seen with algae, bryozoans and lamellibranchs attached to them [182]. Predators include sea birds such as gulls, *Nucella*, pagurid crabs and *Pisaster* spp. [182].

Mitella pollicipes life history traits

- Adult home range - *M. pollicipes* is able to move its peduncle but is largely sedentary and non-migratory [183].
- Mode of reproduction - *M. pollicipes* is a hermaphrodite, cross-fertilization is more apparent and the ability of this species to self-fertilize is contentious [183]. Fertilization is internal and functioning females brood larvae and release planktotrophic nauplii synchronously [182, 184]. Ova development mainly takes place during the warmest months and is temperature dependent [182]. Internal fertilization occurs after the functioning female releases pheromones to alert males of her ripeness, the functioning male releases a spermatophore into the mantle cavity where fertilization takes place [182]. Development continues within the mantle cavity and stage one nauplli are released after approximately 25 days [178, 182]. Nauplli are expelled up to 3 cm away from the adult [182]. Populations are thought to utilize larvae from a common pool, exhibiting a metapopulation dynamic. The hydrodynamics of an area is therefore important to recruitment [179, 185].
- Fecundity - In populations of South West Portugal the minimum size for the maturity of the female gonad is around 12.5 mm and brooding occurs during the spring and summer. Several non-continuous broods may occur in a season [183].
- Dispersal - The larvae are planktotrophic and go through seven development stages that takes around 11 - 24 days (at 15-24 ^{o}C) [182, 186]. The final stage, the cyprid, stops feeding and looks for suitable substrate on which to settle. It usually settles initially on the peduncle of an adult goose barnacle before moving to the substratum. Once settled the cyprid's will metamorphose into juveniles in approximately 8 days. Environmental cues are thought to be an important element of settlement and metamorphosis [186]. Estimates of larval dispersal for *Pollicipes polumerus* are 116-580 miles with current speeds of 0.1-0.5 knots [182]. The metamorphosed cyprid/juvenile stage will often cement to other barnacles and *Mytilus*.
- Recruitment - no information found.

Table 3-30 Summary of the viability assessment for *Mitella pollicipes*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	BR-L-PLK	11 – 24	10-40	[182, 186]

Viability of *Mitella pollicipes*

Mitella pollicipes is largely sedentary and therefore home range does not need to be considered in the design of a viable MPA for this species. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. An area **less than 1256 km^2** has been estimated to be necessary for the protection of a self-seeding population of *M. pollicipes.* Since the dispersal distance has been given a low confidence this estimate should be treated with caution. It is also likely that a series of connected MPAs would be more appropriate for the conservation of this species.

There is evidence from a **1.58 km^2** marine MPA in Gaztelugatxe in northern Spain that showed the density and biomass of *Mitella pollicipes* to be higher and the size of the individuals larger within the MPA compared with a population at an unprotected site. The site had been an MPA for five years but no data on the population prior to its designation are available [180].

Palinurus elephas (Spiny lobster/langouste)

The spiny lobster *Palinurus elephas* has a heavily armoured body with spines covering the carapace and on the antennal stalks. The carapace length can reach 500 mm [118]. In some areas, such as Cornwall, this species exhibits three colour morphs, sandy, brown and the ‘normal’ reddish-brown, which could be due to localized diets [187]. Individuals are thought to live for around 15 years [188].

P. elephas lives between the shore and depths of 200 m, although it is usually found between 5-70 m on rocky and coralline substrates [189]. The species use small caves and holes for protection [190]. Laboratory experiments indicate the size, shape and position of refuge holes are an important feature for maximum predatory protection [191]. Juveniles are often found in groups and inhabit rocky crevices, leaving at night to feed. Adults live in pairs, small groups or are solitary usually living over gravel beds under rocks/boulders [192]. *P. elephas* is a generalist, preying on hard-shelled bottom dwelling organisms such as crustaceans, echinoderms and molluscs [193, 194].

P. elephas is of commercial value in the Atlantic and Mediterranean [195]. In Cornwall intensive SCUBA fishing at the end of the 1960s eliminated the spiny lobster from shallow waters within seven years [187]. The increase in catch altered the demography of the population by removing a large proportion of the male population [187, 195]. A notable reduction in male carapace length was seen between 1963-1971 and 1997. Welsh populations have not shown a reduction in carapace length, which may be due to the artisanal nature of the fishery in the Pembrokeshire area [187, 195, 196].

Palinurus elephas life history traits

- Adult home range - daily movements are generally limited (< 2 km) but they undertake pre and post reproductive migration, offshore and onshore respectively. Tag-recapture studies indicate that adult movement during migration is less than 5 km although some individuals may move as far as 20 km in the Atlantic and up to 70 km in the Mediterranean [190]. Follesa et al. [197] [197] showed that within a Marine Protected Area this species showed high site fidelity and limited movement (less than 2 km outside the MPA zone in most cases). Sexually immature males and females travelled longer distances.

- Mode of reproduction - *P. elephas* displays a moult - mate cycle. Females and males move to deeper water to shelter before moulting. The moult takes 10-15 minutes and the new shell develops and hardens within 7-9 days. In waters around the UK females moult between July and September and males moult throughout the year [194]. Males deposit the spermatophore below the females' genital opening and fertilized eggs are released 5-10 days later [194]. Females reach sexual maturity at a carapace length of around 70 mm and breed once a year (Sep-Oct), while hatching takes place between May-July [194, 196]. Males copulate throughout the breeding season [198]. Larvae go through instar stages (I-VII) before metamorphosing into puerulli (post-larval stage) and settling [194, 198]. The puerulus is considered a juvenile lobster at approximately 2 cm long [198].
- Fecundity - between 30,000 and over 200,000 eggs are released but fecundity is low compared to other Palinurids, larvae are larger but reduced in numbers. Fecundity is positively correlated with female size [198].
- Dispersal - eggs hatch inshore and larvae are poor swimmers, but exhibit vertical migration [199]. In the Atlantic pelagic larvae stages take 10-12 months to develop [194]. The puerulli are found inshore and movement up until this stage is thought to be mainly governed by currents in coastal waters [190]. Puerulli are thought to swim occasionally in mid water but are not good swimmers and are thought to hide in crevices and amongst algae and so they are rarely seen [190, 194].
- Recruitment - no information found.

Table 3-31 Summary of the viability assessment for *Palinurus elephas*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (DAYS)	LARVAL DISPERSAL (km)	REFERENCES
2 - 20	-	BR-L-PLK	10 – 12 months	> 49	[190, 194]

Viability of *Palinurus elephas*

The spiny lobster has a large home range of up to **20 km^2** and a widely dispersing larval stage. The area needed to encompass the complete life cycle has been estimated to be **greater than 1886 km^2**. However, since the dispersal distance has been given a low confidence this estimate should be treated with caution. It is also likely that a series of connected MPAs would be more appropriate for the conservation of this species. There are large gaps in our knowledge of the biology and ecology of this species in particular, data pertaining to the minimum viable population are completely lacking but there is evidence from MPAs in other parts of the world.

A study conducted around the site of a no-take zone of **4 km^2** in the Mediterranean, using mark-recapture methods, found that survival rates within the MPA were higher than those outside, largely due to reduced fishing pressure [188]. Abundance increased within the MPA and in adjacent areas, suggesting a spillover effect [200]. The Columbretes Island Marine MPA in the Spanish Mediterranean is a larger example (**44 km^2**). Increases in abundance, biomass and size were recorded inside this MPA compared to outside, while a gradual increase in catch per unit effort outside the no take zone was noted over a 16 year period [200].

Gitanopsis bispinosa (Amphipod shrimp)

Gitanopsis bispinosa is a white amphipod, with light red beds, up to 6 mm in length [166]. It has only been recorded from a few localities in the North Sea [201]. It is usually found at depths of 40 -100 meters in areas of mud and sandy sediments [166].

Information on the biology and habit of this species is scarce. The Gammaridean amphipods exploit a range of microhabitats including benthic, epibenthic and pelagic and may also be tube dwelling [168]. It is therefore difficult to assign a life history strategy to this species. In general, amphipods are an important food source for fish and other species [202].

Gitanopsis bispinosa life history traits

- Adult home range - locally mobile but non-migratory [168].
- Mode of reproduction - epifaunal gammaridean amphipods do not have a larval phase but brood their young in a marsupium pouch [168].
- Fecundity - no information found.
- Dispersal - in general the young of gammaridean amphipods are recruited directly to the adult population after brooding [168].
- Recruitment - no information found.

Table 3-32 Summary of the viability assessment for *Gitanopsis bispinosa*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
<1	-	BR-DIR	0	0	[168]

Viability of *Gitanopsis bispinosa*

There is no specific information about the home range or life history of this species and so the only evidence comes from a general understanding of amphipod traits. Amphipods are mobile but generally resident to an area and there is no dispersal stage because this species undergoes direct development. Home ranges are, therefore, likely to be small and an area **less than 1 km^2** has been estimated to be sufficient to protect the complete life cycle of this amphipod. There is no information available for the area required for a minimum viable population and little information on the actual distribution of this species so **a precautionary approach** to the conservation of this species, via protection of suitable habitat, is recommended.

Arctica islandica (Ocean quahog/Icelandic cyprine)

The bivalve *Arctica islandica* is an infaunal filter feeder that can reach sizes up to 120 mm in length [203]. It has prominent umbones and in large specimens the shell is dark green/brown or black, smaller specimens are chestnut brown [118]. *A. islandica* adults are slow growing (0-0.5mm/year in Whitsand Bay, UK) and growth rates are variable between geographical locations [204]. They are long lived species, one specimen was recorded to be 374 years old [205]. *Arctica islandica* is a commercially important species in North America [206] and has a range of predators including, haddock, ocean pout and various crustaceans. It is an especially important prey source for Baltic cod [207].

Dense beds of *A. islandica* are found below the surface of medium to fine grained sand, sandy-mud and silty-sand, they inhabit a wide depth range from 4 to over 400 m. This species is found in their greatest densities off the middle Atlantic Coast at depths of 35-75 m and have an optimal temperature range of 6-16^{o}C [208]. This species shows several life history traits that suggest it is sensitive to perturbations and has a low recovery potential, such as late age of sexual maturity, long-lived adults and genetically distinct populations [209].

Arctica Islandica life history traits

- Adult home range - *A. islandica* moves vertically in the sediment is resident and non-migratory [210].
- Mode of reproduction - The ocean quahog is a broadcast spawner and fertilization is external. Populations spawn all year round but spawning activity is concentrated during certain months, it is not entirely understood what environmental cues cause this [210]. The minimum age at sexual maturity is seven years.
- Fecundity - In Nova Scotia the mean female age at sexual maturity was 13.1 years and 12.5 years for males [205].
- Dispersal - The fertilized eggs hatch into trochophore larvae, which in turn develop into veligers (with a bivalve shell) and then develop a burrowing foot (pediveligers) [211, 212]. The development period lasts at least 55 days [211]. Juveniles settle within the adult grounds and populations are genetically distinct from each other [209].
- Recruitment - no information found.

Table 3-33 Summary of the viability assessment for *Arctica islandica*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (DAYS)	(km)	REFERENCES
0	-	FS-L-PLK	55	> 49	[211]

Viability of *Arctica islandica*

This bivalve *Arctica islandica* has a very small home range but widely dispersing larvae indicating an area encompassing the whole life-cycle, and a dispersal distance over 49 km, would need to very large (**greater than 1886 km^2**). However, since the larval dispersal distance has been identified as low confidence this may be an over estimate and it is likely that this species would be better protected by a series of smaller, connected MPAs. There is no information for the area required for a minimum viable population and further research is required to determine the area required for protection. Until such a time as these data become available **a precautionary approach** is recommended.

Atrina pectinata (Fan mussel)

Synonyms: *Pinna fragilis*, *P. borealis*, *P. pectinata*, *P. muricata*, *P. ingens*, *P. laevis*, *P. rudis*, *P. papyracea*, *P. rotundata* and *P. elegans* [213].

The fan mussel *Atrina pectinata* has a thin fan shaped shell, reaching lengths of 40-45 cm. The larger specimens are thought to be 10 -12 years old [214]. Organisms may be solitary or form small groups, although populations in deeper waters may be more dense [215]. *A. pectinata* is found buried within mud, sandy mud or silty sediments or attached to shell and stones by its byssus threads [213, 216]. It can be found on tidal flats and shallow subtidal ranges [217] to depths beyond 400 m [215]. Anecdotal evidence suggests populations are large in areas of strong currents and where the seabed slopes steeply [215]. Encrusting organisms may settle on *A. pectinata* and Hall-Spencer et al. [218] suggested they may help recruitment of other bivalves, such as scallops, to an area.

As a broadcast spawner with a sparse distribution *A. pectinata* has a low recovery potential [219, 220]. Butler et al. [219] hypothesized that these traits were off-set with long-lived adults and therefore, significant mortality rates within the adult (meta)populations would reduce the recoverability of this species. *A. pectinata* is considered rare and has been declining in the past 100 years [214]. *A. pectinata* often occurs where scallops are found so the species is subject to incidental fishing pressure by scallop dredgers, habitat disturbance and dredge spoil [216, 218]. Other threats include that from pollution, climate change and changes in current patterns that may affect recruitment [219].

Atrina pectinata life history traits

- Adult home range - *A. pectinata* is a resident infaunal suspension feeder that does not migrate [217].
- Mode of reproduction - *A. pectinata* is gonochoristic and a broadcast spawner, although hermaphroditic individuals have been noted in laboratory conditions [217]. Sexual maturity is reached between one and two years old [219].
- Fecundity - no information found.
- Dispersal - research on other species of fan mussel indicate that the fertilized larvae stay within the plankton for 7-10 days before settling. Although there is little published research anecodotal evidence suggests it is possible that *Atrina pectinata* in the UK settle from larvae produced in the Bay of Biscay, which are brought by winter currents sweeping northwards and eastwards (personal communication Keith Hiscock). However, it is possible This species has a metapopulation organization with regard to recruitment. The larvae are planktotrophic and have high dispersal potential [219].
- Recruitment - in shallower habitats individuals and groups are sparse and recruitment is probably low. However, populations in deeper waters have not been assessed and may provide a significant larval source [214].

Table 3-34 Summary of the viability assessment for *Atrina pectinata*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	-	FS-L-PLK	7 – 10	4 -10	[217, 219]

Viability of *Atrina pectinata*

The fan mussel has a very small home range but is reported to have a larval dispersal potential of 4-10 km. An area of **79 km^2** is therefore, required to protect a self-seeding population of this species. However, since the larval dispersal distance has been given a low confidence this may be an over estimate. It has been suggested that recruitment to shallow water populations is reliant on larvae from deep water populations [214] which means that the connectivity of these populations is highly important. Further investigations into the recruitment dynamics of these populations is needed in order to ascertain the best MPA design for this species. There is no information for the area required for a minimum viable population and further research is required to determine the area required for protection. Until such a time as these data become available **a precautionary approach** is recommended. Site specific conservation measures are also considered important as *Atrina pectinata* has a very restricted distribution.

Caecum armoricum (Defolin’s lagoon snail)

C. armoricum is a prosobranch snail of less than 1.5 mm long that appears to have a very limited distribution in the UK [55] or is under-recorded due to its small size and habitat [221]. It displays an unusual curved tube like shell that does not have any whorls or ridges, is open at one end and closed at the other by a septum. There is limited information on the lifestyle and habits of this species [55]. A proxy species (*Truncatella subsylindrica*) has therefore been chosen to represent its possible mode of reproduction.

In the UK *C. armoricum* was originally described from The Fleet Lagoon in Dorset, where around 100 specimens were found inhabiting the interstitial spaces between small (1-2 cm) pebbles [222, 223]. Seaward [222] speculated that this species would normally be found sublittorally but the percolation of springs into the Fleet allows it to occupy an intertidal habitat. It has recently been recorded at two other UK lagoons, a site at Pagham Harbour in Sussex and one at Lydd Ranges in Kent [221].

Caecum armoricum life history traits

- Adult home range - mobile, non migratory [223, 224].
- Mode of reproduction - *Truncatella subcylindrica* is a prosobranch that also inhabits lagoon systems and is interstitial between small pebbles in the intertidal zone. This species is oviparous, attaching its egg cases to detritus. The eggs hatch directly as small snails [225].
- Fecundity - no information found.
- Dispersal - no information found.
- Recruitment - no information found.

Table 3-35 Summary of the viability assessment for *Caecum armoricum*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
< 1	-	BR-DIR*	0	0	[221, 222, 225]

* *Truncatella subcylindrica*

Viability of *Caecum armoricum*

This species has a small home range and a mode of reproduction of direct development has been assumed from a similar prosobranch snail so a small area, **less than 1 km^2**, should encompass the whole life cycle. There is no information for the area required for a minimum viable population and further research is required to determine the area required for protection. Until such a time as these data become available **a precautionary approach** is recommended. The known distribution of this species is highly restricted and may be limited to saline lagoons. These populations have been shown to be viable, at least in the short term, and so site based conservation would certainly help ensure the continuation of this species. There is a clear need for further research to determine the mode of reproduction of this species.

Nucella lapillus (Dog whelk)

Nucella lapillus is a snail with an oval or conical shaped shell with a short spire and spiral ridges. The last whorl of the shell comprises around 80% of the total shell height of up to 40 mm [45, 118]. The colouration of the dog whelk is variable from white to brown, often exhibiting patterns such as banding; *N. lapillus* is common on rocky intertidal shores, where algal coverage is not excessive and salinity is not too low. This species can also be found sublittorally to depths of 40 m [118].

N. lapillus feeds on an assortment of annelids (spirorbids), molluscs (*Patella vulgata*, *Mytilus edulis, Ostrea edulis*) and barnacles (*Semibalanus balanoides, Balanus crenatus*) [226, 227]. As a predator *N. lapillus* is thought to have a strong regulatory effect on its prey populations and community structure [228].

Dog-whelks are susceptible to the loss of suitable habitat, pollution from synthetic compounds and oil spills [229].

Nucella lapillus life history traits

- Adult home range - recent studies on the gene flow in this species have highlighted that, even though adults usually do not move out of a 30 m range in their lifetime, some gene flow between population exits. This is probably through rafting and drifting with currents and movement by adults could be up to 100 km [230-232].
- Mode of reproduction - adults are gonochoristic, fertilization is internal and trochophore larvae develop directly from the egg capsule. *N. lapillus* will form dense non-feeding aggregations in moist and shady areas on the shore. The height of the breeding period is during spring and summer [226, 233].
- Fecundity - the female lays a single egg capsule containing around 600 eggs although only around 6% are fertilized, the rest will feed the juveniles [226, 233].
- Dispersal - the trochophore larvae takes four months to develop (seven in some areas) and once hatched will actively avoid bare rock, crawling into empty barnacle or mussel shells for protection [234].
- Recruitment - juvenile snails recruit to the local population.

Table 3-36 Summary of the viability assessment for *Nucella lapillus*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
< 1	833	BR - DIR	0	0	[234]

Viability of *Nucella lapillus*

This species has a small home range and an area of **1 km^2** would encompass the complete life cycle as this species undergoes direct development. The area required to support a minimum viable population of *Nucella lapillus* was estimated to be **500 m^2** but this is based on a single density record. A study of the density of *Nucella lapillus* in an area of intertidal sediment (where density is likely to be lower than many rocky shores) in the Humber estuary was 6 m^{-2} [227] giving an area of **833 m^2** that would contain the minimum viable population number for *Nucella lapillus* for most habitats. The low confidence assigned to this viability assessment means that **a precautionary approach** should be adopted until such a time that more reliable data become available or are identified.

Nucella lapillus is a very common and widespread species on rocky shores all around the UK coastline but is highly sensitive to local extinction because populations are reproductively isolated. *Nucella* is particularly sensitive to TBT many of these populations that were previously impacted have or are in the process of recovering [231, 235]. This shows that recovery from distant populations may be possible (via rafting and drifting of adults with water currents). A series of connected sites would therefore provide good contingency against the extinction of this species.

Ostrea edulis (Native/flat/European oyster)

Ostrea edulis has oval, pear-shaped or circular valves that can reach around 100 mm in diameter. The valves are rough and scaly with radiating ridges, the left valve is larger and deeply concave, while the smaller right valve is flatter. The shell ranges from off white to cream in colour, with blue – brown concentric rings, the meat is creamy beige to pale grey. Longevity can exceed 20 years [45].

Ostrea edulis inhabit rocky, mud, muddy-gravel and muddy-sand in shallow coastal and estuarine habitats that are highly productive. *O. edulis* attaches to rock, boulders, pebbles, shells and artificial substrates. Oyster beds form complex habitats for other organisms and they may also settle on the shells of living organisms such a *Mytilus edulis* and *Buccinum* [236].

Natural oyster beds in the North Sea and English Channel were extensive until the 19th century, when increased fishing pressure, cold winters and a parasitic disease lead to significant falls in population numbers. *Bonamia ostreae* is a parasite which can be particularly devastating to *Ostrea edulis* beds [237]. This devastating disease instigated the development of cultured populations of non-native species such as the Pacific oyster (*Crassostrea gigas*), that are less susceptible to disease and relatively faster growing. In addition the accidentally introduced slipper limpet, *Crepidula fornicata,* has put pressure on *O. edulis* populations in many areas by competing for space and food [238].

Ostrea edulis life history traits

- Adult home range - sessile.
- Mode of reproduction - the European oyster is a hermaphrodite that continually changes between female and male depending on temperature changes. The female keeps her eggs in the mantle cavity, while sperm is released in to the seawater by the functioning male. The sperm is inhaled into the female's mantle cavity with seawater and the eggs are fertilized. The eggs are brooded by the female for 7-10 days until they develop to the veliger stage, when they are released into the plankton [239, 240].
- Fecundity - increases with age up to year four producing up to 1.2 million eggs a year [240].
- Dispersal - the larvae of *O. edulis* go through four stages of development. The veliger is the initial swimming stage, followed by a veliconcha, which is when the umbo starts to develop and the larvae become less mobile. Once the larvae fully develop their umbo they start to develop eyespots and a functioning foot. At this point they are pediveligar and will move along the substrate with their foot before settling on a suitable substrate. The development of the larvae takes between 10-30 days to complete [239, 241].
- Recruitment - the larvae settle on a range of hard surfaces but adult oyster shells and areas of previous spatfall are particularly favoured [242, 243]. Recruitment is generally reported to be sporadic with temperature proposed as a major determinant of success with high settlement observed in warm summers [244].

Table 3-37 Summary of the viability assessment for *Ostrea edulis*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
0	500	FS-L-PLK	10-30	10-40	[239, 241]

Viability of *Ostrea edulis*

The native oyster is essentially sessile and so home range does not need to be considered in the design of a viable MPA. It has been estimated that the minimum area required to protect sufficient genetic variability to guard against extinction is **500 m^2** though this was based on a single density record and should be treated with considerable caution. *O. edulis* has a larval stage in its development and dispersal has been estimated to occur over 10-40km. The area required for a self-seeding population is therefore **less than 1256 km^2**. The low confidence ascribed to the larval dispersal of this species means that this area is likely to be inaccurate and further work on dispersion would be beneficial.

Paludinella littorina (Sea snail)

Paludinella littorina is a small (2 mm high) intertidal gastropod. The shell has 3-4 moderately convex whorls, is globose and semitransparent with a glossy finish. Colours are variable from off-white to orange brown but specimens are usually pale grey in the UK. Populations are found in low densities, typically 1- 20 individuals. There may be more than one species ascribed to the taxon *P. littorina* [245].

Paludinella littorina is found in caves of the upper shore and splash zone, often found sheltering in cavities and crevices. This species can also be found interstitially, where there are overhangs, gullies and ledges just above the water line, and buried in shingle, organic detritus and under embedded rock of lagoon systems [245]. *P. littorina* exhibits a preference for sites with prominent green and red algae coverage, including crustose red seaweeds [245].

The main threats to this species are through habitat degradation by coastal development. Major pollution events such as oil spills may also contaminate sites and impact populations. Many of the areas where *P. littorina* are found are already designated SAC's. Other areas where populations occur are remote therefore limiting disturbance in these places [245].

Paludinella littorina life history traits

- Adult home range - *P. littorina* has limited mobility
- Mode of reproduction - The eggs of *P. littorina* are probably laid in the fissures and crevices of caves and juveniles develop directly from the egg [245].
- Fecundity - Only a few eggs are thought to be laid at a time [245].
- Dispersal - *P. littorina* is thought to only lay a few eggs, exhibit direct development and therefore have limited dispersal potential. Populations are thought to be largely isolated and once local extinctions take place, the chances of recolonisation will be very low [245].
- Recruitment - no information found.

Table 3-38 Summary of the viability assessment for *Paludinella littorina*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
< 1	-	BR-DIR	0	< 0.5 km	[245]

Viability of *Paludinella littorina*

This species has a small home range and there is no dispersing larval stage so an area **less than 0.8 km^2** would adequately encompass the complete life-cycle, although the low confidence ascribed to these aspects of its life-history indicates that this estimate should be treated with caution. Populations are thought to be largely isolated and once local extinctions take place, the chances of recolonisation will be very low so several areas would be necessary to ensure the long term survival of this species. The area for a minimum viable population is not known. The recorded distribution of this species is limited to the Isle of Wight, the Fleet, North Devon, South Devon, Pembrokeshire, Cornwall and Isles of Scilly and so protection of areas of the wider habitat known to harbour this species would be effective.

Tenellia adspersa (Lagoon sea slug)

Tenellia adspersa is a nudibranch mollusc that can reach up to 9 mm in length, varying from pale yellow to dull brown with black speckling. The cerata (dorsal appendages) are arranged in groups of 2-3 along the body and the oral tentacles are small and lobed [118].

Tenellia adspersa lives mainly in brackish water down to salinities of 4 ‰ in harbours, estuaries, lagoons and canals [246] although it has been known to occur in a wide range of salinities [247]. *T. adspersa* is an intertidal species that is restricted to the shallow water zone and can be found amongst seaweeds and hydroids [247]. *T. adspersa* predates on hydroids such as *Cordylophora*, *Protohydra* and *Gonothyraea* [246].

The population of *T. adspersa* in The Fleet (Dorset) is known to fluctuate. This species exhibits a high degree of r-selection and a degree of plasticity in its reproductive strategies [246] which indicates it has a high recovery potential. *T. adspersa* is also known to tolerate wide ranges of salinity and temperature [247]. The main threats to this species are through degradation of its primary habitat, saline lagoons. Many of the lagoons where this species is found are currently designated SSSIs [248].

Tenellia adspersa life history traits

- Adult home range - *T. adspersa* is a small mobile organism that has a fairly restricted habitat and so home range is expected to be small.
- Mode of reproduction - *T. adspersa* are hermaphrodites and fertilization is internal, eggs masses are deposited externally up to 9 days after copulation [249]. Development shows a high degree of plasticity including direct, lecithotrophic and planktotrophic, which may be a function of environmental cues [246].
- Fecundity - *T. adspersa* has a 36 day life span, during this time it can produce up to five spawn masses a day and one individual can produce over 2000 spawn masses in its life time [250, 251].
- Dispersal - Eggs take around 68 – 120 hours to hatch; longer for eggs exhibiting direct development. Planktonic larvae can stay in the plankton around 120 hours before recruiting to the adult population and are fully mature 2-3 weeks after hatching [249].
- Recruitment - no information found.

Table 3-39 Summary of the viability assessment for *Tenellia adspersa*

HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
			(DAYS)	(km)	
< 1	-	DIR and BR-L-LEC or PLK	5	4 - 9.8	[246, 249]

Viability of *Tenellia adspersa*

This nudibranch has a very small home range but can potentially disperse up to 10 km. The area required to protect a self-seeding population is therefore estimated to be **less than 79 km^2**. There are large gaps in our knowledge of the biology and ecology of this species that should be addressed before specific management strategies can be implemented. In particular data pertaining to the minimum viable population are completely lacking. *Tenellia adspersa* shows a specific and limited distribution within the UK, notably in saline coastal lagoons the protection of these systems with therefore be paramount to the conservation of this species.

Habitats of conservation importance

Blue mussel beds: Intertidal *Mytilus edulis* beds on mixed and sandy sediments

Mytilus edulis creates a structurally complex habitat that provides refuge for a range of other flora and fauna not observed on surrounding sediments [252, 253]. Mussel beds form an often rare area of hard substrata in areas of soft sediment [254]. The bioturbation activity and the ability of mussels to selectively filter and process large quantities of suspended material can profoundly influence the dynamics of coastal and estuarine systems, with consequent implications for local patterns of diversity [255].

There is a wide range of encrusting and crevice dwelling organisms associated with mussel beds on sediment shores. Attachment is provided for algal species, such as *Fucus vesiculosus* that contribute to nutrient and detritus cycling [256]. Encrusting suspension feeders, involved in energy and element cycling, such as the barnacle *Semibalanus balanoides* are characteristic of mussel beds [4]. Mobile fauna includes the periwinkle, *Littorina littorea,* the grazing activities of which may control green algal growth (directly grazes the biofilm that contains sporelings [257, 258]). Mussel beds provide a specific habitat for mobile amphipods such as *Gammarus* spp. and *Corophium volutator* that may be absent from adjacent mud flats [252] and are, therefore, included as characteristic species. Infaunal polychaetes, such as *Nereis diversicolor*, that contribute to sediment processing are also characteristic of the infaunal community, although they are often less abundant than on neighbouring sediments [252, 259].

Mytilus edulis is, however, the key species as it forms the habitat and is responsible for most of the production even though the associated community can be highly diverse; for example, in the Wadden Sea mussels accounted for 93 % of total community production of a mussel bed [260].

Mussel beds show high spatial variability consisting of irregularly shaped patches of all sizes, with large patches made up of smaller patches and so forth down to a spatial scale smaller than centimetres [261, 262].

The temporal stability of mussel beds on sediment shores is also highly variable. Some beds are permanent, maintained by recruitment of spat in amongst adults whilst others are ephemeral. Natural damage and loss of sediment from mussel beds, sometimes involving hundreds of hectares, by storms and tidal surges are common in soft sediment mussel beds and form part of natural patch dynamic cycles [263]. In the Wadden Sea for example, a narrow mussel bed, approximately 1km long, in a shallow tidal bay was completely destroyed by storms in 1998 and had not re-established by 2005 [256]. Once dislodged, soft bottom mussel beds are often unlikely to re-establish because of the preference of larvae to settle on hard substrata or adult mussels or empty valves [264]. Persistence of mussel beds within the larger Wadden Sea study area (4.5km^2 of intertidal mudflats) was, however, maintained, probably due to the distribution of patches of varying size and at a range of different hydrodynamic regimes in the area so that not all beds were removed.

Mytilus edulis life history traits

- Adult home range - sessile (limited ability to move very short distances).
- Mode of reproduction - external fertilization, spawning seasonal but protracted in spring/summer months.
- Fecundity - high egg production which increases with age. A small female (~7mm) can produce 7-8 million eggs and in larger individuals as many as 40 million eggs may be produced (Thompson, 1979).

- Dispersal - larvae are planktotrophic and remain in the water column for several weeks (often longer when settlement is delayed due to lack of suitable substrate or low temperature). There may be a two stage settlement pattern, initially to filamentous substrates followed by a secondary drifting phase for selecting sites of permanent attachment [265]. There are observations, however, of direct settlement of *M. edulis* larvae on hard substrata without a secondary pelagic phase [266].
- Recruitment - larvae settle preferentially on adult beds but recruitment is often highly variable and sporadic and many populations have unpredictable pulses of settlement [255]. The distribution of larval settlement is also stochastic and within one tidal inlet spatfall may be successful on one bed and not on another. As larvae almost always seem to be in sufficient supply [up to 105 m-2 in Morecambe Bay: 267] (Bryant, 1999; Vooys, 1999), it is assumed that predation after settlement is an important factor for the success of spatfall. However, in some areas, persistent mussel beds can be maintained by sporadic and sometimes low levels of recruitment as was observed in mussel beds in the Exe estuary that were largely unaffected by large variations in spatfall between 1976 and 1983 [268]

Table 3-40 Summary of viability for blue mussel beds and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	(km)	REFERENCES
Mytilus edulis	**0**	**29**	**FS-L-PLK**	**20-30**	**40**	**[269]**
Corophium volutator	< 1	1	DIR	0	<1	[270-273]
Fucus vesiculosus	0		S	-	<10	[274]
Gammarus spp.	< 1	316	BR-DIR	0	0	[275]
Littorina littorea	< 1	214	BR-L-PLK	30	0-80	[44]
Nereis (Hediste) diversicolor	< 1	16	FS-DIR	0	0	[276] [277, 278]
Semibalanus balanoides	0	12	BR-L-PLK	14-21	25-40	[279]

MVP = minimum viable population

Viability of intertidal sediment *Mytilus edulis* beds

Evidence from the literature has identified mussel beds as small as **0.009 km^2** (largest in the study was **0.5 km^2**) which were seen to persist over a 13 year period [280]. However, even large mussel beds are vulnerable to dislodgement in a single natural disturbance event [256] Therefore, an important factor in determining the size required is the need for a high level of site heterogeneity. Mussel bed sites consisting of a range of different sized patches of different mussel density and size class structure along a gradient of exposures to wind, waves and tides would help to minimize one single disturbance event removing all mussels in an MPA. A high number of protected areas is also considered necessary given the vulnerability of intertidal sediment *Mytilus* beds to extreme weather events.

The estimated area required for a minimum viable population size of 5000 mussels is 29 m^2 and an area smaller than this is likely to be vulnerable to extinction because of a lack of genetic variation. However, for the whole community a larger area of **316 m^2**, based on the maximum value in Table 3-37, is required to protect genetic viability.

The area required for a self-seeding population of *Mytilus edulis*, taking into account the potential dispersal distance of *M. edulis* larvae estimated to be 40 km, would need to be in the order of **1256 km^2**. However, whilst dispersal distances can be very high the larvae are in good supply in the water column and so provided there is high connectivity, less than 40 km between sites, an area considerably smaller than this should ensure persistence. In addition, the habitat is intertidal and this will further limit the dispersal potential of the larvae and therefore, considerably reduce the area required for self-seeding.

One of the most important factors to ensure recruitment success is the presence of existing mussel shell which provides the key settlement substrate [281]. Thus, the continued presence of large adult beds should ensure that even spatially and temporally sporadic recruitment will be adequate for the long-term viability of sediment mussel beds.

Most of the characteristic species associated with mussel beds are either sessile or have small home ranges. The whole life cycle of those with direct development can be protected by very small areas but those with pelagic larvae cannot. However, most species seen in mussel beds are widespread. Protection of the mussel beds will confer protection on the resident species.

On the basis of the best available evidence at the present time the minimum area required to ensure viability of sediment blue mussel beds is between 29 m^2 and 9000 m^2 (i.e. the 0.009 km^2 mussel bed that persisted over 13 years). A number of replicate sites are required and they should be no more than 40 km apart. By placing them no more than 40 km apart there should be larval connectivity between sites, however, given the ubiquitous distribution of *Mytilus edulis* and the high supply of larvae in UK coastal waters this may not be necessary. Further research would be required to give more certainty to this element of the MPA design.

Carbonate mounds

Carbonate mounds are distinct elevations formed from the accumulated remains of cold-water corals, principally *Lophelia pertusa* and *Madrepora oculata* [282]. Mounds are typically covered in carbonate sands, muds and silts, coral rubble and thriving coral communities of *Lophelia pertusa* and *Madrepora oculata* are often, but not always, present [283]. The coral sediment veneer and dense live and dead coral framework significantly enhance biodiversity compared to surrounding areas [284]. The branching structure of dead coral underlying the live coral provides a large surface area for attachment [285-287] and the structural complexity of the reef provides refuge for a number of mobile organisms including crustaceans and fish [288]. The encrusting community is dominated by suspension feeders including: sponges (for example the deep-sea demosponge *Axinella* sp.), bryozoans, hydroids (*Sertularia* sp.), soft corals, ascidians (*Ciona intestinalis*), cerianthid anemones and caridean shrimp *Pandalus* spp. [287, 289].

Carbonate mound habitats are made up of different substrate types from coral debris and rubble to finer carbonate sediments, which are important for larval settlement for a range of species [283]. The coral debris also traps settling material between the coral thus protecting it from erosion [282]. The coral sediments are home to a diverse assemblage of encrusting organisms and infauna, in particular stylasterid corals, such as *Pliobothrus* sp., tube building serpulid polychaetes (*Serpula vermicularis*), infaunal eunicid worms (*Eunice* sp.) and the echiuran *Bonellia* sp. A number of bivalve species are also found, the most numerous of which are from the genus *Arca*, (also *Nucula* sp.) and the suspension feeding ophiuroid *Ophiactis balli* [285, 289, 290]. The direction of tube growth of the eunicid worm *Eunice* sp. was found to be important in determining the early growth of the reef-building coral species [289, 291]. and so this species has also been selected for the habitats assessment. There is also a range of mobile crustaceans such as *Munida rugosa*.

Carbonate mounds have only relatively recently been accessible to study and so knowledge of natural variability is limited. Coral habitats of this type are, however, known to have persisted at some sites for up to 9000 years in some cases [283, 292]. The reef-building coral *Lophelia pertusa* is known to be very slow growing, approximately 6 mm per year [293] and the extant reefs long-lived. Many are estimated to be several hundred years old [294]. Extensive carpets of dead corals or only small coral colonies living on carbonate mounds have been reported in some surveys [295] and have may been caused by natural variability in sedimentation, surface productivity or natural catastrophic events such as slope failures. Given the impact of bottom trawling in these areas [296], such changes in many areas can be attributed to fishing disturbance [297].

Cold-water corals *Lophelia pertusa* and *Madrepora oculata* – life history traits

- Adult home range - sessile.
- Mode of reproduction - individuals are known to be gonochoristic whilst there is some evidence for both asexual budding and sexual reproduction. Asexual budding appears to be particularly important and in some areas where there has been intensive bottom trawling, genetic diversity was low and no reproductive corals were observed. Inbreeding indices were also significant in many sites including South Rockall Trench and the Porcupine Seabight and may be due to spatially restricted effective gene flow and a predominance of self-recruitment of sexually produced larvae within subpopulations. There have been direct observations of planular settlement but genetic evidence indicates sexual reproduction is sporadic [289, 298, 299]. *L. pertusa* is gonochoristic with seasonal gamete production and a lecithotrophic larvae [300]. [301].
- Fecundity - unknown
- Dispersal - Although very little is known about the dispersal of cold-water corals there is good evidence of a dispersive planula larval stage for *Lophelia pertusa* from settlement on oil rigs in the North Sea [293, 302]. This, and the wide distribution of deep-water corals, indicates that the competency period of larvae is likely to be protracted [293, 301]. Although there is no observational or lab data to indicate how long the larvae of *L. pertusa* and *M. oculata* remain in the plankton [303]. Roberts [304] reports that an estimate of 6 - 8 weeks for larval competency in temperate corals (double that of tropical species) may be possible. *L. pertusa* and *M. oculata* are thought to spawn in the first few months of the year [300] possibly triggered by the distinct tidal cycles observed in the NE Atlantic margin [305]
- Recruitment - several reports of recent settlement were observed in surveys from the Porcupine Seabight [290] [306] and the Porcupine Bank [289]. *Lophelia pertusa* and *Madrepora oculata* are widely distributed in the NE Atlantic [306] indicating recruitment success may be high. The presence of cold-water corals in many areas has been correlated with the prevailing North Atlantic water currents. Recruitment success may therefore be determined by a mixture of location and hydrodynamics [293, 307].

Table 3-41 Summary of viability for carbonate mounds and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Lophelia pertusa	**0**		**A + L-PLK**	**42-56**	**>50**	**[293]**
Madrepora oculata *** *Lophelia***	**0**		**A + L-PLK**	**42-56**	**>50**	**[293]**
Arca spp.	0		FS-L			[308]
Axinella spp. *Deep sea sponges	0		A + FS-L-LEC	2	5	[309, 310]
Bonellia viridis	< 1		BR-L	0-7	0-10	[311] [312]
Ciona intestinalis	0	500	FS-L-LEC	0-6	10	[313] [314] [315] [316]
Eunice norvegicus	0		FS-L-PLK	11-30#	10-40#	[277]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
*Munida rugosa *Galathea*			BR-L			[320]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321] [322, 323] [324]
Ophiactis balli	< 1		FS-L-PLK	120-210	<50	[162, 325]
Pandalus spp.	< 1	500	BR-L-LEC	60-90	0-330	[162] [326] [327]
Serpula vermicularis	0		FS-L-PLK	6-60	>10	[328, 329]

dispersal period and distance has been inferred from larval type.

Viability of carbonate mounds

Deep water corals have an estimated dispersal distance of 50 km although there is still significant uncertainty. Thus, the area that would be required to protect the whole life-cycle of reef building corals (in the order of **1964 km^2**) far exceeds the actual extent of individual carbonate mounds and so a viability assessment of this nature is not deemed appropriate. It has not been possible to find data on the actual extent of carbonate mounds but clearly each mound is able to support a viable community (in the absence of human disturbance) and so site based conservation measures would be appropriate. This would also remove the practical difficulties of managing the protection of just part of a mound.

There is some evidence to suggest genetic exchange between carbonate mounds across very large distances and so connectivity appears to be high. However, damaged habitats may have reduced reproductive capacity and so protection of undisturbed carbonate mounds should be considered a priority.

Coastal saltmarsh

The saltmarsh plants are key structural plants which provide habitat and food for a range of organisms and are important in sediment deposition [330-332]. The plant species chosen for the habitat assessment are *Salicornia* spp. and *Suada* spp. which are important pioneer annual species and *Spartina* spp*.* (which includes the native *S. maritima, S.alterniflora* and the hybrid *S. anglica*) which are important colonising perennials. The Atlantic salt meadow plant *Puccinella maritima* is included because it is widely distributed, particularly on lower marshes.

The other marine species that are characteristic of saltmarsh habitats are the polychaetes *Nereis diversicolor,* the amphipod *Corophium volutator* and the mudsnail *Hydrobia ulvae.* These organisms often occur in high abundance providing an important food source for other organisms such as birds and fish. They and also play a role in sediment dynamics through sediment processing and bioturbation activities [273, 333, 334].

Saltmarshes are highly dynamic environments that are subject to the processes of erosion, accretion and progradation (seaward development from high sediment deposition). Predictable tidal cycles, at a range of temporal scales, affect submergence regimes and there is much variation between sites depending on elevation etc. Interactions between unpredictable meteorological conditions and tidal events can produce extreme environmental variations resulting in severe perturbations on saltmarsh ecosystems. Such occurrences can provide colonisation opportunities [335] and can result in changes in plant species composition [336] as well as more catastrophic reshaping of marsh morphology. A marsh can disappear very rapidly if there is a change in conditions and increased exposure to erosive forces. Marshes are therefore, naturally subject to cycles of expansion and erosion [337].

The Tollesbury realignment site in Essex is situated near the Blackwater estuary and encompasses an area of 21 ha (0.21 km^2). The salt-marsh site was successfully restored in 1995 after a 60 m sea defence breach allowed seawater to inundate an area that was formerly farmland [338]. The site has been monitored in terms of plant succession and invertebrate colonisation from 1995 to 2007 [339, 340]. By 2007 twenty one plant species had colonised 13 ha (0.13 km^2) of the Tollesbury site, these species included *Puccinella maritima*, which dominated the upper elevations and *Spartina anglica*, which dominated the lower along with *S. europaea* [339]. The invertebrate community of Tollesbury was found to be similar in terms of composition to that of a nearby marsh area, with only *Gammarus* spp. being notably absent from the realignment site [340].

In a study of a number of different locations Wolters and others [341] suggest that restoration sites should be at least 30 ha (0.3 km^2) in order to be able to harbour 50% or more of the target species. The best results are found for sites larger than 100 ha. It should be noted however, that the width of a site (i.e., the line perpendicular to the coastline) is likely to be more important than the length (i.e., the line parallel to the coastline), due to processes of zonation leading to higher species diversity.

Salt marsh plants life history traits

- Adult home range - non motile
- Mode of reproduction - flowering in saltmarsh plants is intermittent and sexual reproduction occurs rarely. Many saltmarsh plants, however, have the ability to spread by vegetative means, leading to the formation of clones which may be of considerable spatial extent (e.g. up to 10 m diameter in *S. anglica*).

- Fecundity - sexual reproduction and production of seeds is often limited in saltmarsh plants
- Dispersal - saltmarsh range extension and the successful establishment of new saltmarsh in managed realignment sites indicates the successful dispersal of saltmarsh plants. Although long distance dispersal, via ocean currents or birds, is often used to explain the cosmopolitan distribution of many saltmarsh plants, several studies show that dispersal is usually local [342, 343]. However, longer distance waterborne dispersal may be an important mechanism allowing colonisation of new sites within an estuarine system [330]. The role of vegetative propagules in dispersal is largely unknown.
- Recruitment - often determined by the proximity of existing saltmarsh and a local supply of seeds because dispersal is often local.

Table 3-42 Summary of viability for coastal saltmarsh and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Puccinella maritime	**0**		**AV + S**	**0-50**	**0->50**	**[344-346]**
***Salicornia* spp.**	**0**		**AV + S**	**0-50**	**0->50**	**[344-346]**
Spartina alterniflora	**0**		**AV + S**	**0-30**	**0->40**	**[344-346]**
Spartina anglica	**0**		**AV + S**	**0-50**	**0->50**	**[344-346]**
Spartina maritima	**0**		**AV + S**	**0-50**	**0->50**	**[344-346]**
Suaeda maratima	**0**		**AV + S**	**0-50**	**0->50**	**[344-346]**
Abra tenuis	< 1	26	DIR	0	0	[347]
Corophium volutator	< 1	1	DIR	0	<1	[270-273]
Eteone longa	< 1	95	FS-L-PLK	2-10	4-10	[277, 348]
Hydrobia ulvae	< 1	6	BR-L-PLK or DIR	20-30	0-40	[349]
Nereis (Hediste) diversicolor	< 1	16	FS-DIR	0	0	[277] [350]

Viability of coastal saltmarsh

The success and size of various saltmarsh restoration projects gives some guidance to the area that can sustain a viable community. At Tollesbury an area of 0.21 km^2 developed into a saltmarsh community comparable to that of natural communities. This restoration site was very close to existing saltmarsh habitat indicating that connectivity may be important. Realigned saltmarsh sites greater than 1 km^2 are reported to be more successful and could be considered the minimum area required for protection provided there was good connectivity. There is, however, some uncertainty about the dispersal distances of saltmarsh plants with potential for highly local (in the order of metres) and widespread dispersal (> 50 km) and so large MPAs, with high connectivity may be required.

Many of the species associated with saltmarsh habitats are found in very high densities and an area of 95 m^2 is the minimum size required for minimum viable population sizes of 5000 individuals. Several species also have either direct developing young or very short dispersing larvae so small MPA sizes would protect all the life cycle stages. There is no information, however, on the minimum viable area for saltmarsh plants.

Evidence suggests successful saltmarsh restoration sites of at least 1 km^2 are successful so this may be a useful proxy for the area required for a viable population. However, there may need to be good connectivity with other saltmarsh sites for this to be effective considering the reported limitations of sexual reproduction in UK populations.

Cold-water coral reefs

The deep-water coral *Lophelia pertusa* is a reef-builder that creates a three dimensionally complex habitat, providing space and refugia for a diverse community [351, 352]. Other coral species, such as *Madrepora oculata* are also important reef builders in some areas. The polychaete *Eunice norvegicus* is often found on *Lophelia* reefs where its tube building plays an important role in the consolidation of the reef framework [305]. Boring sponges are also important because they are bio-eroders of the dead coral which contributes to the coral sediment [288]. *Lophelia* reefs support a predominantly suspension feeding community [352], important in energy and elemental cycling by providing a link between the pelagic and benthic food webs [353, 354]. Characteristic suspension feeders include bryozoans, sponges (including *Axinella* spp.), tube dwelling polychaetes (*Serpula vermicularis*) and ophiuroids (*Ophiactis balli*). The reefs also harbour grazing, scavenging and predatory invertebrates but none are considered especially important to the viability of the reefs. Species also change from one biogeographic region to another [285, 297].

Lophelia reef colonies are estimated to be several hundred years old [294] and, although natural variability is known to be affected by processes of recruitment and a cycle of reef building and erosion, there is no information on the natural variability of reefs. Most observations have been made in the past few decades and often relate to putative damage from fishing activities [297, 307].

It is estimated by Mortensen and others [288] that approximately 300m^2 of *Lophelia* reef, on hard bottoms, will contain 90 % of the taxa on these habitats.

Cold-water corals *Lophelia pertusa* and *Madrepora oculata* – life history traits

- Adult home range - sessile.
- Mode of reproduction - individuals are known to be gonochoristic whilst there is some evidence for both asexual budding and sexual reproduction. Asexual budding appears to be particularly important and in some areas where there has been intensive bottom trawling genetic diversity was low and no reproductive corals were observed [289, 298, 299]. Inbreeding indices were also significant in many sites including South Rockall Trench and the Porcupine Seabight and may be due to spatially restricted effective gene flow and a predominance of self-recruitment of sexually produced larvae within sub-populations. There have been direct observations of planular settlement but much genetic evidence indicates sexual reproduction is sporadic [289, 298, 299]. *L. pertusa* is gonochoristic with seasonal gamete production and lecithotrophic larvae [300].
- Fecundity - unknown

- Dispersal - although very little is known about the dispersal of cold-water corals there is good evidence of a dispersive planula larval stage for *Lophelia pertusa* from settlement on oil rigs in the North Sea [293, 302]. This, and the wide distribution of deep-water corals, indicates that the competency period of larvae is likely to be protracted [301]. Although there is no observational or lab data to indicate how long the larvae of *L. pertusa* and *M. oculata* remain in the plankton [303], Roberts [293] reports that an estimate of 6 - 8 weeks for larval competency in temperate corals (double that of tropical species) may be possible. *L. pertusa* and *M. oculata* are thought to spawn in the first few months of the year [300], maybe triggered by distinct tidal cycles observed in the NE Atlantic margin [305].
- Recruitment - several reports of recent planular settlement were observed in surveys from the Porcupine Seabight [290] and the Porcupine Bank [289]. *Lophelia pertusa* and *Madrepora oculata* are widely distributed in the NE Atlantic [306] indicating that recruitment success may be high. The presence of cold-water corals in many areas has been correlated with the prevailing North Atlantic water currents and so recruitment success may be determined by a mixture of location and hydrodynamics [293, 307].

Table 3-43 Summary of viability for cold-water coral reefs and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Lophelia pertusa	**0**		**A + L-PLK**	**42-56**	**>50**	**[293]**
Madrepora oculata **** Lophelia***	**0**		**A + L-PLK**	**42-56**	**>50**	**[293]**
Axinella spp. *Deep sea sponges	0		A + FS-L-LEC	0-2	0-10	[309, 310]
Eunice norvegicus	0		FS-L-PLK	11-30[#]	10-40[#]	[277]
Ophiactis balli	< 1		FS-L-PLK	120-210	>50	[162, 325]
Serpula vermicularis	0		FS-L-PLK	6-60	>10	[328, 329]

dispersal period and distance has been inferred from larval type.

Viability of cold-water coral reefs

Like carbonate mounds cold water coral reefs are discrete habitats and the area that would be required to protect the whole life-cycle of reef building corals (in the order of 1964 km^2) far exceeds the actual extent of individual reefs and so a viability assessment of this nature is not deemed appropriate. There is however, some information regarding the size of individual reefs which may be several km long and reach a height of about 30 cm although some 2m high reefs have been reported [355]. In the absence of human disturbance this area is, therefore, sufficiently large to support a viable community. However, because of the practical difficulties of managing part of a reef site based conservation measures are more likely to be fit for purpose.

Approximately **300 m^2** of *Lophelia* reef, on hard bottoms, will contain 90 % of the taxa on these habitats.

There is some evidence to suggest genetic exchange between cold-water coral reefs across very large distances and so connectivity appears to be high. However, corals in damaged habitats may have reduced reproductive capacity and so a priority consideration should be the selection of the least impacted and undisturbed coral reef habitats.

Deep-sea sponge aggregations

Deep-sea sponge aggregations are dominated by glass sponges (Hexactinellidae) and demosponges are often present in very high abundance and diversity [356]. In Norway for example, 206 different sponge species were identified in a survey area smaller than 3 m^2 [355]. Research has also shown that the dense mats of spicules present around sponge fields may inhibit colonisation by infaunal animals, resulting in a dominance of epifaunal elements [357, 358]. It is assumed that the association is largely facultative, with species making use of an available resource (Dr G. Konnecker pers. com.). In some areas sponges make up more than 90 % of the total community biomass [359] and so no other faunal groups are thought to be important to the viability of the sponge community.

The glass sponge most commonly occurring in these habitats is reported to be *Pheronema carpenteri*. Typical aggregations of demosponges include the massive *Geodia* spp. and various species from the following genera: *Stellatta*, *Tragosia*, *Axinella*, *Phakellia*, *Stryphnus*, *Thenea*. For example, *Geodia* spp. and *Thenea* were particularly dominant on the Darwin Mounds in the northeast Atlantic. Carnivorous sponges *Cladorhiza* and *Asbestopluma* may also be present [360].

The population dynamics of deep sea sponges have not been reported in the primary literature although there are reports of general decline in some in response to fishing activity. It is known that glass sponges (Hexactinellidae) have very slow growth rates [361] and large individuals may be several decades old [359]. Similarly, some of the massive demospongids are also likely to be old and so it would appear that sponge aggregations persist for a long time in the absence of disturbance.

The only information that could be found on the extent of deep-sea sponge fields comes from observations of very dense sponge fields or ‘osturs’ in the northeast Atlantic stretch for 8 - 21 km in one direction [362].

Deep-sea sponge life history traits

There is a lack of information for individual deep-sea sponge species and so the following description is a general one, based on the available literature and communications with Dr Gerd Konnecker who has carried out much research into sponge biology and ecology (see references [355, 363, 364]).

- Adult home range - sessile
- Mode of reproduction - Many deep sea species are oviparous and gonochoristic [365, 366], reproducing sexually by the sperm of one individual entering the ostia of another to be transported to an egg. Development to larval stages most often occurs within the parent but the larvae may have a brief planktonic existence before settling. Asexual reproduction by budding is an important feature of a number of Tetractinomorph sponges including *Thenea* species which does not add to long distance dispersal but does lead to dense aggregations (G. Konnecker pers. comm.). In other deep-sea

sponge groups, however, asexual reproduction has not been observed or is not thought to be important [366, 367].

- Fecundity - *Geodia* spp. in a Scandinavian fjord have one or two periods of gamete release per year [366] and the onset coincides with phytoplankton blooms.
- Dispersal - The larvae are generally lecithotrophic and short-lived [355]. High settlement observed close to adult sponges and genetic data also suggest that dispersal distances in sponges are low [309, 310]. Larval period is probably a few days at the most, a fact that is difficult to reconcile with the wide distribution of deep-sea sponges. Many species will settle in 24 hrs but a larval period up to 7 days has been observed in Hadromeridans and may occur in deep-sea species (Dr G. Konnecker pers. com.).
- Recruitment - the short larval period and widespread distribution of many sponge species, often with large distances between known populations points to widespread breeding populations across the whole of the north Atlantic [355]. Sponge larvae have been observed to settle on any substrate and so any solid substrate can act as a stepping stone to other areas (Konnecker pers.com.). Recruitment may be sporadic, however, as observed in deep sea hexactinellid sponges in the fjords of British Columbia, Canada where no recruitment was observed over a 3 year period [368].

Table 3-44 Summary of viability for deep-sea sponge aggregations and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Deep sea sponges	**0**		**AB + FS-L-LEC**	**0-2**	**0-10**	**[309, 310, 355]**

Viability of deep-sea sponge aggregations

There is very little available evidence to indicate the area required for viability of deep-sea sponge aggregations. Asexual reproduction appears to be important and sexual reproduction may be sporadic with a short lived larval stage that does not widely disperse. The estimated maximum larval dispersal distance of 10 km suggests an area of **79 km^2** would protect the whole life cycle, including sexual reproduction, of deep-sea sponges and allow for self-seeding populations. It also suggests that high connectivity would be needed to protect genetic exchange between populations. However, many deep-sea sponges are widely distributed in the Atlantic, suggesting the presence of many larval source populations not yet observed or the ability of sponges to use any hard substrate habitat as a stepping stone.

Estuarine rocky habitats

Rocky habitats in estuaries make a significant contribution to the overall diversity of estuaries by providing attachment for a wide range of algae including fucoids (*Fucus vesiculosus* and *Fucus serratus*) and the egg wrack *Ascophyllum nodosum* in the intertidal [369] and kelps such as *Laminaria digitata* in subtidal habitats [4]. The salinity tolerant *Fucus ceranoides* may also be present further up the estuary [370]. Intertidal fauna includes the barnacle *Semibalanus balanoides* and particularly *Elminius modestus* which penetrates further up some estuaries [369]. Subtidally *Balanus crenatus* and the reduced salinity tolerant *Balanus improvisus* are common. Intertidally the winkles *Littorina littorea* and *Littorina obtusata/mariae* and the limpet *Patella vulgata* are common [369] as are crustaceans including the crab *Carcinus maenas* [371] and gammarid amphipods *(Gammarus* spp*.).* The grazing activity of *Patella vulgata* may be important in determining successful recruitment of fucoid algae [372]. Subtidal rocky estuarine habitats are often subject to increased tidal streams and support a wide range of filter feeding encrusting organisms including sponges *(Halichondria panicea),* ascidians *(Dendrodoa grossularia),* anthozoans *(Alcyonium digitatum* and *Metridium senile)* and hydroids (*Sertularia* spp.) [369, 373]. The native oyster *Ostrea edulis* (UK BAP priority species) may also be present.

Although there is a large body of research into the environmental and biological dynamics of estuarine systems this normally relates to sedimentary habitats. There are very few studies specific to estuarine rocky habitats and so knowledge of natural variation in species abundance in this habitat is lacking. High natural variability in algal cover, however, was observed over a three year period on several different shores in the Severn Estuary [372]. For example, on one shore algal cover of both *Fucus serratus* and *Ascophyllum nodosum* virtually disappeared one year, probably due to wave action and tidal scour. The shore then remained devoid of algae for several years. During the same study the abundance of *Fucus spiralis* and *Pelvetia canaliculata* was reduced, probably due to the effects of desiccation during the hot summers of 1975 and 1976. Thus, there are likely to be changes in the abundance of some faunal species that rely on algae for refuge and habitat. In addition, invertebrate recruitment is often highly stochastic resulting in spatial and temporal variability in distribution and abundance of many species.

Table 3-45 Summary of viability for estuarine rocky habitats and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Alcyonium digitatum	0		FS-L-PLK	>180	> 50	[374, 375]
Ascophyllum nodosum	0		S	-	<10	[274]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Balanus improvisus	0	5	BR-L-PLK	30	40	[279]
Carcinus maenas	1 – 10		BR-L-PLK	80	12-300	[44, 376]
Dendrodoa grossularia	0	16	A + BR-L-LEC	2-3 hrs	<1	[313] [377]
Elminius modestus	0	2	BR-L-PLK	17-34	41±33	[378] [44, 379, 380]
Fucus spp.	0		S	-	<10	[274]
Gammarus spp.	< 1	316	BR-DIR	0	0	[275]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381, 382]
Laminaria digitata	0		S	-	<10	[274]
Littorina littorea	< 1	214	BR-L-PLK	30	0-80	[44]
Littorina obtusata/mariae	< 1		E-DIR	0	0	[379, 383]
Metridium senile	0	10	AB	0	0	[384]
Patella vulgata	< 1		FS-L-PLK	14	25	[349]
Semibalanus balanoides	0	12	BR-L-PLK	14-21	25-40	[279]
Sertularia spp. *Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]

Viability of estuarine rocky habitats

The only information available to indicate the area required to protect the viability of estuarine rocky shore communities comes from the life history data of the species characteristically found there. With the exception of *Carcinus maenas* most species are attached or have very small home ranges of less than 1 km. Many of the species in this habitat are attached or encrusting and it has not been possible to access data that identifies the area of a minimum viable population size of 5000 individuals. The most cautious estimate for the area for a MVP is **316 m^2** which comes from data on the amphipod *Gammarus* spp.

The dispersal potential of some of the mobile components of estuarine rocky habitats, such as *Carcinus maenas* and *Littorina littorea* is very high. Since these are ubiquitous species with expected high rates of recruitment to suitable habitats the high dispersal distances have been excluded from the calculation of area. For the remainder of species in the habitat the maximum dispersal distance is 50 km which gives an area of **1964 km^2** to ensure self-sustaining populations. However, many of the species have a widespread distribution around the UK coastline and so a significantly smaller area should ensure the persistence of populations although there was no specific evidence on which to base an assessment of the actual area required.

File shell beds

Limaria hians is the key species, creating the habitat through the building of 'nests' that are responsible for consolidation of sediments and provision of substratum for the attachment of a wide diversity of associated organisms [385, 386].

Other species characteristically found with *Limaria hians* nests are hydroids (*Sertularia* spp.), small bivalves (*Mysella bidentata*) and barnacles (*Balanus crenatus*), epifaunal animals such as brittlestars (*Ophiothrix fragilis*), nudibranchs, amphipods (*Gammaropsis* spp.) and a range of scavenging and predatory invertebrates such as small crabs (*Pisidia longicornis*), polychaetes (e.g. *Lepidonotus* spp.) and echinoderms (*Asterias rubens, Antedon bifida*) [387, 388]. There may also be an infaunal component of larger bivalves such as *Modiolus modiolus* [387]. In some areas consolidation of the sediment by *Limaria hians* nests creates substratum for holdfasts of algal kelp species such as *Laminaria digitata* which are unable to anchor otherwise [385]. The habitat is often shared with the maerl species *Lithothamnion glaciale* and *Phymatolithon calcareum* (both of which are UK BAP priority species and discussed in other sections of the report).

Although there are no direct studies of the temporal variability of *L. hians* beds it is clear that when undisturbed they are very stable, and several beds are known to have existed for approximately 100 years [388]. In some areas, such as tidal sea lochs, beds form continuous reefs standing 10-20 cm high and several hectares in extent [389]. Some natural damage to nests resulting from the 'uprooting' of kelp holdfasts attached to them has been observed [390].

Limaria hians life history traits

- Adult home range - a mobile species which, although capable of swimming is normally only associated with disturbance of the nest and so the home range is likely to be small [387].
- Mode of reproduction - In *Limaria hians* the sexes are separate [387] and fertilisation is external.
- Fecundity - *Limaria hians* is reported to be sexually mature in its second summer [391] and is thought to live for up to 6 years [387].
- Dispersal - there is a feeding (planktotrophic) veliger larvae which, in the laboratory, was observed to reach settlement size within a few weeks [387, 388] and so a larval period of 21 days is estimated. Dispersal potential is therefore thought to be fairly widespread (up to ~40 km). However in some areas, particularly enclosed bays, local recruitment is probably important appears to be important. In Mulroy Bay in Ireland, for example, poor settlement of larvae to the extensive *Limaria hians* beds was thought to be due to the impact of TBT on a local larval supply [391].

- Recruitment - is not known but where adult *Limaria hians* are present or in nearby areas settlement of new recruits has been observed to occur. For example, in some areas of disturbance settlement of new recruits, probably from neighbouring populations, has been observed soon after cessation of the impact [392].

Table 3-46 Summary of viability for file shell beds and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	(km)	REFERENCES
Limaria hians	**< 1**		**FS-L-PLK**	**21**	**40**	**[391]**
Antedon bifida	< 1	500	BR-L-PLK	5	10	[392]
Asterias rubens	1 – 10	294	FS-L-PLK	<90	>50	[393, 394]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Gammaropsis spp.	< 1	99	BR-DIR	0	0	[275]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Lepidonotus squamata	< 1	149	L-FS-PLK	11–30#	10–40#	[277]
Lithothamnion corallioides	0		AV	0	0	[41, 43, 44]
Lithothamnion glaciale	0		AV	0	0	[44, 395]
Laminaria digitata	0		S	-	<10	[274]
Modiolus modiolus	0	267	FS-L-PLK	30	40	[396]
Mysella bidentata	< 1	65	L-PLK	11–30#	10–40#	[397]
Ophiothrix fragilis	< 1	95	FS-L-PLK	21-26	40	[162, 398, 399]
Phymatolithon calcareum	0		AV	0	0	[19, 43, 44]
Pisidia longicornis	< 1	18	BR-L-PLK	30-60	>50	[400, 401]

dispersal period and distance has been inferred from larval type.

Viability of file shell beds

The home range of this nest building bivalve is small, probably less than 2 m^2, but the reefs are more extensive. The only report of a file bed size, which if it has already shown long term survival can be assumed to be an area sufficient to ensure viability, is 0.03 km^2. The area required for a minimum viable population (MVP) size of 5000 *Limaria hians* individuals is not known but the most cautious estimate on the basis of the other species associated with Limaria hians is **500 m^2**. The maximum dispersal distance for *Limaria hians* is estimated to be 40 km and so the area required to protect the whole life-cycle and self-seeding of *L. hians* is **1257** km^2. *L. hians* has a restricted distribution and so the larvae are likely to also be restricted in their distribution. Thus, larval supply is probably limited in some areas and connectivity will need to link known populations less than 40 km apart.

Fragile sponge and anthozoan communities on subtidal rocky habitats

Areas of bedrock that are close to, but locally sheltered from, tide-swept or wave exposed areas are often dominated by large, slow growing animals, in particular branching sponges and seafans. A good supply of particulate material means these habitats are dominated by filter and suspension feeding organisms although the actual species present are likely to vary depending on the geographical location. The following representative species are commonly found in the illustrative biotopes for this habitat [4]. Branching sponges of the genus *Axinella* are particularly characteristic and other sponge species such as *Cliona celata* may also be present. The most common seafan species are *Eunicella verrucosa* and *Swiftia pallida* and other anthozoans such as *Alcyonium digitatum* and *Caryophyllia smithii* are also likely to be present. A species rich understory may develop, typically consisting of the hydroids *Nemertesia* spp., erect bryozoans including *Bugula* spp., *Pentapora foliacea* and *Alcyonidium diaphanum* and colonial ascidians such as *Clavelina lepadiformis* [402].

This habitat has been modified from the Welsh BAP Habitat Atlas (2008) and has been the subject of very little research. The only information available on variability will come from the natural variability of the constituent species in the community that are likely to be subject to variable recruitment. Sponges are generally slow growing and long-lived and appear to have low recruitment. Populations may be smaller in the winter months when some sponge species regress and fragment [403].

Table 3-47 Summary of viability for fragile sponge & anthozoan communities on subtidal rocky habitats

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Alcyonidium diaphanum	0		FS-L-LEC	<1	<0.1	[374, 375]
Alcyonium digitatum	0		FS-L-PLK	>180	>50	[309, 310]
Axinella spp. *Deep sea sponges	0		A + FS-L-LEC	2	5	[44]
Bugula neritina	0		L-LEC	0-1.5	<0.1	[404-406]
Caryophyllia smithii	0		A + FS-L-PLK	56-70	>50	[118, 407, 408]
Clavelina lepadiformis	0		FS-L-LEC	0.2	<1	[409, 410]
Cliona celata	0	55	A + FS-L-LEC	2	5	[121, 123]
Eunicella verrucosa	0		FS-L-LEC	3–5	4-10	[317-319]
Sertularia spp. *Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[121, 123]
Swiftia pallida	0		FS-L-LEC	3–5[#]	4–10[#]	[411]

dispersal period and distance has been inferred from larval type.

Viability of fragile sponge and anthozoan communities on subtidal rocky habitats

Many of the species in this habitat are sessile encrusting fauna and so the area required to protect the home range of the adult is in the order of metres. Many sponges reproduce asexually by fragmentation and budding and so some local recruitment would be protected by a small area. Sexual reproduction also occurs, often seasonally, in most shallow water sponges with the production of planktonic planula larvae. The dispersal duration for sponge larvae ranges from a few hours to a few days with a maximum dispersal distance estimated to be 5 km. Thus, an area of **79 km^2** would incorporate the complete life cycle of the sponges and many of the other species in the habitat. *Alcyonium digitatum* and *Caryophyllia smithii* have a much greater dispersal distance but since they are common species in UK waters, there is expected to be an adequate supply of larvae to provide adequate recruitment. However, with dispersal distances in the order of 50 km an area of **1964 km^2** is needed to protect the complete life cycle of many species found in these communities.

Intertidal mudflats

Intertidal mudflats are sedimentary habitats created by deposition in low energy, sheltered environments, most often found in estuaries. These habitats support a high abundance and hence biomass of infauna which form an important food resource for shorebirds [412-414]. In terms of abundance these communities are heavily dominated by oligochaete worms such as *Tuficoides benedii* and the amphipod *Corophium volutator* [411]. However, it is the larger animals which seem to be most important for shorebird survival [412-414] and these typically include the cockle, *Cerastoderma edule*, the ragworm, *Nereis* (*Hediste*) *diversicolor,* and the Baltic tellin, *Macoma balthica* [412-414].

Other species which are faithful and frequent in this habitat include the catworm, *Nepthys* spp, the ragworm *Arenicola marina*, the small gastropod, *Hydrobia ulvae* and spionids *Pygospio elegans* and *Streblospio shrubsolii* [415]. *Arenicola marina* is a major ‘bioturbator’, turning over and disrupting the structure of the mud which may have an impact on the presence and distribution of other infaunal organisms [416]. Where mudflats are slightly coarser they may develop into seagrass beds or support intertidal mussel beds. Both of these are considered to be a habitat in their own right and are dealt with elsewhere in this report.

Table 3-48 Summary of viability for intertidal mudflats and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Arenicola marina	< 1	188	E-B-J	0	1-10	[417-419]
Cerastoderma edule	< 1	5	FS-L-PLK	14-21	25-40	[420]
Corophium volutator	< 1	1	DIR	0	<1	[270-273]
Ensis spp.	< 1	37	FS-L-PLK	20-30	40	[416]
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40	[350, 421]
Macoma balthica	< 1	18	FS-L-PLK	30-360	>40	[422, 423]
Nephtys spp.	< 1	81	FS-L-PLK	49 - 56	>50	[382]
Nereis (Hediste) diversicolor	< 1	16	FS-DIR	0	0	[276] [277, 278]

Viability of intertidal mudflats

The species which characterise intertidal mudflats are all infaunal and estimated to have home ranges less than 1 km^2. An area of **202 m^2** should ensure the continued genetic viability of the community. However, high spatial and temporal variability in intertidal mudflats has been reported in response to environmental conditions and recruitment patterns [424, 425] and since this variability has not been quantified in the literature it may not be adequately encapsulated in our MVP estimates. This minimum viable area should therefore be treated with some caution.

The dispersal potential of some components of the intertidal mudflat community is high and so an area of approximately **1964 km^2** would be required to allow for a self-sustaining community. Since the species which characterise this community have a relatively ubiquitous distribution around the UK [426] and it could reasonably be assumed that their larvae are also ubiquitous in the water column in which case a much smaller area could be adequate. Perhaps of greater importance in terms of the viability of this particular habitat is the maintenance of the hydrodynamic regime. If the flow of water were to be interrupted in these areas it could completely change the nature of the substrate and hence the fauna which it is able to support.

Intertidal underboulder communities

The underboulder habitat, together with fissures, crevices and spaces between boulders constitutes a highly heterogeneous area that can greatly enhance local biodiversity [427, 428]. The damp and sheltered undersides of boulders provide refuge for a wide range of encrusting species that are not found on exposed surfaces. These include sponges, in particular the breadcrumb sponge *Halichondria panicea*, barnacles *Balanus crenatus* and *Semibalanus balanoides*, the keel worm *Pomatoceros triqueter* which can often occur in high densities as does the colonial ascidian *Botryllus schlosseri* [429-432]. Mobile organisms that move in and out of the habitat include small crabs like *Pisidia longicornis* and *Porcellana platycheles* [4] and echinoderms (especially brittlestars such as *Ophiothrix fragilis*). Gastropod snails including *Littorina littorea* and *Nucella lapillus* also colonise underboulder communities [424, 425]. Sediment communities in an underboulder habitat are characterized by deposit feeders such as polychaetes (e.g. *Amphitrite* spp.) and amphipods (*Jassa* spp.) that exploit algal macrodetritus [426].

Intertidal boulder communities can experience frequent periods of spatial and temporal variability due to natural perturbations such as wave action (especially during winter storms), which can overturn boulders and remove whole communities, leaving patchy rock- exposed areas. In turn, this provides opportunities for successive colonization. These local extinctions and subsequent re-colonisations occur more frequently on smaller boulders resulting in temporal and spatial community fluctuations [428, 433].

Table 3-49 Summary of viability for intertidal boulder communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Botryllus schlosseri	0		E-L-LEC	1	<4	[434]
Fucus serratus	0		S	-	<10	[274]
Gibbula cineraria	< 1	292	FS-L-PLK	8-9	10	[316, 435]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381, 382]
Jassa spp.	< 1		DIR	0	0	[436]
Littorina littorea	< 1		BR-L-PLK	30	0-80	[44]
Nucella lapillus	< 1	500	BR-DIR	0	0	[234]
Ophiothrix fragilis	< 1	95	FS-L-PLK	21-26	40	[162, 398, 399]
Pisidia longicornis	< 1	18	BR-L-PLK	30-60	>50	[400, 401]
Pomatoceros triqueter	0	59	FS-L-PLK	14-60	>40	[277, 437]
Porcellana platycheles	<1		BR-L-PLK	30-60	>50	[401]
Semibalanus balanoides	0	12	BR-L-PLK	14-21	25-40	[279]

Viability of intertidal underboulder communities

Many of the species in this habitat are encrusting and the mobile species also have fairly small home ranges so an area of 1 km^2 would protect adult ranges. Although minimum viable population data is not available for all species the area required for *Nucella lapillus*, at **500 m^2** is the most conservative estimate available for the species characteristic of this habitat. Species Area Curve analysis would be required to determine the relationship between area and habitat diversity. Many species have potentially large dispersal potential, between 40 and 50 km and so a large area, in the order of **1256 - 1964 km^2** is required to protect the whole life cycle and self-seeding potential. However, many of these species are ubiquitous in UK waters giving good larval supply so protected areas can be considerably smaller. There is little other information on which to base assessment of viability and so site based conservation measures may be applicable, selecting boulder shores known to harbour the highest diversity of species.

Littoral chalk communities

Intertidal chalk shores, because of the porous nature of the substratum, support highly specialised communities that are not found in other habitats [438]. In particular, benthic stages of planktonic Haptophyceae and Chrysophyceae algae are unique to the upper intertidal areas of chalk shore habitats. Haptophyceae species include *Apistonema* spp., *Pleurochrysis carterae* and the orange *Chrysotila lamellosa* and Chrysophyceae includes *Thallochrysis litoralis*. Further down the shore the rock-boring behaviour of piddocks, in particular *Pholas dactylus*, increases the topical complexity of the chalk thereby increasing species diversity [439]. Characteristic species in the littoral zone include the boring polychaete *Polydora ciliata* and several mobile species typical of UK rocky shores including *Littorina littorea, Gibbula cineraria, Porcellana platycheles* and *Patella vulgata* [4, 439, 440].

Haptophyceae and Chrysophyceae life history traits

- Adult home range - benthic or benthic stages of unicellular flagellated algae. *Thallochrysis* for example is benthic with a simple thalloid level of organisation. *Chrysotila lamellosa* is predominately benthic but the motile flagellate part of the life-cycle is abundant in the phytoplankton, previously described as *Isochrysis maritima*. *Pleurochrysis carterae* has a branched filamentous stage found on chalk cliffs and a pelagic stage found in nearshore phytoplankton [27].
- Reproduction - Chrysophyceae and Haptophyceae reproduce predominantly by asexual reproduction although flagellate zoospores may also be produced.
- Fecundity - unknown.
- Dispersal - the fine, filamentous green algae found in this biotope produce motile zoospores and swarmers. Hence, the algal species within this biotope have a high potential for dispersal, depending on local currents. The species *Pleurochrysis carterae* is widely distributed around the temperate coasts of Europe ensuring a good supply of propagules from the water to the relevant chalk habitats.
- Recruitment - unknown but expected to be good on the basis of available dispersal evidence.

Pholas dactylus life history traits

- Adult home range - sessile, burrowing habit
- Reproduction - the sexes are separate and fertilization is thought to be external [441].
- Fecundity - the fecundity of *Pholas dactylus* is not reported. On the south coast of England some one year old individuals were found to be sexually mature and the estimated maximum age was 12 years [442].
- Dispersal - *Pholas dactylus* produces a planktotrophic veliger larva. The only estimate for larval dispersal period in this species is 45 days [441 cited in Pinn et al. 2005]. This compares well with the larval period of a tropical congeneric, *Pholas orientalis*, which is reported to be 10 days at a temperature of 26-29 ^{o}C [443].
- Recruitment - the only information available comes from an analysis of population structure on the south coast of England by Pinn et al. [442] where recruitment of juvenile piddocks (<10 mm) into the population was observed over an extended period between November and February in the course of the 18 month long study.

Table 3-50 Summary of viability for littoral chalk communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL	
				(days)	(km)	REFERENCES

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	LARVAL DISPERSAL (km)	REFERENCES
Pholas dactylus	**0**	**200**	**FS-L-PLK**	**45**	**>50**	**[442]**
***Apistonema* spp.**	**0**		**A + S**		**>50#**	**[27]**
Pleurochrysis carterae	**0**		**A + S**		**>50#**	**[27]**
Chrysotila lamellose	**0**		**A + S**		**>50#**	**[27]**
***Thallochrysis* spp.**	**0**		**A + S**		**>50#**	**[27]**
Gibbula cineraria	< 1	292	FS-L-PLK	8-9	10	[316, 435]
Littorina littorea	< 1	214	BR-L-PLK	30	0-80	[44]
Patella vulgata	< 1		FS-L-PLK	14	25	[349]
Polydora ciliata	0	1	BR-L-LEC	21	40	[277, 444, 445]
Porcellana platycheles	<1		BR-L-PLK	30-60	>50	[401]

dispersal period and distance has been inferred from larval type.

Viability analysis and options

In general, most species found on intertidal chalk shores are either sessile or have small home ranges and so an area less than **1 km^2** would protect adult home ranges of most species in this habitat. There is no information on the minimum viable area for many of these species but the most conservative estimate is **292 m^2** to protect the genetic diversity of many of the species, including *Pholas dactylus*. In contrast the potential dispersal distances for most species are high (> 50 km) so an area of **1964 km^2** would be required for all stages in the life cycle. However, many of the chalk specialist Haptophyceae and Chrysosphyceae algal species are thought to be widely distributed around the temperate coasts of Europe in their planktonic phase. It would appear therefore, that these species will recruit to whatever chalk habitat is available suggesting the area required for viability is likely to be considerably smaller than that needed to incorporate the complete life-cycle.

Many of the faunal species on chalk shores also have large dispersal distances but because of their widespread distribution are also expected to be in high larval supply in the water column giving populations high natural connectivity. The boring bivalve *Pholas dactylus*, which is particularly characteristic of chalk shores only appears to be found in high abundance on the south coast of England. However, where there is available habitat piddocks appear to recruit and there are no reports of declines of this species for reasons other than loss of the chalk and peat/clay habitat it requires for settlement. Thus, protected areas significantly smaller than 1964 km^2 would be adequate although there is little specific information to indicate the optimum size for viability.

Maerl beds

Maerl is the collective term for several species of calcified red seaweed, which in their free living form and under favourable conditions can create extensive maerl beds. The loose open structure of maerl coralline algae, including the species *Lithothamnion corallioides*, *Lithothamnion glaciale* and *Phymatolithon calcareum*, provides habitat and refugia for a very wide range of organisms such that maerl beds typically have very high diversity [36, 395, 446]. Maerl beds are often formed in association with sand and gravel and can constitute both live and dead maerl thalli [447, 448]. Maerl habitats exhibit a high heterogeneity compared to the surrounding substrata [36, 447]. Maerl is also important in calcium carbonate cycling, providing grains for coastal habitats, especially beaches and dunes [449].

The interlocking maerl thalli create an intricate habitat that supports a large diversity of other algal and invertebrate species [395]. The crustacean *Upogebia deltaura* has been recorded in excavated burrows within maerl beds of the Clyde Sea, Scotland. The burrows served as refuges that reduced the impact of scallop dredging on the *Upogebia* population [450]. Several species that are found in maerl beds are obligate to the maerl habitat such as the rhodophyte *Cruoria cruoriaeformis* [395] or rare such as *Dermocorynus montagnei* [24] (see species section for details).

The juvenile queen scallops, *Aequipecten opercularis* will preferentially settle on maerl beds, whether these be pristine, or dead and compacted, as opposed to settling on gravel or sand [451]. Maerl beds support large numbers of juvenile *A. opercularis* and thus may be considered as nursery grounds for this commercially important species [395]. The settlement preference displayed by this species demonstrates the optimum compromise between food supply and refuge availability, allowing the highest growth potential for juveniles settling on maerl [54]. *Pecten maximus,* another bivalve of commercial importance, recruits to maerl bed habitats, due to the low siltation and high water exchange rates in these habitats [36].

Hall-Spencer and others [36] suggest these areas may also be important nurseries for commercially valuable molluscs, such as *Pecten maximus, Venus verrucosa* and *Ensis* spp. [36, 37, 54, 452]. There is also evidence for other species such as the black sea urchin (*Paracentrotus lividus*) in maerl deposits in Ireland and scallops on maerl beds in France and the west of Scotland [395]. Maerl beds also provide structurally complex feeding areas for juvenile fish such as Atlantic cod.

Maerl biotopes are recognised as exhibiting both temporal and spatial biological variability although this has not been fully explored [395]. Patterns of natural variability in maerl biotopes may be masked by the impact of anthropogenic activities such as dredging [37].

The flora and fauna of the maerl habitat can vary greatly seasonally with algal diversity being higher during the summer months due to the heteromorphic (seasonal) life history of many species [395]. Spatial variations in communities and biodiversity may be attributed to environmental influences such as wave action. These may be more influential to communities in shallow maerl habitats [453, 454]. Intensive storm damage can cause long-term damage to the community including the maerl species itself by loss of the maerl thalli and increased turbidity and sedimentation after the event [41, 454]. The various maerl species can show periodic dominance and decline at a site over time scales of between 3 and 30 years [395].

Maerl spp. life history traits

- <u>Adult mobility</u> - sessile although free living forms could be transported via currents. These species normally inhabit sheltered areas

- Mode of reproduction - only vegetative (asexual) reproduction has been observed [41, 43].
- Dispersal - due to the predominance of vegetative reproduction, dispersal in this species is thought to be limited [41].
- Recruitment - recruitment is thought to be low due to the slow growth and mode of reproduction exhibited by this species [28, 32, 455]

Table 3-51 Summary of viability for maerl beds and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Lithothamnion corallioides	**0**		**AV**	**0**	**0**	**[41, 43, 44]**
Phymatolithon calcareum	**0**		**AV**	**0**	**0**	**[41, 43, 44]**
Cruoria cruoriaeformis	0		AV + S	0	<10	[13, 20, 22, 456]
Dermocorynus montagnei	0		AV + S	0	<10	[13, 457, 458]
Ostrea edulis	0	500	BR-L-PLK	10-20	10-40	[241, 459, 460]
Pecten maximus	0		FS-L-LEC	18-48	10-30	[36, 461]

Viability of maerl habitats

There is very little information available to assess the area required for viable maerl beds. The dispersal potential of maerl species is fairly low, limited to the movement of adult plans by water currents, probably less than 1 km, so an area of 1 km^2 would incorporate the complete asexual life cycle. The dispersal potential of sexual propagules is unknown because these have not been observed in UK waters and there have been no studies published of the genetic exchange between populations. In light of this uncertainty and the particularly high sensitivity of maerl beds to disturbance, especially from fishing activity, a precautionary approach should be taken to designate a high number of large areas of maerl beds with variable distances between sites to allow for a range of dispersal distances.

Modiolus modiolus reefs

Modiolus modiolus reefs play an important ecological role in energy transfer, from pelagic to benthic systems and between trophic levels within the reef itself [462]. Reefs are highly productive and in high densities the suspension feeding of *M. modiolus* can remove and store large amounts of suspended material. The reefs support a wide range of epifaunal and infaunal organisms; Witman [463] for example observed 8 times as much organism biomass inside *Modiolus* beds compared to outside. The epifauna are dominated by a wide diversity of suspension feeding animals such as sponges (for example *Halichondria panicea*), hydroids (such as *Sertularia* spp.), bryozoans and ophiuroids (in particular *Ophiothrix fragilis*) that also contribute to energy cycling [463-465]. An infaunal community that includes polychaetes (e.g. *Lepidonotus squamata*) and small bivalves such as *Mysella bidentata* and *Nucula* spp. [466] also plays an important role in the transfer of energy between trophic levels through feeding on the energy rich faeces and pseudofaeces produced by *M. modiolus* [462].

Modiolus modiolus is a long lived species with the age of most British populations in excess of 25 years and some individuals over 50 years old [467]. Temporal variability of *M. modiolus* beds has not been well studied but in the absence of regular disturbance they appear to be fairly stable. Many beds have persisted in the long term, despite intermittent and variable recruitment [468]. Scientific research in the 1950s identified the oldest *M. modiolus* individuals to be 40 years old. Many of these beds still exist indicating that many beds have persisted for at least 80 years in the same location [467, 469]. There is very little information on the size of these persistent reefs although another long-lived bed in the south of Strangford Lough was reported to be approximately 2.5 km^2 in extent [470]. In north Wales *M. modiolus* beds have been present in the same area for more than 150 years and a study between 1999 and 2005 found a large bed of 3.49 km^2 in extent was stable (xxx add in Lindenbaum 2008 at the end xxx).

Modiolus modiolus life history traits

- Adult home range - although mussels are able to detach byssus threads they are effectively sessile.
- Reproduction - the sexes are separate with external fertilization and the development of a planktotrophic veliger larva [471]. In *M. modiolus* reproduction is delayed in favour of early and rapid growth [469] with individuals reaching sexual maturity at between 3 and 6 years [472].
- Fecundity - there was no information found on the number of eggs produced. The spawning period is highly variable from place to place with observed differences with depth and likely differences due to the effect of temperature at different latitudes [473, 474]. Strong seasonality, with spring/summer spawning, has been observed to the east of the Isle of Man [472] and in Scotland [465]. In contrast, populations in Strangford Lough, Northern Ireland appear to release gametes throughout the year [468]. Others report that some populations may spawn only once every few years [Wiborg, 1946 in 472].
- Dispersal - there is very little information available although Comely [465] estimates the period of larval development to be approximately 30 days at 14 ^{o}C. This estimate is used in preference to the ‘extremely long’ planktotrophic stage proposed by Ocklemann [396] on the basis of the size of egg, larvae and adults. However, it is thought that recruitment from distant populations is possible [475].
- Recruitment - the larvae preferentially settle on adults [465]. Recruitment is variable geographically, seasonally and annually. For example, several beds investigated by Brown & Seed [476] in the early 1970s were found to have bimodal size frequency distributions indicating variable recruitment. Successful recruitment in Strangford Lough and Isle of Man populations appears to be a balance between recruitment, rapid growth and very high mortality by predation on young *M. modiolus* [465, 469]. In contrast, there was no recruitment observed over a period of 3 years in several Scottish populations [465]. In enclosed areas, such as Strangford Lough, local recruitment is probably much more important for the persistence of populations.

Table 3-52 Summary of viability for *Modiolus modiolus* and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Modiolus modiolus	**0**	**267**	**FS-L-PLK**	**30**	**40**	**[396]**
Bryozoans	0		EB- L-LEC	2	0-4	[402, 477]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381, 382]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Lepidonotus squamata	< 1	149	FS-L-PLK	11-30$^{\#}$	10-40$^{\#}$	[478]
Mysella bidentata	< 1	65	L-PLK	11-30$^{\#}$	10-40$^{\#}$	[397]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321-324]
Ophiothrix fragilis	< 1	95	FS-L-PLK	21-26	40	[162, 398, 399]

Viability of *Modiolus modiolus* beds

There has been no specific information found on the size of area required to protect the viability of *M. modiolus* beds and so the assessment is largely inferred from the life history traits of the species considered important to the habitat.

The reef forming *Modiolus modiolus* is sessile and so the area required to protect the adult home range is very small but the dispersal potential of *M. modiolus* is considerable, particularly for individuals in open coastal areas, estimated to be 40 km. Thus, an area of **1257 km^2** would be required to encompass the whole of the life cycle of the species. In bays and enclosed areas self-seeding populations are likely to be present in much smaller areas. In Strangford Lough, for example, a bed of 2.5 km^2 was known to have persisted for many years. An area of **267 m^2** would protect enough individuals to ensure genetic viability of *Modiolus* and other species associated with the reef.

Most of the associated species also have potentially widely dispersed larvae though many of them have a widespread distribution and so could be expected to recruit to suitable habitat in the absence of disturbance so an area considerably smaller than 1259 km^2 is likely to adequate.

Mud habitats – sea pens and burrowing megafauna

The fauna that dominate this habitat, sea pens and burrowing crustaceans are functionally and ecologically dissimilar and probably occur together because they occupy the same habitat. No single species can be considered key to the structure of the community although some do have an important ecological role. There are conspicuous populations of sea pens, typically *Virgularia mirabilis* and *Pennatula phosphorea. Funiculina quadrangularis* is also found in fine mud habitats [4]. Burrowing megafauna, in particular the crustaceans *Nephrops norvegicus*, *Calocaris macandreae* and *Callianassa subterranea*, increase habitat complexity through complex burrow systems [479] that also increase oxygenation in the sediment [480]. Where there are dense populations of burrowers, however, infaunal diversity may be reduced [481]. Other species characteristic of this habitat include burrowing anemones such as *Cerianthus lloydii*, brittle stars including *Amphiura chiajei* and a wide range of infaunal polychaetes including *Nephtys*, *Tharyx*, *Glycera* and spionids and bivalves such as *Mysella bidentata* and *Nucula* sp.. The nudibranch *Philine aperta* and the polychaete *Armandia* may also be found in association with seapens.

There has been very little research on sea pen and burrowing megafaunal communities to assess the natural spatial and temporal variability of this habitat. The only evidence of sea pen longevity and population dynamics found comes from a study of *Ptilosarcus guerneyi* by Birkeland [1969 as discussed in 132]. The species was thought to live for as long as 15 years and reach sexual maturity at approximately 5 years and Birkeland [482] noted that *P. guerneyi* was able to maintain a steady-state population despite heavy predation by nudibranchs and starfish.

Sea pen life history traits

- Adult home range - sessile
- Reproduction - the generally accepted view, resulting from research into only a handful of sea pen species is that they are gonochoristic at the colony level and reproduce sexually through broadcast spawning [132, 483-485]. There has been no evidence of brooding in *Pennatula phosphorea* and *Funiculina quadrangularis* [126, 486].
- Fecundity - not known/no information found
- Dispersal - there is a lack of scientific knowledge of sea pen larval development and dispersal. The only reported observation of larval development is from Chia and Crawford's [132] laboratory observations of *Ptilosarcus guerneyi*, a species found in Puget Sound, Washington. At 12 ^{o}C larvae were ready to settle after 7 days although in the absence of a suitable substratum they were able to remain as planula larvae for at least 30 days. Several sea pen studies infer the production of lecithotrophic larvae from the large size of eggs found in mature adults rather than actual observations. The only estimate of larval period is, therefore, 7 – 30 days.
- Recruitment - unknown but likely to be sporadic as has been observed in the other seapen species *Ptilosarcus guerneyi* and *Renilla kollikeri* [487, 488].

Table 3-53 Summary of viability for sea-pen and burrowing megafauna communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL	
				(days)	(km)
Pennatula phosphorea ****Ptilosarcus guerneyi***	**0**		**FS-L-LEC**	**7-30**	**10-40**
Virgularia mirabilis ****P.guerneyi***	**0**		**FS-L-LEC**	**7-30**	**10-40**
Funiculina quadrangularis ****Ptilosarcus guerneyi***	**0**		**FS-L-LEC**	**7-30**	**10-40**
Amphiura chiajei	< 1	107	FS-L-PLK	8-14	10-40
Callianassa subterranea	< 1	257	BR-L-PLK	30-60	>50
Calocaris macandreae	< 1		DIR	0	0
Cerianthus lloydii	0	190	FS-L-PLK	90	>50
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40
Mysella bidentata	< 1	65	L-PLK	11-30#	10-40#
Nephrops norvegicus	< 1	500	FS-L-PLK	50 - 60	>50
Nephtys spp.	< 1	81	FS-L-PLK	49-56	>50
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40
Philine aperta	< 1	272	E-L-PLK	11-30#	10-40#
Tharyx spp.	0	7	BR-DIR	0	0

The REFERENCES column, with the same row labels:

SPECIES	REFERENCES
Pennatula phosphorea ****Ptilosarcus guerneyi***	**[126, 489]**
Virgularia mirabilis ****P.guerneyi***	**[126, 489]**
Funiculina quadrangularis ****Ptilosarcus guerneyi***	**[126, 489]**
Amphiura chiajei	[490]
Callianassa subterranea	[491]
Calocaris macandreae	[348]
Cerianthus lloydii	[379, 492, 493]
Glycera spp.	[276, 420]
Mysella bidentata	[397]
Nephrops norvegicus	[494-496]
Nephtys spp.	[277, 278]
Nucula spp.	[321-324]
Philine aperta	[497]
Tharyx spp.	[277]

dispersal period and distance has been inferred from larval type.

Viability of sea-pen and burrowing megafauna communities

There is very little information available on which to assess viability of seapen and burrowing megafauna communities. Most species have a small adult home range and large potential dispersal distances and so only very large areas (**1964 km^2**) would protect all the life cycle stages of most of the constituent fauna. An estimated area of **500 m^2** would protect population viability of most species although there was no data available for seapens.

Ostrea edulis beds

The oyster *Ostrea edulis* is an ecosystem engineer that creates biogenic reef habitat important to estuarine biodiversity [498, 499], benthic-pelagic coupling and energy cycling through the filter feeding of suspended organic matter [500]. Oyster beds may also serve as a nursery ground for small fish [501]. The associated fauna is dominated by other filter feeding and infaunal species that act to increase the efficiency of energy cycling in the oyster reef [502]. The organisms that are characteristic of the filter feeding community in English oyster beds includes sponges such as *Halichondria panicea*, ascidians including *Dendrodoa grossularia* and bryozoans such as *Flustra foliacea* [498, 499]. The subsystem of organisms living in the sediment includes deposit feeders and predators [502]. Animals in these groups that are characteristically found on oyster beds include *Nucula* spp. and predatory polychaetes such as *Harmothoe* spp. [498, 499]. There are several mobile species found on oyster beds but none is thought to be especially important to the ecology of the reef and so have not been included in the characterising list.

Native oyster beds have been in decline for the past 100 years and so the natural dynamics and variability of the habitat are not well reported. Spärck [244] reported that massive changes in population size of *Ostrea edulis* in the Limfjord in Denmark were due to recruitment failure. In contrast, a single year of good recruitment has been seen to result in very large populations and high fishery yields a decade or two later [503]. Thus, it seems that preserving those oyster beds that may be regarded as important breeding stock populations is a priority. For example, it has been reported that native oysters in the Beaulieu estuary appear to act as breeding stock for the western Solent [504].

Ostrea edulis life history traits

- Adult home range - sessile
- Reproduction - Oysters are protandrous alternating hermaphrodites, starting off as sperm producing males, switching to egg producing females, and then changing sex regularly, depending on the water temperature [459]. Spawning requires a minimum temperature of 15 °C [505]. In the UK sexual maturity is reached approximately one year after settlement and oysters are reported to live up to 12 years or more [243, 506]. Eggs are released into the pallial cavity where they are fertilised by externally released sperm, then brooded for eight to 10 days to the veliger larvae stage before being released into the plankton [460].
- Fecundity - highly fecund producing an average of 91,000 eggs in the first year and up to 1.2 million eggs per year in older oysters [240]. Fertilisation efficiency increases with population size so that small beds may have low rates of reproductive success [244].
- Dispersal - in laboratory studies the larvae of *Ostrea edulis* were planktonic for between 10 and 20 days at 18 °C [241, 459, 460] and 17 days at 16°C [507]. German research suggests a larval period of 10-30 days [503].
- Recruitment - the larvae settle on a range of hard surfaces but adult oyster shells and areas of previous spatfall are particularly favoured [242, 243]. Recruitment is generally reported to be sporadic with temperature proposed as a major determinant of success with high settlement observed in warm summers [244]. Oysters do, however, have the potential to build up large and stable populations following strong recruitment as previously observed in the large populations that developed in Limfjord in Denmark [503]. Beds in enclosed bay areas may be self-recruiting but in open ocean areas, where the larvae may be swept away, recruitment is likely to come from elsewhere.

Table 3-54 Summary of viability for *Ostrea edulis* beds and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Ostrea edulis	**0**	**500**	**BR-L-PLK**	**10-30**	**10-40**	**[241, 459, 460]**
Bryozoans	0		EB- L-LEC	2	0-4	[402, 477]
Dendrodoa grossularia	0	16	A + BR-L-LEC	2-3 hrs	<1	[313, 377]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381, 382]
Harmothoe spp.	< 1	103	BR + FS-L-PLK	11-30#	10-40#	[276, 277]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321-324]

dispersal period and distance has been inferred from larval type.

Viability of *Ostrea edulis* beds

There is very little information in the literature to suggest a suitable MPA size for the protection of native oyster beds. The home ranges of *Ostrea edulis* and associated species are small and could be protected by an area of 1 km^2. An area of **500 m^2** is estimated to be the minimum required to protect the genetic viability of Ostrea edulis. The dispersal distance of native oysters is potentially quite high, 10 – 40 km, and so large areas (**79 – 1256 km^2**) would be required to protect the complete life-cycle of the species. The area required for a minimum viable population of oysters is not known. An estimate of larval availability, based on the current distribution of the remaining healthy native oyster beds, is required to inform decisions about potentially smaller protected areas. Site based conservation measures should also be considered since the abundance of larvae and the availability of suitable substrate for larval settlement are crucial for successful settlement and maintenance of existing beds. Particular areas, already identified as potential seed source populations and issues of connectivity should be considered a priority for conservation.

Peat and clay exposures

The soft peat and clay exposures found in littoral and sublittoral habitats will often be bored by the piddocks *Pholas dactylus*, *Barnea* spp. and *Petricola pholadiformis* which is unable to bore into hard clays and chalks [508]. The old bore holes of dead piddocks provide a habitat for a variety of crevice dwellers including small crabs such as *Carcinus maenas* and the snails *Littorina littorea* and *Gibbula cineraria*. Encrusting fauna are often dominated by suspension feeders including barnacles such as *Semibalanus balanoides,* hydroids (e.g. *Obelia longissima*) and the mussel *Mytilus edulis.* The tube building polychaetes *Lanice conchilega* and *Sabella pavonina* may also be present as are anemones such as *Anemonia viridis* and the boring polychaete *Polydora ciliata* [4, 439]. In the littoral zone there may be a turf of algae including *Ceramium* spp. and *Enteromorpha* spp. [509].

Very little primary literature was found regarding the species assemblage or ecology of peat and clay exposures [limited to 439] and so the list of characterising species has been selected from a number of survey reports and from the representative biotopes in the Marine Habitat Classification [4, 510, 511].

Piddock life history traits

- Adult home range - sessile, burrowing habit
- Reproduction - the sexes are separate and fertilization is external [441, 508].
- Fecundity - the fecundity of *Petricola pholadiformis* was reported to be 3 - 3.5 million eggs per year and individuals are relatively long lived (maybe up to 10 years), reaching sexual maturity at 3 years [508]. On the south coast of England some one year old individuals of *Pholas dactylus* were found to be sexually mature and the estimated maximum age was 12 years [442].
- Dispersal - *Pholas dactylus* and *Petricola* produce a planktotrophic veliger larva. The only estimate for larval dispersal period in this species is 45 days [441 cited in Pinn et al. 2005]. This compares with the larval period of a tropical congeneric, *Pholas orientalis*, which is reported to be 10 days at a temperature of 26-29 °C [443]. Maximum larval period for *Petricola*, inferred from time of spawning and presence of larvae in the water column, is estimated to be 6 weeks [508].
- Recruitment - the only information available comes from an analysis of population structure on the south coast of England by Pinn et al. [442] where recruitment of juvenile piddocks (<10 mm) into the population was observed over an extended period between November and February in the course of the 18 month long study.

Table 3-55 Summary of viability for peat and clay exposures and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Pholas dactylus	**0**	**200**	**FS-L-PLK**	**45**	**> 50**	**[442]**
Carcinus maenas	1 – 10		BR-L-PLK	80	12-300	[44, 376]
Enteromorpha spp.	0		S	-	< 10	[274]
Gibbula cineraria	< 1	292	FS-L-PLK	8-9	10	[316, 435]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512-515]
Littorina littorea	< 1	214	BR-L-PLK	30	0-80	[44]
Mytilus edulis	0	29	FS-L-PLK	20-30	40	[269]
Petricola pholadiformis	0		FS-L-LEC	14	25	[409]
Polydora ciliata	0	1	BR-L-LEC	21	40	[277, 444, 445]
Sabella pavonina	0	61	FS-L-PLK	11-30#	10-40#	[402]
Semibalanus balanoides	0	12	BR-L-PLK	14-21	25-40	[279]

dispersal period and distance has been inferred from larval type.

Viability of peat and clay exposures

Piddocks and many of the other species are sessile, or have small adult home ranges so that a small area would protect adults. An area of **292 m^2** would contain the minimum viable population size of 5000 individuals of most of the species found. However, the dispersal distance of most of the organisms in this community is high, over 50 km for some and so a significantly large area, in the order of **1964 km^2** would be required to protect the whole life cycle of the species typical of peat and clay habitats.

However, where there is available habitat piddocks appear to recruit and there are no reports of declines of this species for reasons other than loss of the chalk and peat/clay habitat it requires for settlement.

Sabellaria alveolata reefs

Sabellaria alveolata reefs are often found on sandy shores where they provide a complex habitat in an otherwise homogeneous environment [516]. The additional heterogeneity provided by *S. alveolata* reefs undoubtedly provides a habitat for a range of species although the overall influence of these structures on marine diversity is the subject of much debate [517]. A number of studies have found that the highest levels of diversity are associated with degraded reef where gaps and cavities in the reef provide shelter for a range of crevice dwellers and sediment pools provide a suitable substrate for interstitial animals [518-520]. That biodiversity is highest in degraded reefs highlights the need to protect the complete range of physical reef forms to ensure the continued viability of the associated faunal community.

Sabellaria alveolata colonies in the UK are known to provide attachment for seaweed communities which include the red algal species *Rhodomenia palmata, Chondrus crispus,* and *Polysyphonia* as well as the brown algal species *Fucus serratus* and *Laminaria digitata* [521-523]. The green algae, *Ulva* spp has also been observed in association with older or damaged colonies although this species is thought to be detrimental to the reef and is not present where the reef is actively growing [521, 523]. The surfaces of *S. alveolata* reef are utilised by a number of other epilithic species including sea anemones, barnacles and the tubiculous polychaete *Pomatoceros lamarcki* [516, 520-524].

One of the key ecological functions of *S. alveolata* reefs is likely to be in the provision of microhabitats in the form of crevices and cavities [516]. It is thought that the environmental conditions (temperature, salinity, humidity etc) within these spaces are more constant than those prevalent on the reef surface or adjacent substrate [516]. Fauna known to inhabit these spaces include the polychaetes *Eulalia viridis*, *Phyllodoce lamelligera* and *Pholoe* spp which have been observed in crevices as well as empty tubes, whereupon it has been postulated that they may have eaten the occupants [523]. Other crevice dwelling fauna associated with this habitat include the porcelain crab *Porcellana platycheles* and the small bivalve *Nucula* spp [516, 518, 520]. Larger, mobile animals have also been observed to utilise gaps amongst the reef including the crabs, *Carcinus maenas*, *Cancer pagurus* and *Pilumnus hirtellus* and small fish such gobies and blennies (*Blennius pholis*) [516, 520, 523]. All of these larger animals are thought to predate on *S. alveolata* and this species has been noted in the stomach contents of both *C. maenas* and *B. pholis* [523].

Dense aggregations of the sand mason, *Lanice conchilega* have been observed in the sediments that surround the reef structures, as well as in the sediments which are impounded between colonies [516]. Dense networks of *L. conchilega* tubes in the sand provide additional stability around the reef and through this stability, contribute to the lateral extension of the reefs [516, 520].

Sabellaria alveolata life history traits

- Adult mobility - tube dwelling, sessile
- Mode of reproduction - free spawning with a planktotrophic larva [277]
- Fecundity - in reefs in France a mean value of 100,000 ovocytes per female has been calculated [525]
- Dispersal - the larvae are planktonic and remain in the water column for between 6 weeks and 6 months [277, 520, 526-528] so dispersal can potentially be widespread. In some enclosed bay areas, however, the larvae can be retained in the area and settle locally [529] particularly as the larvae positively respond to chemical cues produced by congeneric adult and juvenile tubes [530]. Slight settlement has been observed in all months except July, with highest concentrations sometimes observed between September and December [522].
- Recruitment - Observations elsewhere also support the observation that intensity of settlement is extremely variable from year to year and place to place (Cunningham et al., 1984; Gruet, 1982). Settlement occurs mainly on existing colonies or their dead remains; chemical stimulation seems to be involved, and this can come from *S. spinulosa* tubes as well as *S. alveolata* (Cunningham et al., 1984; Gruet, 1982; Wilson, 1971).

Table 3-56 Summary of viability for *Sabellaria alveolata* reefs and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Sabellaria alveolata	**0**	**3**	**L-FS-PLK**	**42-228**	**>50**	**[528, 531-533]**
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512-515]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321-324]
Pomatoceros triqueter	0	59	FS-L-PLK	14-60	>40	[277, 437]
Porcellana platycheles	<1		BR-L-PLK	30-60	>50	[401]

Viability of *Sabellaria alveolata* reefs

The species responsible for creating this habitat, *Sabellaria alveolata*, is sessile, remaining within its tube for the duration of its adult life [520]. Assuming a population of 5000 *Sabellaria alveolata* individuals would adequately protect the genetic diversity of this species then an area greater than 3 m^2 would be required to maintain viability. *S. alveolata* has considerable dispersal potential [525] and an area in the order of 1964 km^2 would be required to encompass a self-seeding population. However, *S. alveolata* reefs are intertidal and in the UK are not thought to extend for more than 10 km [523] and so a series of smaller areas no more than 50 km apart would be a more appropriate way to ensure future recruitment events.

In order to adequately protect the home range and population viability of the faunal communities associated with *S. alveolata* reefs an area of at least **118 m^2** would be required. However a much larger area (>**1964 km^2**) would be required to encompass an entirely self-seeding population since all of the fauna associated with *S. alveolata* reefs have a comparable dispersal potential to *S. alveolata* itself. The association between degraded reef and high biodiversity indicates that it would be necessary to protect the full range of reef forms in order to protect the full complement of associated fauna. This may be particularly important for the viability of the associated community and the reef since the role of individual components of the reef is not yet understood.

The viability of this reef habitat is dependant on a number of key environmental conditions. *S. alveolata* are only found in areas of high turbidity maintained by wave or current action [516, 534] and so consideration of the hydrodynamics in the wider area would be necessary. A good supply of medium sized sand grains is also a pre-requisite as they provide the building materials for the reef [520]. A buffer zone around the MPA in which activities likely to alter the hydrodynamic regime or the supply of sand are limited would be required to ensure the continued viability of this habitat. The size of this buffer zone would be very site specific and dependent on local hydrodynamic and geological conditions.

Sabellaria spinulosa reefs

Like its intertidal congener *Sabellaria spinulosa* can build massive reef structures out of sand [535-538]. In contrast to the honeycomb structures built by *S. alveolata* however, *S. spinulosa* reefs are more haphazard and less robust (B. Pearce personal observations). *S. spinulosa* has a relatively ubiquitous distribution in the UK, occurring mostly in the subtidal with some notable intertidal exceptions in Harwich, the Wash and parts of Scotland [535, 539, 540]. Like other Sabellariids, *S. spinulosa* initially attach themselves to a hard surface such as a shell, rock or cobble although this species has also been observed to build reefs in the troughs of stable sand waves in the Bristol Channel [541]. *S. spinulosa* are most frequently encountered as solitary individuals or in small clumps [542] and extensive reef structures are comparatively rare. The Wash is the best known example of a *S. spinulosa* reef in the UK and this is thought to be, in part, due the hydrodynamic regime of the estuary which may help to retain the larvae, ensuring reef regeneration and longevity.

Very little research has been carried out into the ecology of *Sabellaria spinulosa* reefs due to the difficulties in accessing these sublittoral habitats. *S. spinulosa* reefs are thought to perform a similar ecological role to the more widely studied *S. alveolata* reefs, although differences between the reef morphology and the environments in which they occur make it likely that there are differences in their ecological functions which we do not yet fully understand. George and Warwick [541] report an 80% increase in biodiversity associated with *S. spinulosa* reefs in the Bristol channel. However, this represents a special case of *S. spinulosa* reefs having developed in a sandy environment with sparse fauna. Aggregations formed by this species are more commonly found in association with mixed gravel deposits and it is therefore unlikely that this dramatic increase in biodiversity will be observed elsewhere.

References to an association between *S. spinulosa* reefs and the pink shrimp *Pandalus montagui,* have proliferated the grey literature since Warren and Sheldon [543] reported the practice of fishermen to search for *S. spinulosa* reefs using hand held dredges. These reefs are subsequently trawled for shrimp. Since this time *P. montagui* has been recorded in samples of *S. spinulosa* reef off the east coast of England, though the nature of this interaction remains unclear [544-546]. Like the reefs created by its congener, *S. spinulosa* reefs are home to many crevice dwelling animals including the porcelain crab, *Pisidia longicornis* and the polychaetes *Scoloplos armiger* and *Lumbrineris gracilis* [535, 547]. Larger gaps in the reef structure are often inhabited by large crabs and lobster and the queen scallop *Aequipecten opercularis* [542].

The scale worm *Lepidonotus squamatus,* is reported to predate on *S. spinulosa* by inserting its pharynx into the tubes and pulling the heads of the worms with its jaws [548]. More recent studies of *S. spinulosa* reefs have reported the occurrence of *L. squamatus* in reef communities, alongside other carnivorous scale worms including *Pholoe spp* and *Harmothoe* spp, which may also prey on *S. spinulosa* [535, 547]. The surface of the reef is often utilised by anemones and barnacles, particularly *Balanus crenatus,* as well as the tubiculous polychaete *Pomatoceros lamarcki* [535, 547]. The interstitial polychaete *Scalibregma inflatum* was recorded in high abundances in a recent study of *S. spinulosa* reefs at Hastings shingle bank suggesting that fine sediment trapped in empty tubes and crevices may also form an important microhabitat [547].

Sabellaria spinulosa **life history traits**

- Adult mobility - tube dwelling, sessile
- Mode of reproduction - free spawning with a planktotrophic larva [277]
- Fecundity - not reported but likely to be similar to *S. alveolata* (100,000 ovocytes per female [525])
- Dispersal - the larvae are planktonic and when reared in the laboratory metamorphose after a period of 6 weeks to 4 months [549, 550]. Although the larvae are likely to develop more quickly in the sea, this species clearly has considerable dispersal potential [549, 550]. Where *S.spinulosa* reefs occur in enclosed bays and estuaries, the larvae are likely to be retained and settle locally [551] particularly as the larvae respond positively to chemical cues produced by the cement secretions of adults and juveniles of their own species [550].
- Recruitment - the seasonality of both spawning and recruitment is unclear. There have been several reports of settlement occurring between March and April [541, 550] although there have been sporadic observations of the larvae in the water column throughout much of the year [541, 550, 552, 553]. There have been no studies on the recruitment success of *S. spinulosa* but investigations into the recoverability of this species found that recruitment occurred within three months of the cessation of aggregate extraction [547]. Observations made by George and Warwick [541] and Wilson [550] however, suggest that recruitment success may be variable.

Table 3-57 Summary of viability for *Sabellaria spinulosa* reefs and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Sabellaria spinulosa	**0**	**7**	**L-FS-PLK**	**42-112**	**>40**	**[550]**
Aequipecten opercularis	< 1	208	FS-L-PLK	11-30	10-40	[402, 554]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Lepidonotus squamata	< 1	149	FS - PLK	11-30#	10-40#	[478]
Lumbrineris gracilis	< 1	135	BR-DIR	0	0	[277, 555]
Pandalus spp.	< 1	500	BR-L-LEC	60-90	0-330	[162, 326, 327]
Pisidia longicornis	< 1	18	BR-L-PLK	30-60	>50	[400, 401]
Pomatoceros triqueter	0	59	FS-L-PLK	14-60	>40	[277, 437]
Scoloplos armiger	1 – 10	89	E-DIR	0	0	[277]

dispersal period and distance has been inferred from larval type.

Viability of *Sabellaria spinulosa* reefs

Although the life cycle and ecological function of *S. spinulosa* reefs has been the subject of far less research than reefs built by *S. alveolata,* and whilst there are some obvious differences between the two habitats, many of the considerations in terms of habitat viability are the same. *S. spinulosa* is a sessile tubiculous species and an area <1 m^2 would be adequate to protect the home range of this species. Assuming a population of 5000 individuals would adequately protect the genetic diversity of this species then an area greater than 7 m^2 would be required to maintain viability although an area of **500 m^2** is estimated for the associated community.

The dispersal potential of *S. spinulosa* is less than that of *S. alveolata* [550] but nevertheless an area greater than **1257** km^2 would be required to encompass the whole life cycle. An alternative to such a large area of protection would be a series of smaller protected areas no more than 40 km apart, although water movements would need to be studied in some detail to ensure connectivity of the sites.

There have been no direct studies on the morphological variation of reef structures built by *S. spinulosa.* However, the massive structures present in the Wash [535] are very different from the reef complexes observed further offshore [544, 547, 556]. The ecological significance of different reef forms would need to be established before a reliable assessment of habitat viability could be made. In the meantime a precautionary approach would be advisable, and MPAs for this habitat should incorporate as much morphological variation as possible.

Like its congener, *S. spinulosa* requires sand for building material and high levels of turbidity although again this is an area which would benefit from targeted research. An area around the core MPA in which activities likely to alter the hydrodynamic regime or the supply of sand are limited would be required to ensure the continued viability of this habitat. The extent of this area would be very site specific and dependent on local hydrodynamic and geological conditions.

Saline lagoons

Saline lagoons support a range of opportunistic and specialist species from freshwater, estuarine (brackish) and fully marine sources [557, 558]. Filamentous algae including *Enteromorpha* spp. may be present in saline lagoons and a range of animals, including molluscs, polychaetes and crustaceans, are common [559].

Many saline lagoons have low diversity but there are a number of specialist 'lagoonal' species that are largely or entirely restricted to this habitat [558]. A number of these species are rare or scarce in the UK and are afforded statutory protection under the Wildlife and Countryside Act (1981). These species are the starlet sea-anemone *Nematostella vectenensis*, the polychaetes *Alkmaria romijni* and *Armandia cirrhosa*, the lagoonal amphipod *Gammarus insensibilis*, the snail *Caecum armoricum* and the nudibranch *Tenellia adspersa*. These species are assessed individually for viability in the species section of this report.

Other species restricted to lagoonal, and similar, habitats includes the bivalve *Cerastoderma glaucum*, the small mudsnails *Hydrobia ventrosa* and *Hydrobia neglecta*, *Littorina tenebrosa* and the isopod *Idotea chelipes.* Other, less specialist, species found in saline lagoons include *Abra tenuis, Hydrobia ulvae, Corophium volutator and Palaemon spp.* [559].

Coastal lagoons are ephemeral habitats, naturally lasting from tens to hundreds of years. Some may become extinct whilst others change through a process of natural evolution to become freshwater habitats. An example of a change in lagoon type has been observed in Slapton Ley in Devon, a brackish lagoon that has degraded to a freshwater system over a number of years [560]. Natural factors such as sediment deposition and storms can also cause spatial and temporal variability. For example, in Suffolk a 25,000 m^2 lagoon at Shingle Street had been reduced to approximately 30 m^2 when storms moved a mass of shingle into the lagoon. Within a year the lagoon had ceased to exist [557].

Several studies have indicated that the connection to the sea is crucial to the stability of saline lagoons [559, 561]. Water bodies with unreliable connections to the sea tended towards freshwater plant and animal communities, even though storm surges or through flow could elevate salinity levels.

There has been some investigation of the temporal variation in brackish and saline lagoon communities which show that algal and invertebrate communities and populations in lagoons can be subject to rapid and unpredictable changes [559, 562]. These changes were related to short and long term changes in salinity and tidal regime and indicate the critical role of saline water supply in the maintenance of communities. Some specialist lagoonal species, however, may be especially adapted to characteristically dynamic environments.

Table 3-58 Summary of viability for saline lagoons and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	LARVAL DISPERSAL (km)	REFERENCES
Abra tenuis	< 1	26	DIR	0	0	[347]
Alkmaria romijni	< 1		BR-DIR	20	10-100	[70-72]
Armandia cirrhosa **Armandia* spp.	< 1	47	FS-L-PLK	21-180	15-1000	[62, 563]
Caecum armoricum **Truncatella subcylindrica*	< 1		BR-DIR	0	0	[224, 564, 565]
Cerastoderma glaucum	<1		FS-L-PLK	7	10	[566]
Corophium volutator	< 1	1	DIR	0	<1	[270-273]
Enteromorpha spp.	0		S	-	<10	[274]
Gammarus insensibilis	0-10		BR–DIR	0	0	[171, 175, 176]
Hydrobia neglecta	< 1		E-DIR	0	0	[567, 568]
Hydrobia ulvae	< 1	6	BR-L-PLK or DIR	20-30	40	[349, 569]
Hydrobia ventrosa	< 1		E-DIR	0	0	[276, 567, 568]
Idotea chelipes	< 1	500	BR-DIR	0	0	[570]
Littorina tenebrosa	< 1		BR-DIR	0	0	[276]
Nematostella vectensis	0		AB	0	0	[155, 156]
Palaemon spp.	0 - 10	500	BR-L-PLK	30-60	>40	[571]
Tenellia adspersa	< 1	32	DIR + BR-L-LEC or PLK	5	<10	[246, 249]

Viability of saline lagoons

Many of the key and specialist lagoonal species have limited mobility and are restricted to lagoon habitats. Many of the specialist lagoonal species do not occur in coastal waters and the extreme species poverty of some lagoons, despite the presence of suitable habitat, suggests that dispersal between lagoons is limited [572]. As an example, dispersal of the isopod *Idotea chelipes* between lagoons in Dorset was found to be limited despite their proximity to each other [573] and similarly adjacent lagoons in east Anglia possess widely different fauna suggesting highly variable recruitment of a range of different species [558]. Suggestions of dispersal of lagoonal species by birds' feet have not been borne out by investigations [558]. Dispersal of animals may be associated with the dispersal of algal material during coastal floods but, if this is so, in some lagoonal areas the supply of colonists may have been cut off by recent coastal defence works [558].

There is however, evidence of some dispersal of the lagoonal species from observations of colonisation within six years of a dock redevelopment [574]. For example, the lagoonal specialists *Corophium insidiosum* and *Palaemonetes varians* had recruited to a redeveloped dock from other impounded water bodies on the Mersey Estuary. This may indicate that dispersal from lagoons that have a connection to the sea is possible.

Saline lagoons tend to be highly individual in terms of lagoon type, size (ranging from <1 to 800 ha), connection to the sea and the diversity and composition of the faunas they support.

Given this, the relatively restricted distribution, the intrinsic nature of the habitat and the current raft of conservation designations already applied, this habitat is particularly suited to site-based conservation measures. In particular, a reliable connection to the sea should be considered an important factor when selecting suitable sites for MPA status as this ensures a supply of larvae to the sites and the maintenance of the saline condition.

Those lagoons known to harbour UK BAP lagoonal species should also be included and where possible the largest lagoons possible selected because of the known increase in species number with lagoon size [557].

Seagrass beds

In the British Isles, three species of seagrass (also known as eelgrass) of the genus *Zostera* occur, the common eelgrass *Zostera marina*, the narrow-leaved eelgrass *Zostera angustifolia* and dwarf eelgrass *Zostera noltii*. All three species are considered scarce in the UK [575]. Seagrass beds generally occur in areas of soft sediment where the blades of the seagrass plants and the subterranean rhizomes substantially increase habitat complexity which provides shelter for a wide range of flora and fauna not found in the surrounding areas [576 and the references therein, 577]. Small mudsnails such as *Hydrobia ulvae* and *Hydrobia ventrosa* are important epiphytic grazers keeping the seagrass blades clear of fouling epiphytes [578]. The sediments of seagrass beds support a number of polychaetes including the lugworm *Arenicola marina* and the sandmason *Lanice conchilega* [579] that contribute to detrital based food chains. Seagrass beds may also be associated with some commercial bivalve species such as *Cerastoderma edule* and *Cerastoderma glaucum* [580]. There are a large number of other species found in seagrass habitats but none are thought to be as frequent and faithful.

Over the past 80-90 years the overriding dynamic affecting the number and extent of *Zostera* beds has been the loss of ~ 90 % of beds, particularly in the subtidal, due to a fungal wasting disease [581]. Seagrass beds are however, naturally spatially and temporally dynamic and natural seasonal and longer term changes have been observed [582, 583]. In the UK *Zostera* spp. growth is highly seasonal, peaking in the spring and summer months when total biomass can increase dramatically [578, 584]. In winter months many beds, particularly those in the intertidal, die back to the buried rhizomes as leaves are lost to grazing and wave action [585]. In perennial populations the rhizomes survive the winter to produce new leaves in the spring and the beds develop over the littoral flats during the summer. Storms, hurricanes and extreme winters are also able to remove large areas of habitat [586, 587].

A study of *Zostera marina* beds in Denmark showed substantial changes in the size and position of beds between years with the greatest shifts observed at the more exposed sites [588]. For example, over a four year period some beds had migrated 10-50 m. Stability of seagrass beds is also related to patch size with small beds subject to a higher risk of mortality although many small patches may result from seed dispersal from nearby patches. This is important in terms of further colonisation [588, 589].

In the UK typical seagrass beds are small (100 m² to a few km^2) [590].

Zostera species life history traits

- Adult home range - individual plants have a home range of a few cm^2 but the clone complex interconnected by a subterranean network of rhizomes can extend to many metres [e.g. 17 m observed in the Baltic: 591].
- Reproduction - Seagrasses reproduce asexually and sexually, the proportion of each mode varying between different species and populations. Asexual reproduction via vegetative growth of the underground rhizome network and production of vertical leaf shoots, also known as clonal growth, occurs in all *Zostera* species but appears to be particularly important for *Zostera marina* in UK waters [592]. In contrast *Zostera noltii* and *Zostera angustifolia* in the UK are reported to rely on a combination of vegetative growth and sexual seed production [580](ref).
- Fecundity - low levels of sexual reproduction in *Zostera marina* in UK waters reported
- Dispersal - in field experiments Orth and others [593] observed that hand broadcast seeds of *Zostera marina* rapidly sink to the substrate and that 80% or more of the seeds germinate within 5 m of release suggesting limited dispersal potential. However, genetic analysis of populations in the Wadden Sea and the Baltic showed significant genetic flow between populations that were 60 km so some seeds are able to disperse greater distances [594]. The rafting of reproductive shoots with mature seeds has also been identified as a potential medium range (several km) dispersal mechanism [592].
- Recruitment - appears to be very poor. There has been little recovery of seagrass beds in the UK since the losses in the 1930s [580]. Seed mortality is generally thought to be very high and there are few observations of the presence of seedlings in UK seagrass beds.

Table 3-59 Summary of viability for seagrass beds and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Zostera spp.	**0**		**AV + Seeds**	**-**	**0.05-60**	**[593, 594]**
Arenicola marina	< 1	188	E-B-J	0	1-10	[417-419]
Cerastoderma edule	<1	5	FS-L-PLK	14-21	25-40	[566]
Cerastoderma glaucum	<1		FS-L-PLK	7	10	[566]
Hydrobia ulvae	< 1	6	BR-L-PLK or DIR	20-30	40	[349, 569]
Hydrobia ventrosa	< 1		E-DIR	0	0	[276, 567, 568]
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512-515]

Viability of seagrass beds

The area required to protect the home range and predominant dispersal distance of ~ 5 m observed in the UK is probably small. There are seagrass beds as small as 100 m^2 although there was no information on the persistence of these beds. Studies in other countries have shown genetic exchange between widely separated populations and so the potential for large dispersal distances should also be considered in both size and connectivity of protected seagrass habitats. With dispersal potential estimate to be up to 60 km an area up to **2827 km^2** would be required for the whole life-cycle. The available data on the area required to protect the genetic viability (MVP) of species indicates an area of **188 m^2** would be adequate.

Sheltered muddy gravels

Sheltered muddy gravel habitats are found in areas protected from wave action and strong tidal streams and are primarily found in estuaries, rias (drowned river valleys) and sea lochs. The complex nature of the sediment, which is made up of a mix of particle sizes, enables a rich diversity of fauna to exist although bivalve molluscs and polychaete worms are normally dominant. Common bivalve species are *Venerupis senegalensis*, *Mya truncata* and *Mya arenaria*. Tube building polychaetes such as *Sabella pavonina* and *Terebellides stroemi* and deposit-feeding polychaetes including *Notomastus latericeus*, *Aphelochaeta marioni* and *Melinna palmata* are found in muddy gravel habitats [4, 595]. The burrowing anemone *Cereus pedunculatus* is also likely to be common. The presence of coarse gravel and stones at the sediment surface often provides a substratum for the attachment of a variety of algae, for example fucoids, reds and ephemeral greens with associated littorinids such as *Littorina littorea*.

Information on this habitat type was lacking for several reasons: the habitat is relatively scarce; there has been little specific research found; the biotopes stated to be part of this habitat no longer exist particularly in terms of constituent biotopes (some of which appear to no longer exist); and because there has been little primary research published. All species have been selected on the basis of the BAP report.

There was no information found on the spatial and temporal variability of the habitat.

Table 3-60 Summary of viability for sheltered muddy gravels and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Aphelochaeta marioni	< 1	6	FS-L-LEC	10	10-40	[277, 596]
Cereus pedunculatus	0		A + B	0	0	[384, 402, 597]
Fucus spp.	0		S	-	<10	[274]
Littorina littorea	< 1	214	BR-L-PLK	30	0-80	[44]
Mya arenaria	<1	158	FS-L-PLK	11-30	11-40	[421]
Mya truncata	< 1	278	FS-L			[276]
Sabella pavonina	0	61	FS-L-PLK	11-30#	10-40#	[276, 402]
Terebellides stroemi	< 1	303	DIR	0	0	[277]
Venerupis senegalensis	<1	344	L-PLK	11-30#	11-40#	[598]

dispersal period and distance has been inferred from larval type.

Viability of sheltered muddy gravels

The species which characterise this habitat are all sessile or of limited home range. An area of **344 m^2** would adequately encompass the movements of adult species and ensure the genetic viability of the community. The dispersal potential of many of these species however is high and so an area greater than **1256 km^2** would be required to allow for a self-sustaining community of these species. Many of these species are widely distributed around the UK ensuring a good larval supply, which indicates that considerably smaller areas will encompass larval recruitment to the habitat.

Subtidal chalk

Subtidal chalk habitats are typically bored by bivalve molluscs, the most widespread of which is *Pholas dactylus,* the empty bore holes of which provide habitat for a range of crevice dwelling animals. Other boring species found in these habitats include the polychaete *Polydora ciliata* and yellow boring sponge *Cliona celata*. There is also often a turf of encrusting fauna including sponges such as *Halichondria panicea*, hydroids, bryozoans (*Flustra foliacea*), the colonial ascidian *Clavelina lepadiformis*, anemones including the Devonshire cup coral *Caryophyllia smithii* and *Urticina felina* [4, 440, 599, 600]. In the shallow subtidal, laminarian kelps (*L. hyperborean* and *L. saccharina*) and a turf of red algae may also be present [510]. In deeper water the plumose anemone *Metridium senile* and soft coral *Alcyonium digitatum* are often found [510, 511]. Common mobile species are *Cancer pagurus*, *Asterias rubens* and the butterfish *Pholis gunnellus*

There was almost no primary literature found on the biology and ecology of subtidal chalk habitats. There have however been a number of survey reports produced and these have informed our decision making for the selection of characterising species for the habitat [510, 511, 600]. No information at all was found in relation to natural community dynamics in subtidal chalk habitats.

Pholas dactylus life history traits

- Adult home range - sessile, burrowing habit
- Reproduction - the sexes are separate and fertilization is thought to be external [441].
- Fecundity - the fecundity of *Petricola pholadiformis* was reported to be approximately 3 million eggs per year and individuals are relatively long lived (maybe up to 10 years) [508]. On the south coast of England some one year old individuals were found to be sexually mature and the estimated maximum age was 12 years [442].
- Dispersal - *Pholas dactylus* produces a planktotrophic veliger larva. The only estimate for larval dispersal period in this species is 45 days [441 cited in Pinn et al. 2005]. This compares well with the larval period of a tropical congeneric, *Pholas orientalis*, which is reported to be 10 days at a temperature of 26-29 °C [443].
- Recruitment - the only information available comes from an analysis of population structure on the south coast of England by Pinn et al. [442] where recruitment of juvenile piddocks (<10 mm) into the population was observed over an extended period between November and February in the course of the 18 month long study.

Table 3-61 Summary of viability for subtidal chalks and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Pholas dactylus	**0**	**200**	**FS-L-PLK**	**45**	**>50**	**[442]**
Alcyonium digitatum	0		FS-L-PLK	>180	>50	[374, 375]
Asterias rubens	1 - 10	294	FS-L-PLK	<90	>50	[393, 394]
Cancer pagurus	1 - 10		BR-L-PLK	23-30	40	[601, 602], [603]
Caryophyllia smithii	0		A + FS-L-PLK	56-70	>50	[404-406]
Clavelina lepadiformis	0		FS-L-LEC	0.2	<1	[118, 407, 408]
Cliona celata	0	55	A + FS-L-LEC	2	5	[409, 410]
Flustra foliacea	0		A + FS-L-LEC	Few hrs	<1	[420, 477]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381, 382]
Laminaria spp.	0		S	-	<10	[274]
Metridium senile	0		AB	0	0	[384]
Polydora ciliata	0	1	BR-L-LEC	21	40	[277, 444, 445]
Urticina felina	0	173	FS-L-PLK	11-30#	10-40#	[402]

dispersal period and distance has been inferred from larval type.

Viability for subtidal chalk

This habitat is dominated by sessile organisms that have very small adult home ranges. MVP data was available for only a few species which estimates an area of 200 m^2 would be adequate to protect the genetic variability of *Pholas dactylus*, *Cliona celata* and *Polydora ciliata*, all species that are able to bore into chalk and increase habitat heterogeneity. Dispersal distances of species range from very short, probably 10s of metres in the case of some of the bryozoans and ascidians, to maximum potential dispersal distances of greater than 50 km in the piddocks and anthozoans. Very large areas, in the order of **1964 km^2**, would be required to encompass the entire life-cycle of the wide dispersers. However, considering most species are very widespread, larval supply should also be widespread and so much smaller protected areas would be sufficient to protect all life-cycle stages.

Subtidal sands and gravels

As it stands, the habitat category of subtidal sands and gravels encompasses a large proportion of the sublittoral environment in UK waters. Depth, salinity, sediment stability and hydrodynamic exposure all influence the composition of the faunal communities which inhabit this broad habitat [604, 605] and a viability assessment at this scale would not be meaningful. Therefore, for the purpose of this assessment the eight subclasses suggested by the UK BAP Steering Group in 2007 have been adopted;

- Estuarine coarse sediment
- Coastal coarse sediment
- Shallow coarse sediment
- Shelf/ offshore coarse sediment
- Estuarine sand
- Coastal sand
- Shallow sand
- Shelf/ offshore sand.

These subclasses have yet to be defined and so for the purpose of this assessment the following definitions have been adopted. Sand habitats incorporate deposits which are mainly sand (>80%); all other sand and gravel combinations will be covered by the coarse sediment categories. Estuarine habitats refer to partly enclosed coastal bodies of water with variable salinity. Coastal habitats are defined as those which are within the 6 nautical mile limit and influenced by wave exposure. Shallow habitats are defined here as being <20m and beyond the 6 nautical mile limit. Shelf / offshore habitats are defined as habitats beyond the 6 nautical mile limit in water depths >20m.

a) Estuarine coarse sediment

Most estuaries have soft, muddy substrates which are derived from sediment carried into the estuary from rivers and the sea. Where very high water currents exist fine particles are kept in suspension and only the coarser fractions are able to settle, leading to the development of coarse estuarine deposits. Because these coarse deposits only exist in the presence of very fast water currents the fauna communities they support are often impoverished [606, 607]. Larvae are unable to settle out of the water column and so recruitment to these habitats is reliant primarily on adult movements. Finer sediment carried in the fast moving water will also act to scour the surface of coarse sediment so that it is near impossible for epifauna to establish in these environments.

A recent survey of the Bristol Channel found that the coarse mid-channel sediments were largely afaunal, occasionally supporting small (visibly scoured) clumps of *Sabellaria alveolata*, and impoverished epifauna including the hydroid *Sertularia* [606]. The coarse mid-channel deposits of the Thames estuary support a characteristic fauna which includes the barnacle *Balanus crenatus* and *Elminius modestus* as well as the Ross worm *Sabellaria spinulosa* [608]. The blue mussel *Mytillus edulis* has been found in association with coarse sediments in the outer reaches of both the Thames and the Tay estuaries and it seems possible that dense mussel beds could occur in these areas where the current speeds have dissipated [607, 608].

Table 3-62 Summary of viability for estuarine coarse sediment and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	(km)	REFERENCES
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Mytilus edulis	0	29	FS-L-PLK	20-30	40	[269]
Sabellaria alveolata	0	3	FS-L-PLK	42-228	>50	[60, 277]
Sabellaria spinulosa	0	7	FS-L-PLK	42-112	>40	[60, 609]

Viability of estuarine coarse sediment

The species which characterise this habitat are all sessile and a small area (<**29 m^2**) would adequately encompass the movements of adult species and ensure the genetic viability of the community. The dispersal potential of these species however is high and our estimates may be low considering the high current speeds which exist in these habitats. An area greater than **1964 km^2** would be required to allow for a self-sustaining community of these species. Perhaps of greater importance in terms of the viability of this particular habitat is the maintenance of the hydrodynamic regime. If the flow of water were to be interrupted in these areas it could completely change the nature of the substrate and hence the fauna which it is able to support.

b) Coastal coarse sediment

Sublittoral sediment deposits in UK waters are essentially submerged relics of Quaternary river systems [610]. Sea level changes caused by glaciations repeatedly exposed areas of the present day continental shelf as dry land, upon which sand and gravel was deposited by ancient river systems. These old river systems were submerged when sea levels rose after the last ice age and today the sediments they contain have been re-worked by the action of the sea leaving clean well sorted aggregate deposits in many areas [610]. Coastal coarse sediments are exposed to considerable wave and tidal action which may serve to sort the sediment deposits further.

A number of studies have been carried out to investigate the communities of coastal coarse sediment habitats [604, 611-614]. Dense *Sabellaria* aggregations have been reported to occur in these deposits by a number of authors [611]. *Sabellaria* are capable of creating significant reef structures which are considered as habitats in their own right and are dealt with elsewhere in this report. However, these polychaetes exist in a number of forms and clumps or aggregations which would not necessarily be considered as reef are relatively common in association with coastal coarse sediments and hence they have been included in this assessment.

Other species which have been found to be frequent and faithful components of coastal coarse sediment habitats include epilithic species such as the barnacles, *Balanus crenatus*, the tubiculous polychaetes *Pomatoceros* spp, ascidians including *Distomus variolosus* and erect hydroids and bryozoans such as *Flustra foliacea* [611, 612, 614, 615].

In addition to the fauna living on the surface of the sediments, coastal coarse sediments also support a diverse infauna. Robust bivalve molluscs are a key component of these infaunal communities contributing significantly to the biomass and the wider food web. The dog cockle *Glycymeris glycymeris* is an example of one such robust bivalve. Other bivalves which are characteristic of coastal coarse sediments include *Venus* spp, *Astarte triangularis* and *Nucula* spp [611-615]. Polychaetes, particularly *Lumbrineris* spp., *Glycera* spp. and Syllidae are also characteristic of the infaunal communities supported by coastal coarse sediment habitats and these occur alongside amphipod crustaceans including *Ampelisca* spp. and the pea urchin *Echinocyamus pusilus* [604, 611-615].

The American slipper limpet, *Crepidula fornicata* has also become a common feature of coastal coarse deposits following its introduction in to UK waters [611, 612, 615]. This species is not thought to enhance any aspect of this habitat and given its alien status has not been included in this review.

Table 3-63 Summary of viability for coastal coarse sediment and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	LARVAL DISPERSAL (km)	REFERENCES
Ampelisca spp.	1 - 10	100	BR-DIR	0	0	[437, 555]
Ascidians	0	65	FS-L-LEC	<1	<0.25	[44]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Echinocyamus pusillus	< 1	99	FS-L-PLK	30-60	>40	[276]
Flustra foliacea	0		A + FS-L-LEC	Few hrs	<1	[420, 477]
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40	[276, 420]
Glycymeris glycymeris	< 1	153	FS-L-LEC	1-10#	4-10#	[616]
Lumbrineris spp.	< 1	135	BR-DIR	0	0	[277, 555]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321-324]
Pomatoceros triqueter	0	59	FS-L-PLK	14-60	>40	[277, 437]
Sabellaria alveolata	0	3	FS-L-PLK	42-228	>50	[60, 277]
Sabellaria spinulosa	0	7	FS-L-PLK	42-112	>40	[60, 609]

dispersal period and distance has been inferred from larval type.

Viability of coastal coarse sediment

Coastal coarse sediment habitats support a diverse range of fauna with representatives from most phyla and most functional groups. The mobility of the species typical of this habitat is somewhat limited and so an area of less than 1 km^2 is thought to be adequate to protect the home range and an area of **202 m^2** is expected to ensure the persistent genetic viability of fauna associated with this habitat. The dispersal potential of some components of this community is conversely very high and an area greater than **1964 km^2** would be required to incorporate this element of their life cycle.

c) Shallow coarse sediment

There is considerable overlap between shallow coarse sediment habitats and their coastal counterparts and a very similar suite of fauna are reported to be frequent and faithful. The surface of the sediments is occupied by a range of epilithic fauna including ascidians such as *Pyura microcosmus* and there is a strong bivalve component to the infauna including *Glycymeris glycymeris, Venus verrucosa* and *Timoclea ovata* [617]. The limited literature concerned with this habitat suggests that mobile epifauna, including the brittle star *Ophiothirx fragilis*, the hermit crabs *Pagurus bernhardus* and, *Anapagarus laevis* and the whelks *Buccinum* *undatum* and *Hinia reticulata* are particularly important components of the faunal community [617]. However, it should be noted that in the absence of any studies designed to investigate how these closely related coarse sediment deposits differ, the species identified as characteristic should be treated with some caution.

Table 3-64 Summary of viability for shallow coarse sediment and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Ascidians	0	65	FS-L-LEC	<1	<0.25	[44]
Buccinum undatum	1 – 10	433	E-DIR	0	0	[437, 618]
Ophiothrix fragilis	< 1	95	FS-L-PLK	21-26	40	[162, 398, 399]
Pagurus bernhardus	1 - 10	423	BR-L-PLK	11-30#	10-40#	[437, 619]
Venus spp.	< 1	333	FS-L-LEC			[620]

dispersal period and distance has been inferred from larval type.

Viability of shallow coarse sediment

Like their coastal counterparts, shallow coarse sediment habitats support a diverse range of fauna with representatives from most phyla and most functional groups. There is a mixture of sessile and mobile species present with home ranges estimated to a maximum of 10 km. Many of these mobile species (such as hermit crabs and brittle stars), however, are common. An area of **433 m^2** is thought to be necessary to protect the genetic viability of fauna associated with this habitat. The dispersal potential of some components of this community is reported as moderate to high and an area in the order of **1257 km^2** is thought to be required for a self-sustaining shallow coarse sediment community. The species present, however, are common in UK waters with a good larval supply such that smaller protected areas of suitable habitat would be adequate to protect shallow coarse sediment communities.

d) Shelf / offshore coarse sediment

Offshore coarse sediment is perhaps the best studied subclass of the sublittoral sand and gravel habitat because of its importance to the aggregate extraction industry [617, 621-623]. Even within this subclass there exists significant variability in the nature of the habitat and hence the fauna which it supports. The coarse sediments of the English Channel contain large proportions of shell and cobbles [617, 622, 624], whereas the North sea coarse sediments are mostly composed of sand and gravel [622]. There are also longitudinal gradients if the composition of marine fauna meaning that species which are common in the coarse sediment deposits of the English Channel may be completely absent from the North Sea and Vice Versa.

Offshore coarse sediment habitats support a diverse suite of fauna with representatives from mast taxonomic and functions groups. The epifauna which inhabit these deposits include epilithic species such as, sea anemones (Actiniaria), barnacles (*Balanus crenatus*), ascidians (*Dendrodoa grossularia*), tubiculous polychaetes (*Sabellaria spinulosa* and *Pomatoceros* spp.) and erect hydroids (*Sertularia* spp) and bryozoans (*Flustra foliacea*) [604, 613, 617, 621, 622].

A range of mobile epifauna also inhabit offshore coarse sediments including the sea urchin *Psammechinus miliaris*, the queen scallop, *Aequipecten opercularis* , brittle stars including *Ophiura albida* and small crabs such *Atelecyclus rotundatus* and *Pisidia longicornis* [604, 621, 622].

A vast array of organisms also utilise the sediment running between the coarse sediments. Polychaetes dominate this element of the community with members of most families being present in most areas. The sand mason, *Lanice conchilega* is able to construct its sediment tubes between the coarse sediments which can act to stabilise the deposits. Other polychaetes are important primarily as a source of food for larger marine animals; these are mostly interstitial polychaetes that swim through the sediments and include representatives from the families Polynoidae and Pholidae (Scale worms), Lumbrineridae, Cirratulidae, Phyllodocidae (paddle worms) and Syllidae as well as many others [604, 621, 622].

Small crustaceans, particularly amphipods live alongside the polychaetes. The most common being *Ampelisca* spp. and *Bathyporeia* spp. [622]. Like other coarse sediment habitats offshore sediment deposits are an important habitat for robust bivalve molluscs including *Nucula* spp., *Spisula* spp. as well as the dog cockle *Glycymeris glycymeris* and various venerid bivalve species [613, 617, 621, 622].

Table 3-65 Summary of viability for shelf/offshore coarse sediment and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL	
				(days)	(km)	REFERENCES
Aequipecten opercularis	< 1	208	FS-L-PLK	11-30	10-40	[402, 554]
Ampelisca spp.	1 - 10	100	BR-DIR	0	0	[437, 555]
Atelecyclus rotundatus		421	BR-L-PLK	<30	40	[625]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Bathyporeia elegans	< 1	58	BR-DIR	0	0	[348, 555]
Cirratulidae **Tharyx*	0	7	BR-DIR	0	0	[277]
Dendrodoa grossularia	0	16	A + BR-L-LEC	2-3 hrs	<1	[313, 377]
Flustra foliacea	0		A + FS-L-LEC	Few hrs	<1	[420, 477]
Glycymeris glycymeris	< 1	153	FS-L-LEC	1-10$^{\#}$	4-10$^{\#}$	[616]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512-515]
Lumbrineris spp.	< 1	135	BR-DIR	0	0	[277, 555]
Ophiura spp.	< 1	112	FS-L-PLK	300	>50	[555, 626]
Phyollodocidae **Eumida*	< 1	88	FS-L-PLK	56	>50	[60, 493]
Pisidia longicornis	< 1	18	BR-L-PLK	30-60	>50	[400, 401]
Pomatoceros spp.	0	59	FS-L-PLK	14-60	>40	[277, 437]
Psammechinus miliaris	< 1	299	FS-L-PLK	14-21	<30	[276, 555]
Sabellaria spinulosa	0	7	FS-L-PLK	42-112	>40	[60, 609]
Spisula spp.	< 1	282	FS-L-PLK	30	40	[627, 628]
Syllidae **Exogone hebes*		106	BR-DIR	0	0	[277, 555]

dispersal period and distance has been inferred from larval type.

Viability of shelf/offshore coarse sediment

Offshore coarse sediment habitats have been well studied and whilst the list of characteristic species is long it is thought to be a good representation of the fauna which depend on this habitat. The variety of species present and the spatially separate distribution of some components mean that a relatively large area of around **421 m^2** would be necessary to incorporate the home ranges and genetic viability of all of the components of this community. A much larger area exceeding **1964 m^2** would be necessary to incorporate the whole life cycle of this community but since many of the species present in this community have a ubiquitous distribution around the UK it would perhaps be more appropriate to protect this community through a series of smaller sites approximately 50km apart.

e) Estuarine Sand

The oscillatory nature of estuarine tides means that sand ripples are continually modified and the surface of these habitats are often very unstable [629]. Because these sediments are being continually re-worked by the estuarine currents they also tend to be very well sorted (homogenous). The instability and homogeneity of this habitat means that it generally supports a limited range of benthic fauna [606, 630-634]. Despite this, Elliot and Hemmingway found this habitat to be the single most important habitat for fish, in terms of its capacity as a spawning ground, nursery ground and feeding ground [634].

One group of fauna which do seem to thrive in estuarine sands are the bivalve molluscs. Warwick and others [630] describe a *Venus* community in Carmarthen Bay which is dominated by *Pharus legumen* and *Tellina fabula.* Dense populations of the cockle *Cerastoderma edule* have been identified from the Thames estuary and Solway Firth alongside the mussel *Mytilus edulis* and *Macoma balthica* [608, 632, 633], and dense aggregations of the razor clam *Ensis* spp. have also been identified in the Thames estuary [608].

A number of polychaete worms are also characteristic of this habitat such as *Nephtys* spp., *Glycera* spp, *Arenicola marina, Scoloplos armiger* and the Spionid worms *Spiophanes bombyx, Streblospio shrubsolii, Spio spp* and *Magelona spp* [606, 608, 630, 631]. A number of amphipods are also common in these habitats including *Urothoe* spp., *Haustorius* spp. and *Bathyporeia* spp., where there is a significant proportion of mud *Corophium* spp are also likely to be present [608, 630, 631]. Echinoderms are not common in this habitat since they are all fully marine but in the outer reaches of estuaries where fresh water has become suitably diluted burrowing sea potatoes including the heart urchin *Echinocardium cordatum* are relatively common [608, 630]. The high current speeds and variable salinities make this habitat unfavourable to most mobile epifauna but the masked crab *Corystes cassivelaunus* is often recorded here [608, 630].

Table 3-66 Summary of viability for estuarine sands and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Arenicola marina	< 1	188	E-B-J	0	1-10	[417-419]
Bathyporeia spp.	< 1	58	BR-DIR	0	0	[348, 555]
Cerastoderma edule	<1	5	FS-L-PLK	14-21	25-40	[566]
Corophium spp.	< 1	1	DIR	0	<1	[270-272]
Corystes cassivelaunus	< 1	478	BR-L-PLK	11-30	10-40	[635, 636]
Echinocardium cordatum	< 1	235	FS-L-PLK	39	50	[637]
Ensis spp.	< 1	37	FS-L-PLK	20-30	40	[416]
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40	[276, 420]
Macoma baltica	< 1	18	FS-L-PLK	30-360	>40	[422, 423]
Mytilus edulis	0	29	FS-L-PLK	20-30	40	[269]
Nephtys spp.	< 1	81	FS-L-PLK	49-56	>50	[277, 278]
Scoloplos armiger	1 – 10	89	E-DIR	0	0	[277]
Spiophanes bombyx	< 1	47	FS-L-PLK	56	>50	[277, 555]
Urothoe spp.	< 1	92	BR-DIR	0	0	[402, 625]
Venus spp.	< 1	333	FS-L-LEC			[620]

Viability of estuarine sands

The species which characterise this habitat are mostly infaunal with limited mobility but as some species such as the masked crab, *Corystes cassivelaunus,* are mobile appear in low densities, an area of **478 m^2** would be required to adequately encompass the home range and genetic viability of this community. The dispersal potential within this community is quite variable with some species exceeding 50 km. An area greater than **1964 km^2** would therefore be required in order to adequately protect a self-sustaining estuarine sand community. This may be better addressed by a series of smaller sites provided larval availability and connectivity were adequately assessed. Perhaps of greater importance in terms of the viability of this particular habitat is the maintenance of the hydrodynamic regime. If the flow of water were to be interrupted, or speeded-up in these areas it could completely change the nature of the substrate and hence the fauna which it is able to support

f) Coastal Sand

There have been numerous studies made of coastal sand communities and all report a moderately diverse community dominated by interstitial polychaetes [638-643]. The polychaete families Opheliidae (*Ophelia* spp.), Nephtyidae (*Nephtys* spp.), Phyllodocidae (*Eumida sanguinea*), Spionidae (*Pygospio elegans, Spio filicornis and Polydora spp*), Orbiniidae (*Scoloplos armiger*), Eunicidae (*Marphysa* spp.) Syllidae (*Exogone hebes*) and Capitellidae (*Notomastus* spp., *Mediomastus* spp. and *Capitella* spp.) are all reported to be characteristic of this habitat [613, 638, 639, 641, 642].

Dense aggregations of *Lanice conchilega*, *Owenia fusiformis* and *Ampelisa* spp. are common features [638, 640, 644] and whilst the beds which they form are likely to be restricted to small areas their structuring influence, in what is otherwise a relatively mobile environment, is likely to be significant. Other important characterising infauna reported from coastal sand habitats include the small bivalves *Abra alba*, *Venus gallina, Dosinia lupina* and *Tellina serrata*; Nemerteans and amphipods including *Urothoe s*pp. as well as a number of echinoderms including the sae potato, *Echinocardium cordatum* and brittle stars including *Ophiura* spp. [639-642]

The epifaunal communities associated with coastal sands are sparse because of the lack of attachment surfaces but a number of mobile invertebrates and fish are known to have a strong association with this habitat and these include the hermit crab *Pagurus bernhardus* and the lesser weaver fish *Echiichthys vipera* [640].

Table 3-67 Summary of viability for coastal sands and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Abra alba	< 1	30	FS-L-PLK	30	40	[645]
Ampelisca spp.	1 - 10	100	BR-DIR	0	0	[437, 555]
Echiichthys vipera			FS-L			[646]
Echinocardium cordatum	< 1	235	FS-L-PLK	39	50	[637]
Eumida sanguinea	< 1	109	FS-L-PLK	56	>50	[60, 493]
Exogone hebes		106	BR-DIR	0	0	[277, 555]
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512-515]
Marphysa spp.	< 1	368	A + L-LEC	<1	<1	[277, 647]
Mediomastus spp.	1 - 10	110	E-L-PLK	<1	<1	[277, 648]
Nemertea		131	A-DIR	0	0	[649]
Nephtys spp.	< 1	81	FS-L-PLK	49-56	>50	[277, 278]
Ophelia spp.	1 - 10	99	FS-L-LEC	2-10	4-10	[60, 276]
Ophiura spp.	< 1	112	FS-L-PLK	300	>50	[555, 626]
Owenia fusiformis	< 1	263	FS-L-PLK	11-30#	10-40#	[276, 650]
Pagurus bernhardus	1 - 10	423	BR-L-PLK	11-30#	10-40#	[437, 619]
Pygospio elegans	< 1	9	DIR or L-PLK / LEC	11-30#	10-40#	[277]
Scoloplos armiger	1 – 10	89	E-DIR	0	0	[277]
Urothoe spp.	< 1	92	BR-DIR	0	0	[402, 625]

dispersal period and distance has been inferred from larval type.

Viability of coastal sands

Coastal sand habitats support a faunal community which is heavily dominated by interstitial polychaetes but the presence of some mobile megafauna means that a maximum area of 10 km would be required to protect the home range of all adults residing in this habitat. The genetic viability of the community would be preserved within a protected area of size **423 m^2** although there are some gaps in our knowledge and so these values should be treated with some caution.

The dispersal potential of some components of this community is also very high and an area greater than **1964 km^2** would be required to incorporate this element of their life cycle. Since many of the species present in this community have a ubiquitous distribution around the UK it would perhaps be more appropriate to protect this community through a series of smaller sites no further than 40-50 km apart.

g) Shallow and offshore Sand

There have been very few studies on the shallow sand subclass of the subtidal sand and gravel habitat, despite the fact that shallow sand banks are listed under Annex I of the habitats directive. Most studies concerning sand habitats beyond the 6 nautical mile limit do not give a depth and others span both shallow and offshore sand habitats. This is because many of the offshore sand features are very large and span both depth classes and so for the purpose of this study the two habitats have been combined.

Sublittoral sand waves are an important habitat for sandeel (*Ammodytes marinus*), particularly those composed of coarse to medium sand grains [651]. Sandeels are of particular importance because they represent a key link between the benthos and the wider food-web and represent and important food resource for many commercial fish species.

As in coastal sand habitats, shallow and offshore sands are dominated by polychaetes from a wide range of families; Opheliidae (*Ophelia* spp.), Nephtyidae (*Nephtys* spp.), Glyceridae (*Glycera* spp and *Glycinde normanni*), Scalibregmatidae (*Scalibregma inflatum*), Orbiniidae (*Scoloplos armiger*), Poecilochaetidae (*Poecilochaetus serpens*), Cirratulidae (*Cauleriella alata* and *Chaetazone setosa),* Spionidae (*Aonides* spp., *Laonice bahusiensis*, *Spiophanes bombyx, Spio* spp. *and Polydora* spp.), Pectinaridae (*Lagis koreni*), Syllidae (*Pionosyllis*) and Capitellidae (*Notomastus* spp., and *Mediomastus* spp.) are all reported to be characteristic of this habitat [613, 622, 623, 638, 639, 641-643].

Other infaunal species which are characteristic of shallow and offshore sand habitats include the amphipods *Bathyporeia* spp. and *Urothoe* spp., and the small bivalves, *Mysella bidentata* and *Abra* spp. [613, 622, 623, 638, 639, 641-643]. Like other sand habitats shallow and offshore sands support a sparse epifauna and this component of the community is characterised by brittle stars, particularly *Amphiura filiformis* as well as mysid shrimps such as *Schistomysis* spp. [604, 622, 643].

Table 3-68 Summary of viability for shallow and offshore sand habitats and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Ammodytes marinus			FS-L	70	>50	[646, 652]
Amphiura filiformis	< 1	30	FS-L-PLK	30-360	>50	[276, 653]
Aonides paucibranchiata	< 1	156	FS-L-LEC	2-10	4-10	[277, 555]
Bathyporeia elegans	< 1	58	BR-DIR	0	0	[348, 555]
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40	[420], [276]
Mysella bidentata	< 1	65	L-PLK	11-30$^{\#}$	10-40$^{\#}$	[397]
Nephtys spp.	< 1	81	FS-L-PLK	49-56	>50	[277, 278]
Ophelia spp.	1 - 10	99	FS-L-LEC	2-10	4-10	[60, 276]
Pionosyllis spp.	< 1	302	BR-L-LEC	1-10$^{\#}$	4-10$^{\#}$	[60]
Schistomysis spp.	< 1	267	BR-DIR	0	0	[654]
Scoloplos armiger	1 – 10	89	E-DIR	0	0	[277]

Viability of shallow and offshore sand

Shallow and offshore sand habitats support a faunal community which is heavily dominated by interstitial polychaetes and are important for populations of sandeels. No information was found on the home range of sandeels but as they spawn in areas they inhabit large scale movements appear limited to the planktonic larval stage. Thus, an area of 1 km^2 would protect the home range of a large proportion of the species in these sandy habitats and genetic viability by an area of **302 m^2**. The dispersal potential of some components of this community is also very high and an area greater than **1964 km^2** would be required to incorporate the complete life cycle of all species in this community. Since the species inhabiting this habitat have relatively ubiquitous distribution the continued recruitment to this community would perhaps be better protected through a series of sites approximately 40-50 km apart.

Summary of Subtidal sands and gravels

The following is a summary of the eight subclasses discussed above.

Table 3-69 Summary of viability for subtidal sands and gravels and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	LARVAL DISPERSAL (km)	REFERENCES
Abra alba	< 1	30	FS-L-PLK	30	40	[645]
Aequipecten opercularis	< 1	208	FS-L-PLK	11-30	10-40	[402, 554]
Ammodytes marinus	< 1	-	FS-L	70	>50	[646, 652]
Ampelisca spp.	1 - 10	100	BR-DIR	0	0	[437, 555]
Amphiura filiformis	< 1	30	FS-L-PLK	30-360	>50	[276, 653]
Aonides paucibranchiata	< 1	156	FS-L-LEC	2-10	4-10	[277, 555]
Arenicola marina	< 1	188	E-B-J	0	1-10	[417-419]
Ascidians	0	65	FS-L-LEC	<1	<0.25	[44]
Atelecyclus rotundatus	-	421	BR-L-PLK	<30	40	[625]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Bathyporeia spp.	< 1	58	BR-DIR	0	0	[348, 555]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Buccinum undatum	1 – 10	433	E-DIR	0	0	[437, 618]
Cerastoderma edule	<1	5	FS-L-PLK	14-21	25-40	[566]
*Cirratulidae *Tharyx*	0	7	BR-DIR	0	0	[277]
Corophium spp.	< 1	1	DIR	0	<1	[270-272]
Corystes cassivelaunus	< 1	478	BR-L-PLK	11-30	10-40	[635, 636]
Dendrodoa grossularia	0	16	A + BR-L-LEC	2-3 hrs	<1	[313, 377]
Echiichthys vipera	-	-	FS-L	-	-	[646]

Table continued…

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Echinocardium cordatum	< 1	235	FS-L-PLK	39	50	[637]
Echinocyamus pusillus	< 1	99	FS-L-PLK	30-60	>40	[276]
Ensis spp.	< 1	37	FS-L-PLK	20-30	40	[416]
Urothoe spp.	< 1	92	BR-DIR	0	0	[402, 625]
Eumida sanguinea	< 1	109	FS-L-PLK	56	>50	[60, 493]
Exogone hebes	-	106	BR-DIR	0	0	[277, 555]
Flustra foliacea	0	-	A + FS-L-LEC	Few hrs	<1	[420, 477]
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40	[276, 420]
Glycymeris glycymeris	< 1	153	FS-L-LEC	1-10$^{\#}$	4-10$^{\#}$	[616]
Hydroids	0	-	FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512-515]
Lumbrineris spp.	< 1	135	BR-DIR	0	0	[277, 555]
Macoma baltica	< 1	18	FS-L-PLK	30-360	>40	[422, 423]
Marphysa spp.	< 1	368	A + L-LEC	<1	<1	[277, 647]
Mediomastus spp.	1 - 10	110	E-L-PLK	<1	<1	[277, 648]
Mysella bidentata	< 1	65	L-PLK	11-30$^{\#}$	10-40$^{\#}$	[397]
Mytilus edulis	0	29	FS-L-PLK	20-30	40	[269]
Nemertea	-	131	A-DIR	0	0	[649]
Nephtys spp.	< 1	81	FS-L-PLK	49-56	>50	[277, 278]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321-324]
Ophelia spp.	1 - 10	99	FS-L-LEC	2-10	4-10	[60, 276]
Ophiothrix fragilis	< 1	95	FS-L-PLK	21-26	40	[162, 398, 399]
Ophiura spp.	< 1	112	FS-L-PLK	300	>50	[555, 626]
Owenia fusiformis	< 1	263	FS-L-PLK	11-30$^{\#}$	10-40$^{\#}$	[276, 650]

Table continued…

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Pagurus bernhardus	1 - 10	423	BR-L-PLK	11-30[#]	10-40[#]	[437, 619]
Pionosyllis spp.	< 1	302	BR-L-LEC	1-10[#]	4-10[#]	[60]
Pisidia longicornis	< 1	18	BR-L-PLK	30-60	>50	[400, 401]
Pomatoceros spp.	0	59	FS-L-PLK	14-60	>40	[277, 437]
Psammechinus miliaris	< 1	299	FS-L-PLK	14-21	<30	[276, 555]
Pygospio elegans	< 1	9	DIR or L-PLK / LEC	11-30[#]	10-40[#]	[277]
Sabellaria alveolata	0	3	FS-L-PLK	42-228	>50	[60, 277]
Sabellaria spinulosa	0	7	FS-L-PLK	42-112	>40	[60, 609]
Schistomysis spp.	< 1	267	BR-DIR	0	0	[654]
Scoloplos armiger	1 – 10	89	E-DIR	0	0	[277]
Spiophanes bombyx	< 1	47	FS-L-PLK	56	>50	[277, 555]
Spisula spp.	< 1	282	FS-L-PLK	30	40	[627, 628]
Urothoe spp.	< 1	92	BR-DIR	0	0	[402, 625]
Venus spp.	< 1	333	FS-L-LEC	-	-	[620]

Viability of Subtidal sands and gravels

Subtidal sands and gravels is a very broad habitat classification which encompasses a variety of substrata and environmental conditions. Table 3.66 summarises the characteristic species which have been identified across all of the sublittoral sands and gravel subclasses and from this general conclusions and viability recommendations can be drawn.

The home range of the species which are thought to be characteristic of this habitat would be encompassed by an area **less than 10km^2**. However, it should be noted that information is lacking for a small number of species and is identified as low confidence for others so this value should be treated with some caution. Information is available on the area require to support a genetically viable population of the majority of the characteristic species, although again there are some gaps. An area of **478 m^2** is though to be adequate to protect the majority of species utilising subtidal sand and gravel from extinction. The majority of species identified as being faithful and frequent residents of sublittoral sand and gravel habitats have a larval phase in their development and so are capable of dispersing over large distances. An MPA **greater than 1964 km^2** would be required to protect a self-seeding community in sublittoral sand and gravel. It is likely that a series of smaller MPAs would be more appropriate for the conservation of this habitat and this would also be necessary to conserve the variability that exits within this habitat.

Tide-swept channels

Tide-swept channels are characterised by a diverse assemblage of attached and encrusting epifauna that receive a large supply of water borne particles as a food supply. Assemblages include a wide range of filter and suspension feeding organisms such as sponges, of which *Halichondria panicea* is typical and may be in high abundance, ascidians such as *Ascidiella aspersa* and the colonial species *Clavelina lepadiformis*, tube building polychaete worms including *Pomatoceros triqueter* and bryozoans such as *Alcyonidium diaphanum* and *Alcyonidium hirsutum* [4, 655, 656]. A number of hydroid species (e.g. *Dynamena pumila*) are also likely to be present often forming a turf on tide and wave-swept rock [657]. Diversity and productivity can be high in these areas as the tide replenishes food regularly (Widdows et al. 2009), encouraging suspension feeders such as the mussel *Mytilus edulis* which may form beds in some areas (Simpson et al. 2007; Widdow et al. 2009; Tweedle et al. 2005). In shallower water, where light conditions are suitable, algae and kelps are also present. Typical species include *Fucus serratus*, a number of red algae and the kelps *Laminaria digitata* and *L. hyperborea* [658, 659]. Barnacles and limpets, in particular *Balanus crenatus* and *Patella vulgata*, are also likely to occur and mobile fauna includes *Gibbula cineraria* and *Asterias rubens*

The conditions which define tide-swept channels are broad and encompass a range of habitats and are usually associated with diverse communities [4]. Species selected for the assessment of viability have been found at specific locations (for example the Menai Straits and Strangford Lough) that fit within the tide-swept channel definition.

The only information that could be found on temporal variability of tide-swept channel habitats comes from the Menai Strait, where there is high tidal flow but low wave exposure. The distribution and abundance of the fauna and flora surveyed along a transect 20 years apart were compared [660]. Many of the species were found to have similar distributions in the two surveys suggesting a high degree of biological stability in this dynamic environment.

Table 3-70 Summary of viability for tide-swept channels and associated communities

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Alcyonidium diaphanum	0		FS-L-LEC	<1	<0.1	[403]
Alcyonidium hirsutum	0		FS-L-LEC	<1	<0.1	[661]
Ascidiella aspersa	0	306	FS-L-LEC	1-2	4	[313]
Asterias rubens	1 – 10	294	FS-L-PLK	<90	>50	[393, 394]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Clavelina lepadiformis	0		FS-L-LEC	0.2	<1	[118, 407, 408]
Fucus serratus	0		S	-	<10	[274]
Gibbula cineraria	< 1	292	FS-L-PLK	8-9	10	[316, 435]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381, 382]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Mytilus edulis	0	29	FS-L-PLK	20-30	40	[269]
Patella vulgata	< 1		FS-L-PLK	14	25	[349]
Pomatoceros triqueter	0	59	FS-L-PLK	14-60	>40	[277, 437]

Viability of tide-swept channel habitats

There was no specific evidence to suggest the area required to protect tide-swept channel habitats and communities. However, most species found in these habitats are sessile, living attached to rock so an area of **306 m^2** would likely protect the home ranges and the genetic variability of the community. Dispersal distances range from the very small up to 50 km or more which indicates very large areas in the order of 100 km^2 are needed to encompass the whole life-cycle of all the species. However, many of these species are widely distributed around the UK coastline and presumably supplying larvae in sufficient numbers to realise effective recruitment in much smaller areas than **1256 km^2**.

Tide-swept channels also lend themselves to site specific designations because of the fairly discrete nature of the habitat and to enable protection of specific sites where particularly diverse communities have already been identified.

4 Discussion & Conclusions

This assessment of viability has revealed considerable gaps in our understanding of marine species and habitats. In particular, the life-cycles of some of the rare and scarce species are very poorly understood and this is reflected in the low confidence score (coloured red) applied to a large proportion of the data. Substantial resources would be required to secure the data necessary to undertake robust viability assessments for MPA design and until such a time as these data become available a precautionary approach to viability is recommended.

The best available information has been used to assimilate information on four core aspects of viability:

- home range
- minimum viable population
- dispersal and self-seeding
- spatial and temporal dynamics.

The analysis of viability for the species and habitats of conservation interest have been summarised in Tables 4.1 and 4.2 and should be considered in conjunction with the following discussion on the limitations of the methodologies applied.

In many cases, home range was not found to be a particularly useful indicator of the area required to ensure the persistent viability of marine species or communities. The vast majority of species reviewed as part of this study are sessile (39%) or sedentary (48%) in nature. Thus, the area required to conserve the movements of individuals was always markedly smaller than the area estimated to contain a genetically viable population. This is unlikely to be the case however, where more mobile species are the focus of conservation efforts.

An effective population size of 5000 individuals was used as a proxy for the minimum viable population size (MVP) of the species reviewed as part of this study. This effective population size is in good agreement with the median MVP identified by Traill and others [7] in their review of 212 species as well as the recommendations of Frankham [9] based on genetic information. It is recognised, however, that the effective population size for marine invertebrates is not well described and a precautionary approach should be used when using the data.

Where data on species densities were available in the literature it was used to estimate the area required for an MVP. However, in most cases there was no quantitative data found and so species density records collected from numerous MESL surveys around the UK were used to estimate the area required to support a genetically viable population. The data and the number of records used in these calculations are summarised in Appendix Table 6-1. Although a large number of density records were available for many of the species used in this study, the data are biased towards sediment habitats and it is likely that population densities will vary between habitats. Furthermore, some species are known to exhibit gregarious behaviour which may influence their population densities. Further research in this area, particularly focusing on the genetic viability of marine invertebrate populations would add considerable weight to viability assessments of this kind.

The application of the MVP area does have some other limitations that should be considered. Many marine habitats exist as components of a mosaic of habitat patches that may be smaller than the MVP areas defined for many species. In these instances, the chance of locating contiguous habitats of sufficient size is small and so issues of connectivity will be important.

There are also particular limitations for habitats with particularly dense aggregations of organisms such as *Sabellaria spinulosa* where an estimated 5000 organisms could be found in an area of 7 m^2. This small area, whilst protecting genetic diversity, is unlikely to protect several other aspects of the habitat viability such as resistance to hydrodynamic forces, overall habitat diversity or other ecological processes. Such estimates of the MVP area provide just one component of a viability assessment and should be considered in combination with a wider understanding of the ecology of the species and species assemblages within habitats which are the focus of conservation effort.

The majority of the species covered in this review are sessile but have a larval planktonic phase in their development. Numerous studies have attempted to model larval dispersal but there remains considerable uncertainty around the distance over which planktonic larvae are capable of travelling. Nevertheless, based on the best available evidence the distance for a large proportion of the species reviewed here (35%) exceeds 30 km and so actual dispersal has the potential to cover extensive areas. These distances usually remove larvae from local areas and so the concept of self-seeding may only be appropriate for habitats in specific locations such as bays or lagoons where hydrodynamic conditions retain a local larval supply.

We have identified that a simplistic circle model for estimating dispersal area is likely to be an overestimate in many cases since MPA areas will often be constrained by factors such as the distribution and dimensions of suitable, often patchy habitat, the width of intertidal and so on. The extents identified here using dispersal information far exceeded the extent of MPAs in other parts of the world which have been proven to be viable over a number of years (see the *Mitella* and *Palinurus* examples). Thus, designating a series of smaller MPAs with some consideration for their connectivity may be considered to be a more effective way to protect species and communities which exhibit large planktonic dispersal distances. Where dispersal distances are high species are more likely to be protected by connectivity between MPAs than an individual site which may be too large to be practical.

The spatial and temporal variability and dynamics of the species and habitats studied here was found to be an important component in assessing the requirements of a viable MPA, despite the lack of quantitative data. Where variability is important to the persistence of a habitat or species, this should be encompassed in the MPA design.

It is also important to recognise that the scope of this report, and the brief, has necessarily been limited to area and consideration of other factors that are potentially important for viability have not been addressed. For example, factors such as the quality of the habitat and its continuing capacity to support its signature assemblage have not been addressed but are likely to be important in the selection of appropriate MPA locations. Similarly, the requirements for habitats of conservation importance that have already been subject to heavy exploitation and are remnants of habitats will also need to address the requirements for recovery.

We conclude, therefore, that a combination of the MVP area and the dispersal distance would be the most appropriate data upon which to base the design of a viable network of MPAs, with adequate connectivity to ensure future persistence. Establishing the area required to support the minimal viable population (MVP) is considered to be a useful component of viability assessments and more focused research in this area would be very beneficial to the design of the UK MPA network. For many of the species in this review, that have small home ranges but high dispersal distances, connectivity between MPAs will be particularly important. It should also be recognised that in reality the size and spacing of MPAs, especially for less common habitats, will be driven by habitat availability and distribution.

Table 4-1 Summary of trait information collected for species of conservation importance

SPECIES	AREA FOR VIABLE POPULATION (m^2)	SELF SEEDING POPULATION (km^2)	MAX DISPERSAL (km)	ADDITIONAL CONSIDERATIONS
Anotrichium barbatum	~	79	<10	Only known from one location
Cruoria cruoriaeformis	~	0.8	<1	Restricted to live maerl
Dermocorynus montagnei	~	0.8	<1	Associated with maerl
Lithothamnion corallioides	~	0.8	<1	
Padina pavonica	~	79	<10	
Phymatolithon calcareum	~	0	0	
Alkmaria romijni	~	7854	100	Lagoonal and estuarine distribution
Armandia cirrhosa	47	~	1000	Lagoonal distribution Based on proxy
Gobius cobitis	~	1886	49	Restricted distribution
Gobius couchi	~	1886	49	Restricted distribution Based on proxy
Hippocampus guttulatus	~	>1886	>49	Often associated with eelgrass
Hippocampus hippocampus	~	>1886	>49	
Victorella pavida	~	0	0	Only known from one location
Amphianthus dohrnii	~	0	0	Associated with seafans
Edwardsia ivelli	~	>1886	>49	Based on proxy
Edwardsia timida	~	> 1886	>49	
Eunicella verrucosa	~	79	10	
Funiculina quadrangularis	~	1256	40	Based on proxy
Haliclystus auricula	~	0.2	<0.5	Based on proxy
Leptopsammia pruvoti	~	< 13	4	

Table continued...

SPECIES	AREA FOR VIABLE POPULATION (m^2)	SELF SEEDING POPULATION (km^2)	MAX DISPERSAL (km)	ADDITIONAL CONSIDERATIONS
Lucernariopsis campanulata	~	< 13	<4	
Lucernariopsis cruxmelitensis	~	< 13	<4	Based on proxy species
Nematostella vectensis	~	0	0	At northern limit of distribution in UK
Pachycerianthus multiplicatus	~	38	7	
Swiftia pallida	~	13	<4	Very limited distribution
Arrhis phyllonyx	~	0	0	
Gammarus insensibilis	316*	0	0	*Based on *Gammarus* spp.
Gitanopsis bispinosa	~	0	0	Lack of evidence
Mitella pollicipes	~	1256	40	An MPA size of 1.58km^2 has been shown to be effective [181].
Palinurus elephas	~	1886	>49	An MPA size of 4km^2 has been shown to be effective [188]
Arctica islandica	~	1886	>49	
Atrina pectinata	~	79	10	Found in only a few locations
Caecum armoricum	~	<0.8	0	Restricted to saline lagoons Based on proxy
Nucella lapillus	833	<0.8	0	
Ostrea edulis	500	1256	40	
Paludinella littorina	~	0.8	<0.5	
Tenellia adspersa	~	79	9.8	Restricted to coastal lagoons

Table 4-2 Summary of trait information collected for all characteristic species in the habitat analysis

HABITATS	VIABLE POPULATION (m^2)	SELF SEEDING POPULATION (km^2)	MAX DISPERSAL (km)	ADDITIONAL CONSIDERATIONS
Blue mussel beds	316	1257	40	Beds smaller than 0.5 km^2 persist
Carbonate mounds	~	85530	330	Discrete habitat
Coastal saltmarsh	~	>1964	>50	Minimum 1 km^2 estimated for restoration sites
Cold-water coral reefs	~	>1964	>50	Discrete habitat
Deep-sea sponge aggregations	~	79	10	
Estuarine rocky habitats	316	1964	50	
File shell beds	500	1257	40	
Fragile sponge & anthozoan communities on subtidal rocky habitats	55	1964	>50	
Intertidal mudflats	202	>1964	>50	
Intertidal underboulder communities	500	1256-1964	40-50	
Littoral chalk communities	292	1964	50	
Maerl beds	500	1	1	
Modiolus modiolus beds	267	1257	40	2.5 km^2 beds known to persist
Mud habitats in deep water - sea-pen and burrowing megafauna communities	500	>1964	>50	
Ostrea edulis beds	500	1257	40	
Peat and clay exposures	292	1964	50	
Sabellaria alveolata reefs	118	>1964	>50	

Table continued...

HABITATS	VIABLE POPULATION (m^2)	SELF SEEDING POPULATION (km^2)	MAX DISPERSAL (km)	ADDITIONAL CONSIDERATIONS
Sabellaria spinulosa reefs	500	1257	40	
Saline lagoons	500	~	~	Discrete habitat
Seagrass beds	188	2827	60	
Sheltered muddy gravels	344	1257	40	
Subtidal chalk	294	>1964	>50	
Subtidal sands and gravels	See subclasses below			
Estuarine Coarse Sediment	29	>1964	>50	
Coastal Coarse Sediment	202	>1964	>50	
Shallow Coarse Sediment	433	1257	40	
Shelf / Offshore Coarse Sediment	421	>1964	>50	
Estuarine Sand	478	>1964	>50	
Coastal Sand	423	>1964	>50	
Shallow / Offshore Sand	30	>1964	>50	
Tide-swept channels	306	>1256	>50	

5 References

1. DEFRA, Draft guidance on selection and designation of Marine Conservation Zones. 2009, Department for Environment, Food and Rural Affairs and the Welsh Assembly Government: London.
2. Roberts, C.M., J.P. Hawkins, J. Fletcher, S. Hands, K. Raab, and S. Ward, Guidance on the size and spacing of Marine Protected Areas in England. 2009, Unpublished report to Natural England: Environment Department, University of York, York, YO10 5DD, UK.
3. Tyler-Walters, H.J., A., Assessing seabed species and ecosystems sensitivities. 1999, Rationale and user guide. Report to English Nature, Scottish Natural Heritage and the Department of the Environment Transport and the Regions from the Marine Life Information Network (MarLIN). Plymouth, Marine Biological Association of the UK. (MarLIN Report No.4.). January 2000 edition.
4. Connor, D.W., J.H. Allen, N. Golding, K.L. Howell, L.M. Leiberknecht, K.O. Northen, and J.B. Reker, The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC, Peterborough. 2004.
5. Nehls, G., I. Hertzler, and G. Scheiffarth, 1997 Stable mussel *Mytilus edulis* beds in the Wadden Sea - They're just for the birds. Helgolander Meeresuntersuchungen. **51**(3): p. 361-372.
6. Rosa, S., J.P. Granadeiro, C. Vinagre, S. Franca, H.N. Cabral, and J.M. Palmeirim, 2008 Impact of predation on the polychaete *Hediste diversicolor* in estuarine intertidal flats. Estuarine Coastal and Shelf Science. **78**(4): p. 655-664.
7. Traill, L.W., C.J.A. Bradshaw, and B.W. Brook, 2007 Minimum viable population size: A meta analysis of 30 years of published estimates. Biological Conservation. **139**: p. 159-166.
8. Mace, G.M., N.J. Collar, K.J. Gaston, E.J. Milner-Gulland, and S.N. Stuart, 2008 Quantification of extinction risk: IUCN's system for classifying threatened species. Conservation Biology. **22**(6): p. 1424-1442.
9. Frankham, R., 1995 Effective population-size adult-population size ratios in wildlife: a review. Genetic Research. **66**: p. 95-107.
10. Maggs, C.A., The rare red alga *Anotrichium barbatum*. Species Action Plan and its implementation in CCW Contract Science Report No.397. 2000, CCW.
11. Maggs, C.A. and M.H. Hommersand, Seaweeds of the British Isles; Volume 1 Rhodophyta, Part 3A Ceramiales. Seaweeds of the British Isles. Vol. 1. Rhodophyta. 1993, London: The Natural History Museum, London
12. Hiscock, K. and H. Jones, Testing criteria for assessing 'national importance' of marine species, biotopes (habitats) and landscapes, in Report to Joint Nature Conservation Commitee from the Marine Life information Network (MarLIN). 2004, Marine Biological Association of the UK: Plymouth. p. 63pp.
13. Kinlan, B.P. and S.D. Gaines, 2003 Propagule dispersal in marine and terrestrial environments: a community perspective. Ecology. **84**(8): p. 2007-2020.
14. Hiscock, S., A field Key to the British Red Seaweeds (Rhodophyta). AIDGAP: Field Studies Council. 1986: Occasional Publication 13.
15. Maggs, C.A. and M.D. Guiry, 1989 A re-evaluation of the crustose red alage genus *Cruoria* and the family Cruoriaceae. British Phycological Journal. **24**: p. 253-269.
16. Maggs, C.A. and M.D. Guiry, 1989 A re-evaluation of the crustose red alage genus *Cruoria* and the family Cruoriaceae. British Phycological Journal **24**: p. 253-269.
17. Barbara, I., J. Cremades, and A.J. Veiga, 2004 Floristic study of a maerl and gravel subtidal bed in the 'Ria de Arousa' (Galicia, Spain) Botanica Complutensis. **28**: p. 27-37.
18. Maggs, C.A., 1983 A seasonal study of seaweed communities on subtidal Maerl (unattached corraline algae). Progress in Underwater Science. **9**: p. 27-40.

19. Birkett, D.A., C. Maggs, and M.J. Dring, Maerl. An overview of dynamics and sensitivity characteristics for conservation management of marine SACs in Prepared by Scottish Association of Marine Science (SAMS) for the UK Marine SACs Project 1998.
20. Brodie, J., Report from the Biodiversity and Conservation Committee, in The Phycologist. The Newsletter of the British Phycological Society J. Krokowski, Editor. 2008, The British Phycological Society p. 12-12.
21. Brodie, J., D.M. John, I. Tittley, M.J. Holmes, and D.B. Williamson, Important areas for algae: a provisional review of sites and areas of importance for algae in the United Kingdom. 2007, Plantlife International Salisbury p. 81pp.
22. Maggs, C.A., Special Protection and Local Action for Species and Habitats (SPLASH) 2004-2008, in Funded by the Esmée Fairbairn Foundation. Co-ordinated by Quercus Centre for Biodiversity and Conservation Biology Queen's University Belfast. 2008.
23. Wilkes, R.J., L.M. McIvor, and M.D. Guiry, 2005 Using rbcL sequence data to reassess the taxonomic position of some *Grateloupia* and *Dermocorynus* species (Halymeniaceae, Rhodophyta) from the north-eastern Atlantic. European Journal of Phycology. **40**(1): p. 53-60.
24. Guiry, M.D. and C.A. Maggs, 1982 The morphology and life-history of *Dermocorynus montagnei* Crouan Frat (Halymeniaceae, hodophyta) from Ireland. British Phycological Journal. **17**(2): p. 215-228.
25. Hardy, G. and M.D. Guiry, A Check-list and Atlas of the Seaweeds of Britain and Ireland 2003, London: British Phycological Society. p. 225pp.
26. Jackson, E., O. Langmead, J. Evans, R. Ellis, and H. Tyler Walters, Protecting nationally important marine Biodiversity in Wales, in Report to the Wales Environment Link form the Marine Life Information Network (MarLIN). 2008, The Marine Biological Association of the UK Plymouth. p. 78 pp.
27. Van den Hoek, C., D.G. Mann, and H.M. Jahns, Algae: an introduction to phycology. 1995, Cambridge, UK: University Press.
28. Hall-Spencer, J.M., J. Kelly, and C.A. Maggs, Assessment of maerl beds in the OSPAR area and the development of a monitoring program, in Prepared for the Department of the Environment, Heritage and Local Government (DEHLG), Ireland 2007.
29. Foster, M.S., 2001 Rhodoliths: Between rocks and soft places. Journal of Phycology. **37**(5): p. 659-667.
30. Barbera, C., C. Bordehore, J.A. Borg, M. Glemarec, J. Grall, J.M. Hall-Spencer, C. De la Huz, E. Lanfranco, M. Lastra, P.G. Moore, J. Mora, M.E. Pita, A.A. Ramos-Espla, M. Rizzo, A. Sanchez-Mata, A. Seva, P.J. Schembri, and C. Valle. Conservation and management of northeast Atlantic and Mediterranean maerl beds. in International Workshop on the Conservation and Management of Mearl. 2001. Millport, Scotland: John Wiley & Sons Ltd.
31. Mitchell, A. and K. Collins, Understanding the distribution of maerl, a calcareous seaweed, off Dorset, UK: an application of regression-modelling, in GIS/Spatial Analyses in Fishery and Aquatic Sciences (Vol. 2) T. Nishida, P.J. Kailola, and C.E. Hollinworth, Editors. 2004, Fishery-Aquatic GIS Research Group Saitama, Japan. p. 735pp.
32. Hall-Spencer, J. and R. Bamber, 2007 Effects of salmon farming on benthic Crustacea. Ciencias Marinas. **33**(4): p. 353-366.
33. Riul, P., C.H. Targino, J.D. Farias, P.T. Visscher, and P.A. Horta, 2008 Decrease in *Lithothamnion* sp (Rhodophyta) primary production due to the deposition of a thin sediment layer. Journal of the Marine Biological Association of the United Kingdom. **88**(1): p. 17-19.
34. BIOMAERL, 2003 Conservation and management of northeast Atlantic and Mediterranean maerl beds. Aquatic Conservation: Marine and Freshwater Ecosystems. **13**: p. S65-S76.

35. Kamenos, N.A., P.G. Moore, and J.M. Hall-Spencer, 2004 Small-scale distribution of juvenile gadoids in shallow inshore waters; what role does maerl play? ICES Journal of Marine Science. **61**(3): p. 422-429.
36. Hall-Spencer, J.M., J. Grall, P.G. Moore, and R.J.A. Atkinson, 2003 Bivalve fishing and maerl-bed conservation in France and the UK - retrospect and prospect. Aquatic Conservation Marine and Freshwater Ecosystems. **13**: p. S33-S41.
37. Hall-Spencer, J.M. and P.G. Moore, 2000 Scallop dredging has profound, long-term impacts on maerl habitats. Ices Journal of Marine Science. **57**(5): p. 1407-1415.
38. Hall-Spencer, J., J. Kelly, and C.A. Maggs, Assessment of maerl beds in the OSPAR area and the development of a monitoring program. 2008, Prepared for the Department of the Environment, Heritage & Local Government (DEHLG), Ireland. p. 30 pp.
39. Grall, J. and J.M. Hall-Spencer, 2003 Problems facing maerl conservation in Brittany. Aquatic Conservation-Marine and Freshwater Ecosystems. **13**: p. S55-S64.
40. Wilson, S., C. Blake, J.A. Berges, and C.A. Maggs, 2004 Environmental tolerances of free-living coralline algae (maerl): implications for European marine conservation. Biological Conservation. **120**(2): p. 279-289.
41. Birkett, D.A., C. Maggs, and M.J. Dring, Maerl: An Overview of Dynamics and Sensitivity Characteristics for Conservation Management of Marine SAC's in Natura 2000. 1998, Prepared by Scottish Association for Marine Science (SAMS) for the UK Marine SACs Project p. 116 p.
42. Adey, W.H. and D.L. McKiblin, 1970 Studies on maerl species *Phymatolithon calcareum* (Pallas) Nov Comb and *Lithothamnion corallioides* Crouan in Ria De Vigo. Botanica Marina. **13**(2): p. 100-&.
43. De Grave, S., H. Fazakerley, L. Kelly, M.D. Guiry, M. Ryan, and J. Walshe, A Study of selected maerl beds in Irish waters and their potential for sustainable extraction in Final Report of the Marine Research Measure Project IR.95.MR.019. Marine Institute, Dublin. . 2000.
44. Shanks, A.L., B.A. Grantham, and M.H. Carr, 2003 PROPAGULE DISPERSAL DISTANCE AND THE SIZE AND SPACING OF MARINE RESERVES. Ecological Applications. **13**(sp1): p. 159-169.
45. Hayward, P., T. Nelson-Smith, and C. Shields, Collins Pocket Guide to the Sea Shore of Britain and Europe. Collins Pocket Guides. 1996: Harper Collins.
46. Carter, P.W., 1927 The life-history of *Padina pavonica*: I. The structure and cytology of the tetrasporangial plant. Annals of Botany. **41**(1): p. 139-160.
47. Liddle, L.B., 1975 Effect of intertidal stress on *Padina sanctae* Crucis (Phaeophyta). Journal of Phycology. **11**(3): p. 327-330.
48. Bulleri, F., I. Bertocci, and F. Micheli, 2002 Interplay of encrusting coralline algae and sea urchins in maintaining alternative habitats. Marine Ecology Progress Series. **243**: p. 101-109.
49. Tyler-Walters, H. and K. Hiscock, A biotope sensitivity database to underpin delivery of the Habitats Directive and Biodiversity Action Plan in the seas around England and Scotland in Report to English nature and Scottish Natural Heritage from the Marine Life Information Network (MarLIN) 2003, Marine Biological Association of the UK Plymouth.
50. Hiscock, K., A. Southward, I. Tittley, and S. Hawkins, 2004 Effects of changing temperature on benthic marine life in Britain and Ireland. Aquatic Conservation-Marine and Freshwater Ecosystems. **14**(4): p. 333-362.
51. Gomez Gareta, A., J. Rull Lluch, M.C. Barcelo Marti, and M.A. Ribera Siguan, 2007 On the presence of fertile gametophytes of *Padina pavonica* (Dictyotales, Phaeophyceae) from the Iberian coasts. Anales del Jardin Botanico de Madrid. **64**(1): p. 27-33.
52. Ni-Ni-Win, T. Hanyuda, S. Arai, M. Uchimura, I.A. Abbott, and H. Kawai, 2008 Three new records of *Padina* in Japan based on morphological and molecular markers. Phycological Research. **56**(4): p. 288-300.

53. Kinlan, B.P., S.D. Gaines, and S.E. Lester, 2005 Propagule dispersal and the scales of marine community process. Diversity and Distributions. **11**(2): p. 139-148.
54. Kamenos, N.A., P.G. Moore, and J.M. Hall-Spencer, 2004 Nursery-area function of maerl grounds for juvenile queen scallops *Aequipecten opercularis* and other invertebrates. Marine Ecology Progress Series. **274**: p. 183-189.
55. Barnes, R.S.K., The brackish-water fauna of northwestern Europe: An identification guide to brackish-water habitats, ecology and macrofauna for field workers, naturalists and students. 1994, Cambridge: Cambridge University Press.
56. Barne, J.H., C.F. Robson, S.S. Kaznowska, J.P. Doody, and N.C. Davidson, Coasts and seas of the United Kingdom, Region 9 Southern England: Hayling Island to Lyme Regis, in Peterborough, Joint Nature Conservation Committee (Coastal Directories Series). 1996.
57. Downie, A.J., The Lagoon Sand Worm *Armandia cirrhosa* in English Nature Research Report 202. 1996, English Nature p. 26pp.
58. Mulazzani, A., Creative Conservation of Soft Coastal Habitats in Britain in Department of Civil and Offshore Engineering 1998, Heriot-Watt University Edinburgh. p. 60pp.
59. Woodin, S.A., 1974 Polychaete abundance patterns in a marine soft-sediment environment - Importance of biological interactions. Ecological Monographs. **44**(2): p. 171-187.
60. Rouse, G.W. and F. Pleijel, Polychaetes. 2001: Oxford University Press.
61. Tamaki, A., 1985 Zonation by size in the *Armandia* sp. (Polychaeta, Opheliidae) population on an intertidal sand flat. Marine Ecology Progress Series. **27**(1-2): p. 123-133.
62. Carson, H.S. and B.T. Hentschel, 2006 Estimating the dispersal potential of polychaete species in the Southern California Bight: Implications for designing marine reserves. Marine Ecology Progress Series. **316**: p. 105-113.
63. Jones, P.J.S. and A. Carpenter, 2009 Crossing the divide: The challenges of designing an ecologically coherent and representative network of MPA for the UK. Marine Policy. **33**(5): p. 737-743.
64. Wesenberg-Lund, E., 1934 A viviparous brackish-water Ampharetid *Alkmaria romijni* Horst from Ringköbing Fjord. Videnskabelige meddelelser fra Dansk naturhistorisk forening i København. **98**: p. 215-222.
65. Arndt, A.A. Ecological, physiological and historical aspects of brackish water fauna distribution. in Reproduction, Genetics and Distributions of Marine Organisms, Proceedings of the 23rd Symposium 1989. Fredensberg, Denmark: Olsen and Olsen International Symposium Series
66. Gilliland, P.M. and W.G. Sanderson, 2000 Re-evaluation of marine benthic species of nature conservation importance: a new perspective on certain 'lagoonal specialists' with particular emphasis on *Alkmaria romijni* Horst (Polychaeta : Ampharetidae). Aquatic Conservation-Marine and Freshwater Ecosystems. **10**(1): p. 1-12.
67. JNCC, Fifth Quinquennial Review of Schedule 5 and 8 of the Wildlife Countryside Act, 1981, in Report and Recommendations from the Joint Nature Conservation Committee. 2008, Joint Nature Conservation Committee. p. 120pp.
68. Cardoso, P.G., M.A. Pardal, D. Raffaelli, A. Baeta, and J.C. Marques, 2004 Macroinvertebrate response to different species of macroalgal mats and the role of disturbance history. Journal of Experimental Marine Biology and Ecology. **308**(2): p. 207-220.
69. Cardoso, P.G., M. Bankovic, D. Raffaelli, and M.A. Pardal, 2007 Polychaete assemblages as indicators of habitat recovery in a temperate estuary under eutrophication. Estuarine Coastal and Shelf Science. **71**(1-2): p. 301-308.
70. Cazaux, C., 1982 Larval development of the lagoon Ampharetidae *Alkmaria romijni,* Horst 1919. Cahiers de Biologie Marine. **23**(2): p. 143-157.

71. Zal, F., D. Jollivet, P. Chevaldonne, and D. Desbruyeres, 1995 Reproductive biology and population structure of the deep-sea Hydrothermal vent worm *Paralvinella grasslei* (Polychaeta, Alvinellidae) at 13^{o} N on the east Pacific Rise. Marine Biology. **122**(4): p. 637-648.
72. Rouse, G. and F. Pleijel, Polycheates. 2001: Oxford University Press.
73. Faria, C., V. Almada, and M.D. Nunes, 1998 Patterns of agonistic behaviour, shelter occupation and habitat preference in juvenile *Lipophrys pholis*, *Coryphoblennius galerita* and *Gobius cobitis.* Journal of Fish Biology. **53**(6): p. 1263-1273.
74. Faria, C. and V.C. Almada, 1995 Some aspects of the breeding ecology of *Gobius cobitis* Pallas and *Gobius paganellus* L. in the west coast of Portugal Arquivos do Museu Bocage. **II**(29): p. 463-471.
75. Gibson, R.N., 1972 Vertical distribution and feeding relationships of intertidal fish on Atlantic coast of France. Journal of Animal Ecology. **41**(1): p. 189-207.
76. Gil, M.F., E.J. Goncalves, C. Faria, V.C. Almada, C. Baptista, and H. Carreiro, 1997 Embryonic and larval development of the Giant goby *Gobius cobitis* (Pisces: Gobiidae). Journal of Natural History. **31**(5): p. 799-804.
77. Rogers, S.I., R.S. Milner, and T.A. Mead, The distribution and abundance of young fish on the east coast and south coast of England (1981 to 1997), in Science Series Technical Report Number 108. 1998, CEFAS: Lowestoft p. 130 pp.
78. Faria, C. and V.C. Almada, 2009 Tidal shifts in microhabitat use by *Gobius cobitis*: an adaptation to its feeding strategy? Journal of the Marine Biological Association of the United Kingdom. **89**(3): p. 641-643.
79. Macpherson, E., 1994 Substrate utilization in a Mediterranean littoral fish community. Marine Ecology Progress Series. **114**(3): p. 211-218.
80. Almada, V.C. and C. Faria, 2004 Temporal variation of rocky intertidal resident fish assemblages - patterns and possible mechanisms with a note on sampling protocols. Reviews in Fish Biology and Fisheries. **14**(2): p. 239-250.
81. Stefanni, S. and C. Mazzoldi, 1999 The presence of Couch's goby in the Mediterranean Sea. Journal of Fish Biology. **54**(5): p. 1128-1131.
82. Gibson, R.N., 1970 Observations on biology of Giant goby *Gobius cobitis* Pallas. Journal of Fish Biology. **2**(3): p. 281-&.
83. ICES, Report of the Working Group on Fish Ecology 2003, ICES Headquarters, Living Resources Committee.
84. Minchin, D., 1988 Couch Goby, *Gobius couchi* (Teleosti, Gobiidae), from Irish waters. Journal of Fish Biology. **33**(5): p. 821-822.
85. Wilkins, H.K.A. and A.A. Myers, 1992 Microhabitat utilization by an assemblage of temperate Gobiidae (Pisces, Teleostei). Marine Ecology Progress Series. **90**(2): p. 103-112.
86. Kovacic, M., 2001 The Kvarner population of *Gobius couchi* (Teleostei, Gobiidae), a fish new to the Adriatic fauna. Natura Croatica. **10**(1): p. 1-10.
87. Miller, P.J. and M.Y. Eltawil, 1974 Multidisciplinary approach to a new species of *Gobius* (Teleostei, Gobiidea) from southern Cornwall. Journal of Zoology. **174**(DEC): p. 539-574.
88. Hung Lui, H.T., H. Ahnelt, G.A.C. Balma, and G.B. Delmastro, 2009 First record of the rare gobiid fish *Gobius couchi* in the Ligurian Sea (north-western Mediterranean). Marine Biodiversity Records.
89. Potts, G.W. and S.E. Swaby, Evaluation of the conservation requirements of rarer British marine fishes in Final Report to the Nature Conservancy Council 1991.
90. Curtis, J.M.R. and A.C.J. Vincent, 2006 Life history of an unusual marine fish: survival, growth and movement patterns of *Hippocampus guttulatus* Cuvier 1829. Journal of Fish Biology. **68**(3): p. 707-733.

91. Garrick-Maidment, N.G., British Seahorse Survey 2007, in Funded and supported by The Estate of Betty Van Pepperzeel and WWF. 2007, British Seahorse Survey. The Seahorse Trust
92. Curtis, J.M.R. and A.C.J. Vincent, 2005 Distribution of sympatric seahorse species along a gradient of habitat complexity in a seagrass-dominated community. Marine Ecology-Progress Series. **291**: p. 81-91.
93. Foster, S.J. and A.C.J. Vincent, 2004 Life history and ecology of seahorses: implications for conservation and management. Journal of Fish Biology. **65**(1): p. 1-61.
94. Curtis, J.M.R., J. Ribeiro, K. Erzini, and A.C.J. Vincent, 2007 A conservation trade-off? Interspecific differences in seahorse responses to experimental changes in fishing effort. Aquatic Conservation-Marine and Freshwater Ecosystems. **17**(5): p. 468-484.
95. Vandendriessche, S., M. Messiaen, M. Vincx, and S. Degraer, 2005 Juvenile *Hippocampus guttulatus* from a neuston tow at the French-Belgian border. Belgian Journal of Zoology. **135**(1): p. 101-102.
96. Lourie, S.A., E. Foster, E.W. Cooper, and A.C.J. Vincent, A Guide to the Identification of Seahorses in Project Seahorse and TRAFFIC North America 2004, University of British Columbia and World Wildlife Fund Washington D.C.
97. Naud, M.J., J.M.R. Curtis, L.C. Woodall, and M.B. Gaspar, 2009 Mate choice, operational sex ratio, and social promiscuity in a wild population of the long-snouted seahorse *Hippocampus guttulatus.* Behavioral Ecology. **20**(1): p. 160-164.
98. Kitsos, M.S., T. Tzomos, L. Anagnostopoulou, and A. Koukouras, 2008 Diet composition of the seahorses, *Hippocampus guttulatus* Cuvier, 1829 and *Hippocampus hippocampus* (L., 1758) (Teleostei, Syngnathidae) in the Aegean Sea. Journal of Fish Biology. **72**(6): p. 1259-1267.
99. Pinnegar, J.K., V. Stelzenmuller, J. Van der Kooij, G.H. Engelhard, N. Garrick-Maidment, and D.A. Righton, 2008 Occurrence of the short-snouted seahorse *Hippocampus hippocampus* in the central North Sea. Cybium. **32**(4): p. 343-346.
100. Evans, N.J., R.N. Bamber, B.D. Smith, P.F. Clark, H. Taylor, P. Lund, and P.J. Chimonides, Swanpool Ecological Study, Falmouth, Cornwall. Final Report. 2003, The Natural History Museum London.
101. Gainey, P.A., Trembling Sea Mat. Baseline Distribution in England and Species Action Plan in English Nature Research Report No. 225. 1997.
102. Dorey, A.E., C. Little, and R.S.K. Barnes, 1973 An ecological study of the Swanpool, Falmouth. Part 2: Hydrography and its relation to animal distributions. Estuarine and Coastal Marine Science. **1**(2): p. 153-176.
103. Carter, M.C., The biology and genetic diversity of the trembling sea mat *Victorella pavida* (Bryozoa: Ctenostomata) from Swanpool, Falmouth 2004, University of Plymouth
104. Carter, M.C., J.D.D. Bishop, N.J. Evans, and C.A. Wood, The biology of the trembling sea mat *Victorella pavida* (Bryozoa: Ctenostomata) from Swanpool, Falmouth, Cornwall in Report for English Nature 2005.
105. Menon, N.R. and N.B. Nair, 1967 Observations on the structure and ecology of *Victorella pavida* Kent (Bryozoa) for the south west coast of India. Internationale Revue der Gesamten Hydrobiologie. **52**: p. 237-256.
106. Bushnell, J.H. and K.S. Rao, 1974 Dormant or quiescent stages and structures among Ectoprocta - Physical and chemical factors affecting viability and germination of statoblasts. Transactions of the American Microscopical Society. **93**(4): p. 524-543.
107. Dimitris, V. and C. Chariton, 2002 *Segonzactis hartogi* sp n. (Condylanthidae) and other sea anemones of the Aegean deep water. Belgian Journal of Zoology. **132**(2): p. 87-93.
108. Manuel, R.L., British Anthozoa. Synopses of the British Fauna, no. 18. 1981: The Linnean Society of London.
109. Excoffon, A.C., F.H. Acuña, and J. Cortés, 2009 The sea anemone *Nemanthus californicus* (Cnidaria: Actiniaria: Nemanthidae) from Costa Rica: re-description and first record outside the type locality. Marine Biodiversity Records. **2**(1).

110. Ocana, O. and J.C. den Hartog, 2002 A catalouge of Actiniaria and Corallimorpharia from the Canary Islands and from Madeira. Arquipélago. Life and Marine Sciences. **19A**: p. 33-54.
111. Hiscock, K., J. Sewell, and J. Oakley, Marine Health Check 2005. Areport to gauge the health of the UK's sea-life. 2005, WWF-UK: Godalming.
112. Wood, C., Pink sea fan survey 2001/2, in A report to the Marine Conservation Society 2003.
113. Manuel, R.L., 1975 New sea anemone from a brackis lagoon in Sussex, *Edwardsia ivelli*, Sp-nov. Journal of Natural History. **9**(6): p. 705-711.
114. Bamber, R.N., S.D. Batten, M. Sheader, and N.D. Bridgwater, 1992 On the ecology of brackish water lagoons in Great Britain. Aquatic Conservation-Marine and Freshwater Ecosystems. **2**(1): p. 65-94.
115. Walton, C.L. and O.M. Rees, 1913 Some rare and interesting sea anemones from Plymouth Journal of the Marine Biological Association of the United Kingdom. **X**(1): p. 60-69.
116. Lewis, G., R. Parslow, A. Gall, and P. McCartney, Isles of Scilly Biodiversity Audit 2008, in Funded by the Aggregates Levy Sustainability Fund. 2008, Isles of Scilly Wildlife Trust.
117. Rawlinson, R., 1935 *Edwardsia callianthus* spec. nov. A new British species from Menai Straits Journal of the Marine Biological Association of the United Kingdom. **20**(1): p. 129-146.
118. Hayward, P. and J. Ryland, Handbook of the Marine Fauna of North-West Europe. 1995: Oxford University Press.
119. Tinsley, P., Worbarrow Reefs Seafan Project 2003-2005, in A Dorset Wildlife Trust report. 2005. p. 16pp.
120. Lumbis, R., Distribution of Southwest England inshore fishing effort and the Pink seafan, *Eunicella verrucosa* (Pallas, 1766) between 1990 and 2007. 2008, University of Plymouth Plymouth. p. 76pp.
121. Tyler-Walters, H., D.B. Lear, and K. Hiscock, Irish Sea Pilot - Mapping Sensitivity within Marine Landscapes in Report to English Nature and the Joint Nature Conservation Commitee from the Marine Life Information Network (MarLIN). 2003, Marine Biological Association of the UK: Plymouth. p. 150pp.
122. Munro, C., Reef Research; East Tennants Reef Seafan Study in Padi Project Aware. 2001.
123. Munro, L., Determining the reproductive cycle of *Eunicella verrucosa*, in A report to CCW. 2004, Reef Research p. 28pp.
124. Hiscock, K., A. Southward, I. Tittley, A. Jory, and S. Hawkins, The Impact of Climate Change on Subtidal and Intertidal Benthic species in Scotland, in Report to the Scottish Natural Heritage from the Marine Biological Association of the United Kingdom 2001, Marine Biological Association p. 211pp.
125. Hiscock, K., S. Sharrock, J. Highfield, and D. Snelling, 2010 Colonisation of an artificial reef in south-west England – ex-HMS *Scylla.* in press.
126. Edwards, D.C.B. and C.G. Moore, 2009 Reproduction in the sea pen *Funiculina quadrangularis* (Anthozoa: Pennatulacea) from the west coast of Scotland. Estuarine Coastal and Shelf Science. **82**(1): p. 161-168.
127. Greathead, C.F., D.W. Dorman, J.M. Mair, and G.R. Saunders, 2007 The sea pens *Virgularia mirabilis*, *Pennatula phosphorea* and *Funiculina quadrangularis*: distribution and conservation issues in Scottish waters. Journal of the Marine Biological Association of the United Kingdom. **87**(5): p. 1095-1103.
128. Hughes, D.J., Subtidal brittlestar beds (volume IV). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs in Scottish Association for Marine Science (UK Marine SACs Project). 1998, Scottish Association

for Marine Science (UK Marine SACs Project), Centre for Coastal and Marine Sciences Dunstaffnage Marine Laboratory. p. 78pp.

129. Eno, N.C., D.S. MacDonald, J.A.M. Kinnear, S.C. Amos, C.J. Chapman, R.A. Clark, F. Bunker, and C. Munro, 2001 Effects of crustacean traps on benthic fauna. Ices Journal of Marine Science. **58**(1): p. 11-20.

130. Greathead, C.F., D.W. Donnan, and J.M. Mair, Impact of *Nephrops* trawling on the distribution of the Sea Pens *Virgularia mirabilis*, *Pennetula phosphorea* and *Funiculina quadrangularis* in Scottish Waters in Fisheries Research Services internal report No 02/05 2005, Fisheries Research Services Aberdeen. p. 20pp.

131. Kinnear, J.A.M., P.J. Barkel, W.R. Mojsiewicz, C.J. Chapman, A.J. Holbrow, C. Barnes, and C.F. Greathead, Effects of Nephrops creels on the environment, in Fisheries Research Services Report No 2/96. 1996, Scottish Office Agriculture, Environment and Fisheries Department, Atlantic Diving Services

132. Chia, F.S. and B.J. Crawford, 1973 Some observations on gametogenesis, larval development and substratum selection of sea pan *Ptilosarcus guerneyi.* Marine Biology. **23**(1): p. 73-82.

133. Nichols, D., J. Cooke, and D. Whiteley, The Oxford Book of Invertebrates. 1971, London: Oxford University Press.

134. Zagal, C.J., 2004 Population biology and habitat of the stauromedusa *Haliclystus auricula* in southern Chile. Journal of the Marine Biological Association of the United Kingdom. **84**(2): p. 331-336.

135. Zagal, C.J., 2004 Diet of the stauromedusa *Haliclystus auricula* from southern Chile. Journal of the Marine Biological Association of the United Kingdom. **84**(2): p. 337-340.

136. Otto, J.J., Early development and planula movement in *Haliclystus* (Schyphozoa: Stauromedusae), in Coelenterate Ecology and Behaviour G.O. Mackie, Editor. 1976, Plenum Press New York. p. 319-329.

137. Zagal, C.J., 2008 Morphological abnormalities in the stauromedusa *Haliclystus auricula* (Cnidaria) and their possible causes. Journal of the Marine Biological Association of the United Kingdom. **88**(2): p. 259-262.

138. Otto, J.J., The Settlement of *Haliclystus planulae*, in Settlement and Metamorphosis of Marine Invertebrate Larvae F.S. China and M.E. Rice, Editors. 1978, Elsevier - North Holland: New York. p. 13-20.

139. Goffredo, S., V. Airi, J. Radetic, and F. Zaccanti, 2006 Sexual reproduction of the solitary sunset cup coral *Leptopsammia pruvoti* (Scleractinia, Dendrophylliidae) in the Mediterranean. 2. Quantitative aspects of the annual reproductive cycle. Marine Biology. **148**(5): p. 923-931.

140. Irving, R., 2004 *Leptopsammia pruvoti* at Lundy - teetering on the brink? Porcupine Marine Natural History Newsletter. **15**: p. 29-34.

141. Seasearch, Isles of Scilly Survey September 2004 Summary Report in www.seasearch.org.uk. 2004.

142. Sharrock, S., Plymouth Drop Off Seasearch Surveys 2006-2009, in www.seasearch.org.uk. 2009.

143. Hiscock, K., Consultation on measures to protect biodiversity in Lyme Bay - response from the Marine Biological Association P. Cotter, Editor. 2007, Marine Biological Association of the United Kingdom Plymouth p. 3pp.

144. Goffredo, S., S. Di Ceglie, and F. Zaccanti, 2009 Genetic differentiation of the temperate subtropical stony coral *Leptopsammia pruvoti* in the Mediterranean sea. Israel Journal of Ecology & Evolution. **55**(2): p. 99-115.

145. Goffredo, S., J. Radetic, V. Airi, and F. Zaccanti, 2005 Sexual reproduction of the solitary sunset cup coral *Leptopsammia pruvoti* (Scleractinia : Dendrophylliidae) in the Mediterranean. 1. Morphological aspects of gametogenesis and ontogenesis. Marine Biology. **147**(2): p. 485-495.

146. Irving, R. and K. Hiscock, in press The status of the sunset cup coral *Letopsammia pruvoti* at Lundy. Journal of the Lundy Field Society, 2010.

147. Southward, A.J., P.A. Tyler, C. Young, M, and L. Fuiman, A, Long term oceanographic and ecological research in the Western English Channel in Advances In Marine Biology. 2005, .

148. Corbin, P.G., 1979 The seasonal abundance of four species of Stauromedusae (Coelenterata: Scyphomedusae) at Plymouth. Journal of the Marine Biological Association of the UK. **59**(02): p. 385-391.

149. Corbin, P.G., 1978 A new species of the stauromedusan genus *Lucernariopsis* (Coelenterata: Scyphomedusae). Journal of the Marine Biological Association of the UK. **58**(02): p. 285-290.

150. Hand, C. and K.R. Uhlinger, 1994 The unique, widley distributed, estuarine sea anemone, *Nematostella vectensis* Stephenson - A review, new facts, and questions. Estuaries. **17**(2): p. 501-508.

151. Sheader, M., A.M. Suwailem, and G.A. Rowe, 1997 The anemone, *Nematostella vectensis*, in Britain: Considerations for conservation management. Aquatic Conservation. **7**(1): p. 13-25.

152. Williams, R.B., 1987 The current status of the sea anemone *Nematostella vectensis* in England Transactions of the Norfolk and Norwich Naturalists Society. **27**: p. 371-374.

153. Williams, R.B., 1999 The current status of the sea anemone *Nematostella vectensis* in England - a correction Transactions of the Norfolk and Norwich Naturalists Society. **28**: p. 50.

154. Posey, M.H. and A.H. Hines, 1991 Complex predator-prey interactions within an estuarine benthic community. Ecology. **72**(6): p. 2155-2169.

155. Reitzel, A.M., J.A. Darling, J.C. Sullivan, and J.R. Finnerty, 2008 Global population genetic structure of the starlet anemone *Nematostella vectensis*: multiple introductions and implications for conservation policy. Biological Invasions. **10**(8): p. 1197-1213.

156. Darling, J.A., A. Kuenzi, and A.M. Reitzel, 2009 Human-mediated transport determines the non-native distribution of the anemone *Nematostella vectensis*, a dispersal-limited estuarine invertebrate. Marine Ecology Progress Series. **380**: p. 137-146.

157. Darling, J.A., A.M. Reitzel, and J.R. Finnerty, 2004 Regional population structure of a widely introduced estuarine invertebrate: *Nematostella vectensis* Stephenson in New England. Molecular Ecology. **13**(10): p. 2969-2981.

158. Hand, C. and K.R. Uhlinger, 1992 The culture, sexual and asexual reproduction, and growth of the sea anemone *Nematostella vectensis.* Biological Bulletin. **182**(2): p. 169-176.

159. Jones, L.A., K. Hiscock, and D.W. Connor, Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs 2000, Joint Nature Conservation Commitee (UK Marine SACs Project report): Peterborough

160. Jonsson, L.G., T. Lundalv, and K. Johannesson, 2001 Symbiotic associations between anthozoans and crustaceans in a temperate coastal area. Marine Ecology-Progress Series. **209**: p. 189-195.

161. Hughes, D.J., Sea pens and burrowing megafauna (volume III). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. 1998, Scottish Association for Marine Science (UK Marine SACs Project). Centre for Coastal and Marine Sciences, Dunstaffnage Marine Laboratory, Oban. p. 105 pp.

162. Thorson, G., 1949 Reproductive and larval ecology of marine bottom invertebrates. Biological Reviews. **25**(1): p. 1 - 45.

163. Molodtsova, T.N., 2004 On the taxonomy and presumable evolutionary pathways of planktonic larvae of *Ceriantharia* (Anthozoa, Cnidaria). Hydrobiologia. **530**: p. 261-266.

164. Minchin, D., 1987 *Swiftia pallida* Madsen (Coelenterata, Gorgonacea) in Irish waters with a note on *Pseudanthessius thorelli*, new record Brady (Crustacea, Copepoda) new to Ireland. Irish Naturalists' Journal. **22**(5): p. 183-185.
165. Sainte-Marie, B., 1983 Differences in life history and success between suprabenthic shelf populations of *Arrhis phyllonyx* (Amphipoda Gammaridea) in two ecosystems of the Gulf of St. Lawrence. Journal of Crustacean Biology. **3**: p. 45-67.
166. Lincoln, R.J., British marine Amphipoda: Gammaridea. 1979: British Museum (Natural History), London.
167. Weslawski, J.M. and J. Legezynska, 2002 Life cycles of some Arctic amphipods. Polish Polar Research. **23**(3-4): p. 253-264.
168. Nelson, W.G., 1980 Reproductive patterns of Gammaridean amphipods. Sarsia. **65**(2): p. 61-71.
169. Bamber, R.N., S.D. Batten, and N.D. Bridgwater, 1993 Design criteria for the creation of brackish lagoons. Biodiversity and Conservation. **2**(2): p. 127-137.
170. Sheader, M. and A.L. Sheader, 1985 New distribution records for *Gammarus insensibilis* Stock, 1966, in Britain. Crustaceana. **49**(JUL): p. 101-105.
171. Sheader, M., 1996 Factors influencing egg size in the gammarid amphipod *Gammarus insensibilis.* Marine Biology. **124**(4): p. 519-526.
172. Mancinelli, G. and L. Rossi, 2001 Indirect, size-dependent effects of crustacean mesograzers on the Rhodophyta *Gracilaria verrucosa* (Hudson) Papenfuss: evidence from a short-term study in the Lesina Lagoon (Italy). Marine Biology. **138**(6): p. 1163-1173.
173. Ersoy-Karacuha, M., M. Sezgin, and E. Dagli, 2009 Temporal and spatial changes of crustaceans in mixed eelgrass beds, *Zostera marina* L. and *Z.noltii* Hornem., at the Sinop Peninsula coast (the southern Black Sea, Turkey). Turkish Journal of Zoology. **33**: p. 1-12.
174. Helluy, S. and F. Thomas, 2003 Effects of *Microphallus papillorobustus* (Platyhelminthes: Trematoda) on serotonergic immunoreactivity and neuronal architecture in the brain of *Gammarus insensibilis* (Crustacea: Amphipoda). Proceedings of the Royal Society - Biological Sciences. **270**(1515): p. 563-568.
175. Ponton, F., D. Duneau, M.I. Sanchez, A. Courtiol, A.T. Terekhin, E.V. Budilova, F. Renaud, and F. Thomas, 2009 Effect of parasite-induced behavioral alterations on juvenile development. Behavioral Ecology. **20**(5): p. 1020-1025.
176. Ponton, F., D.G. Biron, C. Joly, S. Helluy, D. Duneau, and F. Thomas, 2005 Ecology of parasitically modified populations: a case study from a gammarid-trematode system. Marine Ecology Progress Series. **299**: p. 205-215.
177. Karakiri, M. and A. Nicolaidou, 1987 Population studies on the Amphipoda of Mazoma Lagoon (Greece). Helgolander Meeresuntersuchungen. **41**(4): p. 453-464.
178. Cardoso, A.C. and A.B. Yule, 1995 Aspects of the reproductive biology of *Pollicipes pollicipes* (Cirrepedia; Lepadomorpha) from the Southwest Coast of Portugal. Netherlands Jounal of Aquatic Ecology. **29**(3-4): p. 391-396.
179. Molares, J. and J. Freire, 2003 Development and perspectives for community-based management of the goose barnacle (*Pollicipes pollicipes*) fisheries in Galicia (NW Spain). Fisheries Research. **65**(1-3): p. 485-492.
180. Borja, A., P. Liria, I. Muxika, and J. Bald, 2006 Relationships between wave exposure and biomass of the goose barnacle (*Pollicipes pollicipes*, Gmelin, 1790) in the Gaztelugatxe Marine eserve (Basque Country, northern Spain). ICES Journal of Marine Science. **63**(4): p. 626-636.
181. Borja, A., I. Muxika, and J. Bald, 2006 Protection of the goose barnacle *Pollicipes pollicipes*, Gmelin, 1790 population: the Gaztelugatxe Marine Reserve (Basque Country, northern Spain). Scientia Marina. **70**(2): p. 235-242.
182. Barnes, M., 1996 Pedunculate Cirripedes of the genus *Pollicipes.* Oceanography and Marine Biology. **34**: p. 303-394.

183. Cruz, T. and S.J. Hawkins, 1998 Reproductive cycle of *Pollicipes pollicipes* at Cabo de Sines, south-west coast of Portugal. Journal of the Marine Biological Association of the United Kingdom. **78**(2): p. 483-496.
184. Macho, G., J. Molares, and E. Vazquez, 2005 Timing of larval release by three barnacles from the NW Iberian Peninsula. Marine Ecology Progress Series. **298**: p. 251-260.
185. Quinteiro, J., J. Rodriguez-Castro, and M. Rey-Mendez, 2007 Population genetic structure of the stalked barnacle *Pollicipes pollicipes* (Gmelin, 1789) in the northeastern Atlantic: influence of coastal currents and mesoscale hydrographic structures. Marine Biology. **153**(1): p. 47-60.
186. Kugele, M. and A.B. Yule, 1996 The larval morphology of *Pollicipes pollicipes* (Gmelin, 1790) (Cirripedia: Lepadomorpha) with notes on cypris settlement. Scientia Marina. **60**(4): p. 469-480.
187. Hunter, E., S.E. Shackley, and D.B. Bennett, 1996 Recent studies on the crawfish *Palinurus elephas* in South Wales and Cornwall. Journal of the Marine Biological Association of the United Kingdom. **76**(4): p. 963-983.
188. Follesa, M.C., D. Cuccu, R. Cannas, and A. Cau, 2007 On the growth of the European spiny lobster, *Palinurus elephas* from Sardinian waters (central western Mediterranean Sea). New Zealand Journal of Marine and Freshwater Research. **41**(4): p. 377-383.
189. Giacalone, V.M., G. D'Anna, C. Pipitone, and F. Badalamenti, 2006 Movements and residence time of spiny lobsters, *Palinurus elephas* released in a marine protected area: an investigation by ultrasonic telemetry. Journal of the Marine Biological Association of the United Kingdom. **86**(5): p. 1101-1106.
190. Goni, R. and D. Latrouite, 2005 Review of the biology, ecology and fisheries of *Palinurus* spp. species of European waters: *Palinurus elephas* (Fabricius, 1787) and *Palinurus mauritanicas* (Gruvel, 1911). Cahiers De Biologie Marine. **46**(2): p. 127-142.
191. Gristina, M., F. Fiorentino, G. Garofalo, and F. Badalamenti, 2009 Shelter preference in captive juveniles of European spiny lobster *Palinurus elephas* (Fabricius, 1787). Marine Biology. **156**(10): p. 2097-2105.
192. Diaz, D., M. Mari, P. Abello, and M. Demestre, 2001 Settlement and juvenile habitat of the European spiny lobster *Palinurus elephas* (Crustacea: Decapoda: Palinuridae) in the western Mediterranean Sea. Scientia Marina. **65**(4): p. 347-356.
193. Goni, R., A. Quetglas, and O. Renones, 2001 Diet of the spiny lobster *Palinurus elephas* (Decapoda: Palinuridea) from the Columbretes Islands Marine Reserve (north-western Mediterranean). Journal of the Marine Biological Association of the UK. **81**(02): p. 347-348.
194. Hunter, E., 1999 Biology of the European spiny lobster, *Palinurus elephas* (Fabricius, 1787) (Decapoda, Palinuridea). Crustaceana. **72**: p. 545-565.
195. Galhardo, A.C., P. Serafim, and M. Castro. Aspects of the biology and fishery of the European spiny lobster (*Palinurus elephas*) from the Southwest coast of Portugal. in IEEE Swarm Intelligence Symposium. 2005. Pasadena, CA: Crustacean Soc.
196. Hepper, B.T., 1977 Fishery for crawfish, *Palinurus elephas*, off the coast of Cornwall. Journal of the Marine Biological Association of the United Kingdom. **57**(4): p. 925-941.
197. Follesa, M.C., D. Cuccu, R. Cannas, A. Sabatini, A.M. Deiana, and A. Cau, 2009 Movement patterns of the spiny lobster *Palinurus elephas* (Fabricius, 1787) from a central western Mediterranean protected area. Scientia Marina. **73**(3): p. 499-506.
198. Goni, R., A. Quetglas, and O. Renones, 2003 Size at maturity, fecundity and reproductive potential of a protected population of the spiny lobster *Palinurus elephas* (Fabricius, 1787) from the western Mediterranean. Marine Biology. **143**(3): p. 583-592.
199. Kittaka, J. and E. Ikegami, 1988 Culture of the Palinurid *Palinurus elephas* from egg stage to Puerulus. Nippon Suisan Gakkaishi. **54**(7): p. 1149-1154.
200. Follesa, M.C., D. Cuccu, R. Cannas, S. Cabiddu, M. Murenu, A. Sabatini, and A. Cau. Effects of marine reserve protection on spiny lobster (*Palinurus elephas* Fabr., 1787) in

a central western Mediterranean area. in 41st European Marine Biology Symposium. 2008. Cork, IRELAND: Springer.

201. NBN. National Biodiversity Network Gateway. [web page] 2008 2008 [cited 15.12.09]; Available from: ttp://data.nbn.org.uk/gridMap/gridMap.jsp?allDs=1&srchSpKey=NBNSYS0000182247.
202. Yu, O.H., H.L. Suh, and Y. Shirayama, 2003 Feeding ecology of three amphipod species *Synchelidium lenorostralum*, *S. trioostegitum* and *Gitanopsis japonica* in the surf zone of a sandy shore. Marine Ecology Progress Series. **258**: p. 189-199.
203. Rees, H.L. and P.J. Dare, Sources of mortality and associated life-cycle traits of selected benthics species - a review in Fisheries Research Data Report No. 33, F.a.F. Ministry of Agriculture, Directorate of Fisheries Research, Editor. 1993, MAFF: Lowestoft p. 37pp.
204. Witbaard, R., G.C.A. Duineveld, and P. de Wilde, 1999 Geographical differences in growth rates of *Arctica islandica* (Mollusca : Bivalvia) from the North Sea and adjacent waters. Journal of the Marine Biological Association of the United Kingdom. **79**(5): p. 907-915.
205. Schone, B.R., S.D. Houk, A.D. FREYRE CASTRO, J. FIEBIG, W. OSCHMANN, I. KRONCKE, W. DREYER, and F. GOSSELCK, 2005 Daily growth rates in shells of *Arctica islandica*: assessing sub-seasonal environmental controls on a long-lived bivalve mollusk. Palaios. **20**: p. 78-92.
206. Loosanoff, V.L., 1953 Reproductive cycle in *Cyprina islandica.* Biological Bulletin. **104**(2): p. 146-155.
207. Brey, T., W.E. Arntz, D. Pauly, and H. Rumohr, 1990 *Arctica* (*Cyprina*) *islandica* in Keil Bay (Western Baltic) - growth, production and ecological significance. Journal of Experimental Marine Biology and Ecology. **136**(3): p. 217-235.
208. Witbaard, R. and M.J.N. Bergman, 2003 The distribution and population structure of the bivalve *Arctica islandica* L. in the North Sea: what possible factors are involved? Journal of Sea Research. **50**(1): p. 11-25.
209. Holmes, S.P., R. Witbaard, and J. Van der Meer, 2003 Phenotypic and genotypic population differentiation in the bivalve mollusc *Arctica islandica*: results from RAPD analysis. Marine Ecology Progress Series. **254**: p. 163-176.
210. Thórarindsóttir, G.G., 2000 Annual gametogenic cycle in ocean quahog, *Arctica islandica* from north-western Iceland. Journal of the Marine Biological Association of the United Kingdom. **80**(4): p. 661-666.
211. Cargnelli, L.M., S.J. Griesbach, D.B. Packer, and E. Weissberger, Essential Fish Habitat Source Document: Ocean Quahog, *Arctica islandica*, Life History and Habitat Characteristics, in NOAA Technical Memorandum NMFS-NE-148, NOAA, Editor. 1999, National Oceanic and Atmospheric Administration.
212. Mann, R. and C.C. Wolf, 1983 Swimming behaviour of larvae of the ocean quahog, *Arctica Islandica* in repsonse to pressure and temperature. Marine Ecology Progress Series. **13**(2-3): p. 211-218.
213. Woodward, F.R., 1985 The fan-mussel *Pinna fragilis* in Scotland, UK. Glasgow Naturalist. **21**(1): p. 63-69.
214. Solandt, J.L., 2003 *Atrina fragilis* (Pennant 1777): A Species of Conservation Concern British Wildlife. **14**(6): p. 423-427.
215. Solandt, J.L., Fanshell survey at West Hoe, Plymouth Sound. A collaborative project between: The Marine Conservation Society, Seasearch and the Marine Biological Association. 2004.
216. Simunovic, A., C. Piccinetti, M. Bartulovic, and I. Grubelic, 2001 Distribution of *Atrina fragilis* (Pennant, 1777) (Pinnidae, Mollusca Bivalvia) in the Adriatic Sea. Acta Adriat.,. **42**(1): p. 61-70.

217. Maeno, Y., K. Suzuki, T. Yurimoto, R. Fuseya, S. Kiyomoto, i.S. Ohash, and H. Oniki, 2009 Maturation process of broodstock of the Pen Shell *Atrina pectinata* (Linnaeus, 1767) in Suspension Culture. Journal of Shellfish Research. **28**(3): p. 561-568.
218. Hall-Spencer, J.M., C. Froglia, R.J.A. Atkinson, and P.G. Moore, 1999 The impact of Rapido trawling for scallops, *Pecten jacobaeus* (L.), on the benthos of the Gulf of Venice. Ices Journal of Marine Science. **56**(1): p. 111-124.
219. Butler, A., N. Vicente, and B. de Gaulejac, 1993 Ecology of the pterioid bivalves *Pinna bicolor* Gmelin and *Pinna nobilis* L. Marine Life. **3**(1-2): p. 37-45.
220. Hiscock, K. and H. Jones, Test feature dossiers compiled as part of the work on the identification of nationally important marine features in the Irish Sea (part 2), in Report to Joint Nature Conservation, Committee from the Marine Life Information Network (MarLIN), MBA, Editor. 2004, Marine Biological Association of the UK: Plymouth. p. 52pp.
221. Pain, C., S. Wilkinson, and J. Light, 2009 Two further UK sites for *Caecum armoricum*, de Folin, 1869, formerly known only in the Fleet, Dorset, as a member of the interstitial 'springs' community. Journal of Conchology. **39**: p. 779-780.
222. Seaward, D.R., 1987 *Caecum armoricum* de Folin 1869 new to British marine fauna, living in the Fleet, Dorest, within an unusual habitat. Proceedings Dorset Natural History and Archaeological Society. **109**: p. 165.
223. Seaward, D.R., 1989 *Caecum armoricum* (Prosobranchia, Rissoacea) new to the British Marine Fauna. Journal of Conchology. **33**: p. 268-268.
224. Seaward, D.R., 1987 *Caecum armoricum* deFolin 1869 new to british marine fauna, living in the Fleet, Dorest, within an unusual habitat. Proceedings Dorset Natural History and Archaeological Society **109**: p. 165.
225. Graham, A., Molluscs: Prosobranch and Pyramidellid Gastropods: Keys and Notes for Identification of the Species (Synopses of the British Fauna No 2), in Published for the Linnean Society of London and the Estuarine and Brackish-water Sciences Association, E.J. Brill and W. Backhuys, Editors. 1988, Leiden; New York.
226. Crothers, J.H., 1985 Dog-whelks and introduction to the biology of *Nucella lapillus.* Field Studies. **6**(2): p. 291-360.
227. Morgan, P.R., 1972 The influence of prey availability on the distribution and predatory behaviour of *Nucella lapillus* (L.). Journal of Animal Ecology. **41**(2): p. 257-&.
228. Ingolfsson, A., 2009 Predators on rocky shores in the northern Atlantic: Can the results of local experiments be generalized on a geographical scale? Estuarine Coastal and Shelf Science. **83**(3): p. 287-295.
229. Thompson, R.C., T.P. Crowe, and S.J. Hawkins, 2002 Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. Environmental Conservation. **29**(2): p. 168-191.
230. Bell, J.J. and B. Okamura, 2005 Low genetic diversity in a marine nature reserve: re-evaluating diversity criteria in reserve design. Proceedings of the Royal Society B-Biological Sciences. **272**(1567): p. 1067-1074.
231. Colson, I. and R.N. Hughes, 2004 Rapid recovery of genetic diversity of dogwhelk (*Nucella lapillus* L.) populations after local extinction and recolonization contradicts predictions from life-history characteristics. Molecular Ecology. **13**(8): p. 2223-2233.
232. McInerney, C., A.L. Allcock, M.P. Johnson, and P.A. Prodohl, 2009 Understanding marine reserve function in a seascape genetics context: *Nucella lapillus* in Strangford Lough (Northern ireland) as an example Aquatic Biology. **7**: p. 45-58.
233. Feare, C.J., 1970 The reproductive cycle of the Dog whelk *Nucella lapillus.* Proceedings of the Malacological Society of London. **39**(2-3): p. 125-137.
234. Gosselin, L.A. and F.S. Chia, 1995 Distribution and dispersal of early juvenile snails: Effectiveness of intertidal microhabitats as refuges and food sources. Marine Ecology Progress Series. **128**(1-3): p. 213-223.

235. Morton, B., 2009 Recovery from imposex by a population of the dogwhelk, *Nucella lapillus* (Gastropoda: Caenogastropoda), on the southeastern coast of England since May 2004: A 52-month study*.* Marine Pollution Bulletin. **58**(10): p. 1530-1538.
236. Barnes, R.S.K., 1973 A preliminary survey of the macroscopic bottom fauna of the Solent, with particular reference to *Crepidula fornicata* and *Ostrea edulis.* Proceedings of Molluscan Journal.
237. Culloty, S.C., M.A. Cronin, and M.F. Mulcahy, 2001 An investigation into the relative resistance of Irish flat oysters *Ostrea edulis* L. to the parasite *Bonamia ostreae* (Pichot et al., 1980)*.* Aquaculture. **199**(3-4): p. 229-244.
238. Kennedy, R.J. and D. Roberts, 1999 A survey of the current status of the flat oyster *Ostrea edulis* in Strangford Lough, Northern Ireland, with a view to the restoration of its oyster beds*.* Biology and Environment-Proceedings of the Royal Irish Academy. **99B**(2): p. 79-88.
239. Cole, H.A., 1935 The Fate of the Larval Organs in the Metamorphosis of *Ostrea edulis* Journal of the Marine Biological Association **XXII**: p. 469-484.
240. Cole, H.A., 1941 The fecundity of *Ostrea edulis* Journal of the Marine Biological Association of the United Kingdom. **25**(2): p. 243-260.
241. Acarli, S. and A. Lok, 2009 Larvae Development Stages of the European Flat Oyster (*Ostrea edulis*)*.* Israeli Journal of Aquaculture-Bamidgeh. **61**(2): p. 114-120.
242. Cole, H.A. and E.W. Knight Jones, 1949 The setting behaviour of larvae of the european flat oyster, *Ostrea edulis* L. and its influence on methods of cultivation and spat collection*.* Fishery Investigations, Series 2. **17**: p. 1-39.
243. Knight Jones, E.W., 1951 Aspects of the settling behaviour of larvae of *Ostrea edulis* on Essex oyster beds*.* Rapports et Procès-verbaux des Réunions. Conseil Permanent International pour L'exploration de la Mer. **128**: p. 30-34.
244. Spärck, R., 1951 Fluctuations in the stock of oyster (*Ostrea edulis*) in the Limfjord in recent time*.* Rapports et Procès-verbaux des Réunions. Conseil Permanent International pour L'exploration de la Mer. **128**: p. 27-29.
245. Killeen, I.J. and J.M. Light, 2002 The status, distribution and ecology of *Paludinella littorina* (Delle Chiaje, 1828) (Gastropoda: Assimineidae) in the British Isles*.* Journal of Conchology. **37**: p. 551-563.
246. Barnes, R.S.K., The Brackish Water Fauna of Northwestern Europe. 1994: Cambridge University Press.
247. Roginskaya, I.S., 1970 *Tenellia-adspersa* a nudibranch new to the Azov sea with notes on its taxonomy and ecology*.* Malacological Review. **3**(PART 2): p. 167-174.
248. UKBAP. Action plan for *Tenellia adspersa* UK Biodiversity Action Plan 1999 [cited 2009 15 December]; Available from: www.ukbap.org.uk/UKPlans.aspx?ID=595.
249. Eyster, L.S., 1979 Reproduction and developmental variability in the opisthobranch *Tenellia pallida.* Marine Biology. **51**(2): p. 133-140.
250. Chester, Life history and reproductive biology of the estuarine nudibranch *Tenellia adspersa* (Nordmann, 1845). 1996, University of New Hampshire
251. Blezard, D.J., Salinity as a refuge from predation in a nudibranch-hydroid relationship within the Great Bay estuary system. 1999, University of New Hampshire
252. Ragnarsson, S.A. and D. Raffaelli, 1999 Effects of the mussel *Mytilus edulis* L. on the invertebrate fauna of sediments*.* Journal of Experimental Marine Biology and Ecology. **241**(1): p. 31-43.
253. Thiel, M. and N. Ullrich, 2002 Hard rock versus soft bottom: the fauna associated with intertidal mussel beds on hard bottoms along the coast of Chile, and considerations on the functional role of mussel beds*.* Helgoland Marine Research. **56**(1): p. 21-30.
254. Dittmann, S., 1990 Mussel beds-amensalism or amelioration for intertidal fauna? Helgolander Meeresuntersuchungen. **44** p. 3-4.
255. Seed, R. and T.H. Suchanek, Population and community ecology of *Mytilus*, in The mussel *Mytilus*: ecology, physiology, genetics and culture, E. Gosling, Editor. 1992,

Elsevier Science Publishing, Developments in Aquaculture and Fisheries Science, Vol 25.

256. Buttger, H., H. Asmus, R. Asmus, C. Buschbaum, S. Dittmann, and G. Nehls, 2008 Community dynamics of intertidal soft-bottom mussel beds over two decades. Helgoland Marine Research. **62**(1): p. 23-36.
257. Lubchenko, J., 1978 Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilites. American Naturalist. **112**: p. 23-39.
258. Norton, T.A., S.J. Hawkins, N.L. Manley, G.A. Williams, and D.C. Watson, 1990 Scraping a living - a review of Littorinid grazing. Hydrobiologia. **193**: p. 117-138.
259. Commito, J.A., W.E. Dow, and B.M. Grupe, 2006 Hierarchical spatial structure in soft-bottom mussel beds. Journal of Experimental Marine Biology and Ecology. **330**(1): p. 27-37.
260. Asmus, H., 1987 Secondary production of an intertidal mussel bed community related to its storage and turnover compartments. Marine Ecology Progress Series. **39**(3): p. 251-266.
261. Snover, M.L. and J.A. Commito, 1998 The fractal geometry of *Mytilus edulis* L. spatial distribution in a soft-bottom system. Journal of Experimental Marine Biology and Ecology. **223**(1): p. 53-64.
262. Kostylev, V. and J. Erlandsson, 2001 A fractal approach for detecting spatial hierarchy and structure on mussel beds. Marine Biology. **139**: p. 497-506.
263. Nehls, G. and M. Thiel, 1993 Large scale distribution patterns of the mussel *Mytilus edulis* in the Wadden Sea of Schleswig Holstein - do storms structure the ecosystem? Netherlands Journal of Sea Research. **31**(2): p. 181-187.
264. Dankers, N., A.G. Brinkman, A. Meijboom, and E. Dijkman, 2001 Recovery of intertidal mussel beds in the Wadden Sea: use of habitat maps in the management of the fishery. Hydrobiologia. **465**(1-3): p. 21-30.
265. Bayne, B.L., 1964 Primary and secondary settlement in *Mytilus edulis* L. (Mollusca). Journal of Animal Ecology. **33**: p. 513-523.
266. Lutz, R.A. and M.J. Kennish, Ecology and morphology of larval and early postlarval mussels, in In: The mussel *Mytilus*: ecology, physiology, genetics and culture, E. Gosling, Editor. 1992: Developments in Aquaculture and Fisheries Science, vol. 25. Elsevier Science Publishers, Amsterdam, pp 53–85.
267. Dare, P.J., D.B. Edwards, and G. Davies, Experimental collection and handling of spat mussels (*Mytilus edulis* L.) on ropes for intertidal culture, in Fisheries Research Technical Report. 1983: MAFF, Lowstoft, 74: 1-23.
268. McGrorty, S., R.T. Clarke, C.J. Reading, and J.D. Gosscustard, 1990 Population-dynamics of the mussel *Mytilus edulis* - density changes and regulation of the population in the Exe estuary, Devon. Marine Ecology Progress Series. **67**(2): p. 157-169.
269. Bayne, B.L., 1965 Growth and the delay of metamorphosis of the larvae of *Mytilus edulis* (L.). Ophelia. **2**: p. 1-47.
270. Fish, J.D. and A. Mills, 1979 The reproductive biology of *Corophium volutator* and *C. arenarium* (Crustacea: Amphipoda). Journal of the Marine Biological Association of the United Kingdom. **59**: p. 355-368.
271. Hughes, R.G., 1988 DISPERSAL BY BENTHIC INVERTEBRATES - THE INSITU SWIMMING BEHAVIOR OF THE AMPHIPOD COROPHIUM-VOLUTATOR. Journal of the Marine Biological Association of the United Kingdom. **68**(4): p. 565-579.
272. Lawrie, S.M. and D.G. Raffaelli, 1998 Activity and mobility of *Corophium volutator*: A field study. Marine and Freshwater Behaviour and Physiology. **31**(1): p. 39-53.
273. Meadows, P.S. and A. Reid, 1966 The behaviour of *Corophium volutator* (Crustacea, Amphipoda). Journal of Zoology, London. **150**: p. 387-399.
274. Kinlan, B.P. and S.D. Gaines, 2003 Propagule dispersal in marine and terrestrial environments: a community perspective. Ecology. **84**(8).

275. Powell, R., 1992 Biometry of brooding in seven species of amphipod (Crustacea) from the Clyde Sea area. Journal of Natural History. **26**(2): p. 353 - 371.
276. Thorson, G., 1946 Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the Sound (Øresund). Meddelelser fra Kommissionen for Danmarks Fiskeri- Og Havundersögelser, Serie: Plankton. **4**: p. 1-523.
277. Wilson, W.H., 1991 Sexual reproductive modes in polychaetes: classification and diversity. Bulletin of Marine Science. **48**(2): p. 500-516.
278. Cazaux, C., 1969 Etude morphologique du developpement larvaire d'annelides polychcaetes (Bassin d'Arcachon).II. Phyllodocidae, Syllidae, Nereidae. Archives de Zoologie Experimentale et Generale. **109**: p. 477-543.
279. Rainbow, P.S., 1984 An introduction to the biology of British littoral barnacles. Field Studies. **6**(1): p. 1-52.
280. Herlyn, M., G. Millat, and B. Petersen, 2008 Documentation of sites of intertidal blue mussel (*Mytilus edulis* L.) beds of the Lower Saxonian Wadden Sea, southern North Sea (as of 2003) and the role of their structure for spatfall settlement. Helgoland Marine Research. **62**(2): p. 177-188.
281. Vine, H., Blue mussels in the Wash. 1999, Wadden Sea Newsletter 1999 - 1.
282. Wheeler, A.J., T. Beck, J. Thiede, M. Klages, A. Grehan, and F.X. Monteys, Deep-water coral mounds on the Porcupine Bank, Irish Margin: preliminary results from the Polarstern ARK-XIX/3a ROV cruise, in Cold-Water Corals and Ecosystems, 2nd International Symposium on Deep-Sea Corals, Sept 2003, A. Freiwald and J.M. Roberts, Editors. 2005. p. 393-402.
283. Mienis, F., C. van der Land, H.C. de Stigter, M. van de Vorstenbosch, H. de Haas, T. Richter, and T.C.E. van Weering, 2009 Sediment accumulation on a cold-water carbonate mound at the Southwest Rockall Trough margin. Marine Geology. **265**(1-2): p. 40-50.
284. Henry, L.A. and J.M. Roberts, 2007 Biodiversity and ecological composition of macrobenthos on cold-water coral mounds and adjacent off-mound habitat in the bathyal Porcupine Seabight, NE Atlantic. Deep-Sea Research Part I-Oceanographic Research Papers. **54**(4): p. 654-672.
285. Roberts, J.M., L.A. Henry, D. Long, and J.P. Hartley, 2008 Cold-water coral reef frameworks, megafaunal communities and evidence for coral carbonate mounds on the Hatton Bank, north east Atlantic. Facies. **54**(3): p. 297-316.
286. Wheeler, A.J., M. Kozachenko, A. Beyer, A. Foubert, V.A.I. Huvenne, M. Klages, D.G. Masson, K. Olu-Le Roy, and J. Thiede, Sedimentary processes and carbonate mounds in the Belgica Mound province, Porcupine Seabight, NE Atlantic, in In: Cold-Water Corals and Ecosystems, 2nd International Symposium on Deep-Sea Corals Sept 2003, A. Freiwald and J.M. Roberts, Editors. 2005. p. 571-603.
287. Jonsson, L.G., P.G. Nilsson, F. Floruta, and T. Lundalv, 2004 Distributional patterns of macro- and megafauna associated with a reef of the cold-water coral *Lophelia pertusa* on the Swedish west coast. Marine Ecology-Progress Series. **284**: p. 163-171.
288. Mortensen, P.B., M. Hovland, T. Brattegard, and R. Farestveit, 1995 Deepwater bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64°N on the Norwegian shelf: structure and associated megafauna. Sarsia **80**: p. 145–158.
289. Wilson, J. and C. Vina Herbon, Macrofaunas and biogenic carbonates from the north slope of Porcupine Bank, south east slope of Rockall Bank and west of Faeroe Bank Channel. 1998, In: Kenyon, N.H., Ivanov, M.K. & Akhmetzhanov, A.M. (Eds) (1998) Cold water carbonate mounds and sediment transport on the Northeast Atlantic margin. Intergovernmental Oceanographic Commission Technical Series 52. UNESCO 1998.
290. Sumida, P. and R. Kennedy, Porcupine Seabight: biological data, in Cold water carbonate mounds and sediment transport on the Northeast Atlantic margin, N.H.

Kenyon, M.K. Ivanov, and A.M. Akhmetzhanov, Editors. 1998, UNESCO: Intergovernmental Oceanographic Commission technical series 52.

291. Roberts, J.M., 2005 Reef-aggregating behaviour by symbiotic eunicid polychaetes from cold-water corals: do worms assemble reefs? Journal of the Marine Biological Association of the United Kingdom **85**(4): p. 813-819.

292. Hovland, M. and P.B. Mortensen, Norske korallev og processer i havbunnen. 1999: John Grieg, Bergen.

293. Roberts, J.M., 2002 The occurrence of the coral *Lophelia pertusa* and other conspicuous epifauna around an oil platform in the North Sea. Underwater Technology. **25**(2): p. 83-91.

294. Wilson, J.B., 1979 Distribution of the coral *Lophelia pertusa* (L.) (Porifera (Pallas)) in the northeast Atlantic. Journal of the Marine Biological Association of the United Kingdom. **59**(1): p. 149-164.

295. Kenyon, N.H., M.K. Ivanov, and A.M. Akhmetzhanov, Cold water carbonate mounds and sediment transport on the Northeast Atlantic margin, in Intergovernmental Oceanographic Commission technical series 52. 1998, UNESCO.

296. Gubbay, S., The Offshore Directory. Review of a selection of habitats, communities and species of the north-east Atlantic. 2002, A report for WWF by Susan Gubbay with contributions from Maria Baker, Brian Bett and Gerd Konnecker.

297. Hall-Spencer, J., V. Allain, and J. Helge Fosså, 2002 Trawling damage to Northeast Atlantic ancient coral reefs. Proceedings of the Royal Society, Series B - Biological Sciences. **269**: p. 507-511.

298. Le Goff-Vitry, M.C. and A.D. Rogers, Molecular ecology of *Lophelia pertusa* in the NE Atlantic, in In: Cold-Water Corals and Ecosystems, 2nd International Symposium on Deep-Sea Corals, Sept 2003, A. Freiwald and J.M. Roberts, Editors. 2003: Erlangen, GERMANY. p. 653-662.

299. Le Goff-Vitry, M.C., O.G. Pybus, and A.D. Rogers, 2004 Genetic structure of the deep-sea coral *Lophelia pertusa* in the northeast Atlantic revealed by microsatellites and internal transcribed spacer sequences. Molecular Ecology. **13**(3): p. 537-549.

300. Waller, R.G. and P.A. Tyler, 2005 The reproductive biology of two deep-water, reef-building scleractinians from the NE Atlantic Ocean. Coral Reefs. **24**(3): p. 514-522.

301. Rogers, A.D., 1999 The biology of *Lophelia pertusa* (LINNAEUS 1758) and other deep-water reef-forming corals and impacts from human activities. International Review of Hydrobiology. **84**(4): p. 315-406.

302. Gass, S.E. and J.M. Roberts, 2006 The occurrence of the cold-water coral *Lophelia pertusa* (Scleractinia) on oil and gas platforms in the North Sea: Colony growth, recruitment and environmental controls on distribution. Marine Pollution Bulletin. **52**(5): p. 549-559.

303. Waller, R.G., Deep water scleractinians (Cnidaria: Anthozoa): current knowledge of reproductive processes, in Cold-Water Corals and Ecosystems, 2nd International Symposium on Deep-Sea Corals, Sept 2003, A. Freiwald and J.M. Roberts, Editors. 2005.

304. Roberts, C.M., 2002 Deep impact: the rising toll of fishing in the deep sea. Trends in Ecology & Evolution. (Forum Paper).

305. Roberts, C.M., O.C. Peppe, L.A. Dodds, D.J. Mercer, W.T. Thomson, J.D. Gage, and D.T. Meldrum, Monitoring environmental variability around cold-water coral reefs: the use of a benthic photolander and the potential of seafloor observations. 2003 conference proceedings, ed. A. Freiwald and J.M. Roberts. 2005.

306. Wilson, J.B., 1979 The distribution of the coral *Lophelia pertusa* (L.) [L Prolifera (Pallas)] in the north-east Atlantic. Journal of the Marine Biological Association of the UK. **59**: p. 149-164.

307. Fossa, J.H., P.B. Mortensen, and D.M. Furevik, 2002 The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia. **471**: p. 1-12.
308. Pehardaa, M., I. Mladineoa, J. Bolotinb, L. Kekeza, and B. Skaramucab, 2006 The reproductive cycle and potential protandric development of the Noah's Ark shell, *Arca noae* L.: Implications for aquaculture. Aquaculture. **252**(2-4): p. 317-327.
309. Maldonado, M. and A. Riesgo, 2008 Reproductive output in a Mediterranean population of the homosclerophorid *Corticium candelabrum* (Porifera, Demospongiae), with notes on the ultrastructure and behavior of the larva. Marine Ecology-an Evolutionary Perspective. **29**(2): p. 298-316.
310. Nichols, S.A. and P.A.G. Barnes, 2005 A molecular phylogeny and historical biogeography of the marine sponge genus Placospongia (Phylum Porifera) indicate low dispersal capabilities and widespread crypsis. Journal of Experimental Marine Biology and Ecology. **323**(1): p. 1-15.
311. Berec, L., P.J. Schembri, and D.S. Boukal, 2005 Sex determination in *Bonellia viridis* (Echiura : Bonelliidae): population dynamics and evolution. Oikos. **108**(3): p. 473-484.
312. Agius, L., 1979 Larval settlement in the echiuran worm *Bonellia viridis*: Settlement on both the adult proboscis and body trunk Marine Biology. **53**(2): p. 125-129.
313. Jacobs, M.W., B.M. Degnan, J.D.D. Bishop, and R.R. Strathmann, 2008 Early activation of adult organ differentiation during delay of metamorphosis in solitary ascidians, and consequences for juvenile growth. Invertebrate Biology. **127**(2): p. 217-236.
314. Havenhand, J.N. and I. Svane, 1991 Roles of hydrodynamics and larval behaviour in determining spatial aggregation in the tunicate *Ciona intestinalis.* Marine Ecology Progress Series. **68**: p. 271-276.
315. Svane, I. and J.N. Havenhand, 1993 Spawning and dispersal in *Ciona intestinalis* (L.) Marine Ecology, Pubblicazioni della Stazione Zoologica di Napoli. **14**: p. 53-66.
316. Underwood, A.J., 1972 Observations on the reproductive cycles of *Monodonta lineata*, *Gibbula umbilicalis* and *G. cineraria.* Marine Biology. **17**: p. 333-340.
317. Panteleeva, N.N., 2002 Life-Cycle adaptation of hydroids of the family Corynidae and the subfamily Obeliinae to habitat conditions. Doklady Biological Sciences. **386**(1-6): p. 457-459.
318. Cornelius, P.F.S., North-west European thecate hydroids and their medusae. Synopses of the British Fauna New Series 50,, ed. R.S.K. Barnes and J.H. Crothers. Vol. 1. 1995: Field Studies Council. 347.
319. Jackson, J.B.C., 1986 Modes of dispersal of clonal benthic invertebrates: consequences for species' distributions and genetic structure of local populations. Bulletin of Marine Science. **39**: p. 588-606.
320. Hartnoll, R.G., A.L. Rice, and M.J. Attrill, 1992 Aspects of the biology of the galatheid genus *Munida* (Crustacea, decapoda) from the Porcupine Seabight, northeast Atlantic. Sarsia. **76**(4): p. 231-246.
321. Scheltema, R.S. and I.P. Williams, 2009 Reproduction among protobranch bivalves of the family Nuculidae from sublittoral, bathyal, and abyssal depths off the New England coast of North America. Deep-Sea Research Part Ii-Topical Studies in Oceanography. **56**(19-20): p. 1835-1846.
322. Anderson, A., 1971 Intertidal activity, breeding and the floating habit of *Hydrobia ulvae* in the Ythan estuary. Journal of the Marine Biological Association of the United Kingdom. **51**: p. 423-437.
323. Chia, F.S., J. Buckland-Nicks, and C.M. Young, 1984 Locomotion of marine invertebrate larvae: a review. Canadian Journal of Zoology **62**: p. 1205–1222.
324. Wilson, J.G., 1992 Age-specific energetics of reproduction in *Nucula turgida* (Leckenby and Marshall) a bivalve with lecithotrophic larval development. Invertebrate Reproduction & Development. **22**(1-3): p. 275-280.
325. Hendler, O.L., Reproduction of Marine Invertebrates. 1991.

326. Michaela Aschan, R.I., 2009 Recruitment of shrimp (Pandalus borealis) in the Barents Sea related to spawning stock and environment
Deep Sea Research Part II:. Topical Studies in Oceanography,. **56**(Issues 21-22): p. Pages 2012-2022.
327. Pedersen et al., O.P.P., M. Aschan, K. Tande, D. Slagstad and T. Rasmussen, , 2003 Larval dispersal and mother populations of previous termPandalusnext term borealis investigated by Lagrangian particle tracking model,. Fisheries Research **65**: p. pp. 173-190.
328. Nelson-Smith, A., Serpulids, in Catalogue of Marine Fouling Organisms. 1967, O.E.C.D. Paris.
329. Elmhirst, R., Notes on the breeding and growth of marine animals in the Clyde Sea Area, in Report of the Scottish Marine Biological Association. 1922. p. 19-43.
330. Adam, P., Saltmarsh Ecology. 1990, Cambridge University Press.
331. Hughes, R.G., 2004 Climate change and loss of saltmarshes: consequences for birds. Ibis. **146**: p. 21-28.
332. Langlois, E., A. Bonis, and J.B. Bouzillé, 2003 Sediment and plant dynamics in saltmarshes pioneer zone: *Puccinellia maritima* as a key species? Estuarine, Coastal and Shelf Science. **56**(2): p. 239-249.
333. Barnes, R.S.K. and J.G. Greenwood, 1978 The response of the intertidal gastropod *Hydrobia ulvae* (Pennant) to sediments of differing particle size. Journal of Experimental Marine Biology and Ecology. **31**: p. 43-54.
334. Morris, R.K.A., I.S. Reach, M.J. Duffy, T.S. Collins, and R.N. Leafe, 2004 On the loss of saltmarshes in south-east England and the relationship with *Nereis diversicolor.* Journal of Applied Ecology. **41**(4): p. 787-791.
335. Swinbanks, D.D., 1982 Intertidal exposure zones: a way to subdivide the shore. Journal of Experimental Marine Biology and Ecology. **62**: p. 69-86.
336. Bleakney, J.S., 1972 Ecological implications of annual variation in tidal extremes. Ecology. **53**: p. 933-938.
337. Haynes, J. and M. Dobson, 1969 Physiography, Foraminifera and sedimentation in the Dovey estuary (Wales). Geological Journal. **6**: p. 217-256.
338. Garbutt, R.A., C.J. Reading, M. Wolters, A.J. Gray, and P. Rothery, 2006 Monitoring the development of intertidal habitats on former agricultural land after the managed realignment of coastal defences at Tollesbury, Essex, UK. Marine Pollution Bulletin. **53**(1-4): p. 155-164.
339. Reading, C.J., A.J. Gray, Paramor, O.A.L., R.A. Garbutt, C.W. Watts, J.R. Spearman, D.R. Barratt, T. Chesher, R. Cox, R.G. Hughs, J.L. Mann, D.G. Myhill, P. Rothery, J. Semmence, and M. Wolters, Managed realignment at Tollesbury and Saltram, in Final Report. Defra/NERC contract. CSA 2313 Defra, Editor. 2002: London.
340. Reading, C.J., R.A. Garbutt, C.W. Watts, P. Rothery, A. Turk, M. Yates, C. Boffey, J. Saunders, and M. Wolters, Managed realignment at Tollesbury, in R&D Technical Report FD 1922/TR, Defra, Editor. 2008.
341. Wolters, M., A. Garbutt, and J.P. Bakker, 2005 Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. Biological Conservation. **123**(2): p. 249-268.
342. Wolters, M., A. Garbutt, R.M. Bekker, J.P. Bakker, and P.D. Carey, 2008 Restoration of salt-marsh vegetation in relation to site suitability, species pool and dispersal traits. Journal of Applied Ecology. **45**(3): p. 904-912.
343. Wolters, M., A. Garbutt, and J.P. Bakker, 2005 Plant colonization after managed realignment: the relative importance of diaspore dispersal. Journal of Applied Ecology. **42**(4): p. 770-777.
344. Huiskes, A.H.L., B.P. Koutstaal, P.M.J. Herman, W.G. Beeftink, M.M. Markusse, and W.D. Munck, 1995 Seed dispersal of halophytes in tidal salt marshes. Journal of Ecology. **83**(4): p. 559-567.

345. Ackerman, J., Sexual reproduction in seagrasses; Pollination in the marine context. Seagrasses: biology, ecology, and conservation
ed. A.W.D. Larkum, R.J. Orth, and C.M. Duarte. 2006: Springer. 691.

346. Elsey-Quirk, T., B.A. Middleton, and C.E. Proffitt, 2009 Seed flotation and germination of salt marsh plants: The effects of stratification, salinity, and/or inundation regime. Aquatic Botany. **91**(1): p. 40-46.

347. Bachelet, G., Recruitment in *Abra tenuis* (Montagu) (Bivalvia, Semelidae), a species with direct development and a protracted meiobenthic phase., in 23rd European Marine Biology Symposium, J.S. Ryland and P.A. Tyler, Editors. 1989. p. 23-30.

348. Eckert, G.L., 2003 Effects of the planktonic period on marine population fluctuations. Ecology. **84**(2): p. 372-383.

349. Fretter, V. and A. Graham, 1976 The Prosobranch Molluscs of Britain and Denmark. Part 1. - Pleurotomariacea, Fissurellacea and Patellacea. Journal of Molluscan Studies. (Supplement 1).

350. Dales, R.P., 1950 The reproduction and larval development of *Nereis diversicolor* O. F. Müller. Journal of the Marine Biological Association of the United Kingdom. **29**: p. 321-360.

351. Roberts, J.M., A.J. Wheeler, and A. Freiwald, 2006 Reefs of the deep: The biology and geology of cold-water coral ecosystems. Science. **312**(5773): p. 543-547.

352. Jensen, A. and R. Frederiksen, 1992 The fauna associated with the bank-forming deep-water coral *Lophelia pertusa* (Scleractinaria) on the Faroe shelf. Sarsia. **77**(1): p. 53-69.

353. Duineveld, G.C.A., M.S.S. Lavaleye, and E.M. Berghuis, 2004 Particle flux and food supply to a seamount coldwater coral community (Galicia Bank, NW Spain). Marine Ecology Progress Series. **277**: p. 13–23.

354. van Oevelen, D., G. Duineveld, M. Lavaleye, F. Mienis, K. Soetaert, and C.H.R. Heip, 2009 The cold-water coral community as a hot spot for carbon cycling on continental margins: A food-web analysis from Rockall Bank (northeast Atlantic). Limnology and Oceanography. **54**(6): p. 1829-1844.

355. Konnecker, G., Sponge Fields. 2002: In: Gubbay, S. Offshore Directory. Review of a selection of habitats, communities and species of the North-East Atlantic. WWF-UK. North-East Atlantic Programme.

356. Rice, A.L., M.H. Thurston, and A.L. New, 1990 Dense aggregations of a hexactinellid sponge, *Pheronema carpenteri*, in the Porcupine Seabight (northeast Atlantic Ocean) and possible causes. Progress in Oceanography. **24**: p. 179–206.

357. Klitgaard, A.B., 1995 The fauna associated with outer shelf and upper slope sponges (Porifera, Demospongiae) at the Faroe Islands, northeastern Atlantic. Sarsia. **80**: p. 1–22.

358. Bett, B.J. and A.L. Rice, 1992 The influence of hexactinellid sponge (*Pheronema carpenteri*) spicules on the patchy distribution of macrobenthos in the Porcupine Sea Bight (Bathyal NE Atlantic). Ophelia **36**: p. 217-226.

359. Klitgaard, A. and O.S. Tendal, "Ostur" - "cheese bottoms" - sponge dominated areas in Faroese shelf and slope areas, in Marine biological investigations and assemblages of benthic invertebrates from the Faroe Island, G. G. and O.S. Tendal, Editors. 2001, Kaldbak Marine Biological Laboratory, The Faroe Islands. p. 13-21.

360. Vacelet, J., 2008 A new genus of carnivorous sponges (Porifera : Poecilosclerida, Cladorhizidae) from the deep N-E Pacific, and remarks on the genus Neocladia. Zootaxa. (1752): p. 57-65.

361. Yahel, G., F. Whitney, H.M. Reiswig, D.I. Eerkes-Medrano, and S.P. Leys, 2007 In-situ feeding and metabolism of glass sponges (Hexactinellida, Porifera) studied in a deep temperate fjord with a remotely operated submersible. Limnology and Oceanography. **52**(1): p. 428-440.

362. Klitgaard, A.B. and O.S. Tendal, 2004 Distribution and species composition of mass occurrences of large-sized sponges in the northeast Atlantic. Progress in Oceanography. **61**(1): p. 57-98.

363. Konnecker, G. and A. Freiwald, 2005 *Plectroninia celtica* n. sp (Calcarea, Minchinellidae), a new species Of "pharetronid" sponge from bathyal depths in the northern Porcupine Seabight, NE Atlantic. Facies. **51**(1-4): p. 57-63.

364. Konnecker, G.F. and B.F. Keegan, 1983 Littoral and benthic investigations on the west-coast of Ireland.17. The epibenthic animal associations of Kilkieran Bay. Proceedings of the Royal Irish Academy Section B-Biological Geological and Chemical Science. **83**(25): p. 309-324.

365. Corriero, G., M. Sara, and P. Vaccaro, 1996 Sexual and asexual reproduction in two species of *Tethya* (Porifera: Demospongiae) from a Mediterranean coastal lagoon. Marine Biology. **126**(2): p. 175-181.

366. Spetland, F., H.T. Rapp, F. Hoffmann, and O.S. Tendal, 2007 Sexual reproduction of *Geodia barretti* Bowerbank, 1858 (Porifera, Astrophorida) in two Scandinavian fjords. Museu Nacional Serie Livros. p. 613-620.

367. Witte, U., 1996 Seasonal reproduction in deep sea sponges - Triggered by vertical particle flux? Marine Biology. **124**(4): p. 571-581.

368. Leys, S.P. and N.R.J. Lauzon, 1998 Hexactinellid sponge ecology: growth rates and seasonality in deep water sponges. Journal of Experimental Marine Biology and Ecology. **230**(1): p. 111-129.

369. Mettam, C., 1994 Intertidal zonation of animals and plants on rocky shores in the Bristol Channel and Severn Estuary - the northern shores. Biological Journal of the Linnean Society. **51**(1-2): p. 123-147.

370. Suryono, C.A. and F.G. Hardy, 1997 Studies on the distribution of *Fucus ceranoides* L. (Phaeophyta, Fucales) in estuaries on the north-east coast of England. Transactions of the Natural History Society of Northumbria. **57**: p. 153-168.

371. Amaral, V., H.N. Cabral, S. Jenkins, S. Hawkins, and J. Paula, 2009 Comparing quality of estuarine and nearshore intertidal habitats for *Carcinus maenas.* Estuarine Coastal and Shelf Science. **83**(2): p. 219-226.

372. Little, C. and L.P. Smith, 1980 Vertical zonation on rocky shores in the Severn Estuary. Estuarine and Coastal Marine Science. **11**(6): p. 651-669.

373. Bassindale, R., 1943 Studies on the biology of the Britsol Channel. XI. The physical environment and intertidal fauna of the southern shores of the Bristol Channel and Severn Estuary. Journal of Ecology. **31**: p. 1-29.

374. McFadden, C.S., P.M. Rettig, and E.J. Beckman, 2005 Molecular evidence for hybridization between two alcyoniid soft coral species with contrasting life histories. Integrative and Comparative Biology. **45**(6): p. 1042-1042.

375. Hartnoll, R.G., 1975 The annual cycle of *Alcyonium digitatum.* Estuarine and Coastal Marine Science. **3**: p. 71-78.

376. Hunter, E. and E. Naylor, 1993 Intertidal migration by the shore crab *Carcinus maenas.* Marine Ecology Progress Series. **101**: p. 131-138.

377. Millar, R.H., 1952 The annual growth and reproductive cycle in four ascidians. Journal of the Marine Biological Association of the United Kingdom. **31**(01): p. 41-61.

378. Crisp, D.J., 1958 The spread of *Elminius modestus* Darwin in north-west Europe. Journal of the Marine Biological Association of the United Kingdom. **37** (2): p. 483-520.

379. Hunter, W., The life of invertebrates. 1979: Macmillan.

380. Harmes, J., 1986 Effects of temperature and salinity on larval development of *Elminius modestus* (Crustacea, Cirripedia) from Helgoland (North Sea) and New Zealand. Helgolander Meeresunters. **40**: p. 355-376.

381. Morris, R.H., D. Putnam Abbott, and E.C. Haderlie, Intertidal Invertebrates of California. 1980: Stanford University Press. 690.

382. Witte, U., Barthel, D., Reproductive cycle and oogenesis of *Halichondria panicea* (Pallas) in Keil Bight. Sponges in Time and Space, ed. v.K. van Soest, Breakman. 1994.

383. Patterson, I.G., V. Partridge, and J. Buckland-Nicks, 2001 Multiple paternity in *Littorina obtusata* (Gastropoda, Littorinidae) revealed by microsatellite analyses. Biological Bulletin. **200**: p. 261-267.

384. Manuel, R., British Anthozoa. 1981: The Linnean Society of London.

385. Hall-Spencer, J.M. and P.G. Moore, 2000 *Limaria hians* (Mollusca : Limacea): a neglected reef-forming keystone species. Aquatic Conservation-Marine and Freshwater Ecosystems. **10**(4): p. 267-277.

386. Hall-Spencer, J.M., Conservation issues relating to maerl beds as habitats for molluscs. 1998, In: Kileen, I.J., Seddon, M.B., Holmes, A.M. (Eds.), Molluscan Conservation: A Strategy for the 21st Century. Journal of Conchology. Henry Ling, The Dorset Press, Dorchester, pp. 271–286. Special Publication 2.

387. Minchin, D., 1995 Recovery of a population of the flame shell, *Lima hians*, in an Irish bay previously contaminated with TBT. Environmental Pollution. **90**(2): p. 259-262.

388. Trigg, C. and C.G. Moore, 2009 Recovery of the biogenic nest habitat of *Limaria hians* (Mollusca: Limacea) following anthropogenic disturbance. Estuarine Coastal and Shelf Science. **82**(2): p. 351-356.

389. Donovan, D.A., J.P. Elias, and J. Baldwin, 2004 Swimming behavior and morphometry of the file shell *Limaria fragilis.* Marine and Freshwater Behaviour and Physiology. **37**(1): p. 7-16.

390. Ansell, A.D., 1974 Seasonal changes in biochemical composition of bivalve *Lima hains* from Clyde Sea area. Marine Biology. **27**(2): p. 115-122.

391. Lebour, M.V., 1937 Larval and post-larval *Lima* from Plymouth. Journal of the Marine Biological Association of the United Kingdom. **21**: p. 705-710.

392. Nichols, D., 1991 Seasonal reproductive periodicity in the european comatulid criniod *Antedon bifida* Pennant. Yanagisawa, T., Et Al. (Ed.). Biology of Echinodermata; Seventh International Echinoderm Conference, Atami, Japan, September 9-14, 1990. Xviii+590p. a. a. Balkema: Rotterdam, Netherlands; Brookfield, Vermont, USA. Illus. Maps. p. 241-248.

393. Barker, M.F. and D. Nichols, 1983 Reproduction, recruitment and juvenile ecology of the starfish *Asterias rubens* and *Marthasterias glacialis.* Journal of the Marine Biological Association of the United Kingdom. **63**: p. 745-765.

394. Villalobos, F.B., P.A. Tyler, and C.M. Younge, 2006 Temperature and pressure tolerance of embryos and larvae of the Atlantic seastars *Asterias rubens* and *Marthasterias glacialis* (Echinodermata: Asteroidea): potential for deep-sea invasion. Marine Ecology Progress Series. **314**: p. 109-117.

395. Birkett, D.A., C.A. Maggs, and M.J. Dring, Maerl (volume V). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs, in Scottish Association for Marine Science/UK Marine SACs Project. 1998.

396. Ocklemann, K.W., Developmental types in marine bivalves and their distribution along the Atlantic coast of Europe. 1965, In: Proceedings of the first European Malacological Congress, London 1962. London: Conchological Society of Great Britain and Ireland and Malacological Society of London. 25-35.

397. Ockelmann, K.W. and K. Muus, 1978 Biology, ecology and behavior of bivalve *Mysella bidentata* (Montagu). Ophelia. **17**(1): p. 1-93.

398. Davoult, D., F. Gounin, and A. Richard, 1990 Dynamics and reproduction of *Ophiothrix fragilis* (Abilgaard) population of Dover Strait (eastern English Channel). Journal of Experimental Marine Biology and Ecology. **138**(3): p. 201-216.

399. Morgan, R. and M. Jangoux, 2005 Larval morphometrics and influence of adults on settlement in the gregarious ophiuroid *Ophiothrix fragilis* (Echinodermata). Biological Bulletin. **208**(2): p. 92-99.

400. Sampedro, M.P., L. Fernandez, J. Freire, and E. Conzalex-Gurriaran, 1997 Fecundity and reproductive output of *Pisidia longicornes* (Decapoda, Anomura) in the Ria De Arousa (Galicia, NW Spain). Crusaceana. **70**(1): p. 95-109.
401. Smaldon, G., 1972 Population structure and breeding biology of *Pisidia longicornis* and *Porcellana platycheles.* Marine Biology. **17**: p. 171-179.
402. Fish, J.D. and S. Fish, A student's guide to the seashore. 1996, Cambridge, UK: Cambridge University Press.
403. Reed, C.G., Bryozoa. 1991: California: Boxwood Press.
404. Fadlallah, Y.H., 1983 Sexual reproduction, development and larval biology in scleractinian corals Coral Reefs **2**: p. 129-150.
405. Fadlallah, Y.H. and J.S. Pearse, 1983 Sexual reproduction in solitary corals: Synchronous gametogenesis and broadcast spawning in *Paracyathus stearnsii.* Marine Biology. **71**(3): p. 233-239.
406. Tranter, P.R.G., D.N. Nicholson, and D. Kinchington, 1982 A description of spawning and post-gastrula development of the cool temperate coral, *Caryophyllia smithii*. Journal of the Marine Biological Association of the United Kingdom. **62**(845-854).
407. Svane I, Y.C., Oceanogr. Mar. Biol. Annu. Rev,, in THE ECOLOGY AND BEHAVIOUR OF ASCIDIAN LARVAE pp 45-90. , M. Barnes, Editor. 1989, Routledge, 1988.
408. Sònia de Caralt, S. López-Legenti, I. Tarjuelo, M.J. Uriz, and X. Turon, 2002 Contrasting biological traits of *Clavelina lepadiformis* (Ascidiacea) populations from inside and outside harbours in the western Mediterranean MEPS. **244**: p. 125-137.
409. Warburton, E., F, 1958 Reproduction of fused larvae in the boring sponge, *Cliona celata* Grant*.* Nature. **181**: p. 493-494.
410. Warburton, F.E., 1966 The Behaviour of Sponge Larvae*.* Ecology. **47**(4): p. 672 - 674.
411. Stillman, R.A., A.D. West, J.D. Goss-Custard, S. McGrorty, N.J. Frost, D.J. Morrisey, A.J. Kenny, and A.L. Drewitt, 2005 Predicting site qiulaity of shorebird communities: a case study on the Humber estuary, UK*.* Marine Ecology Progress Series. **305**: p. 203-217.
412. MESL, London Gateway Port Project Benthic Intertidal Biology of the Lower Thames Estuary, in July 2002. 2002: St. Ives, Cornwall.
413. Warwick, R.M. and J.R. Davies, 1977 The distribution of sublittoral macrofauna communities in Bristol Channel in relation to substrate*.* Estuarine and Coastal Marine Science. **5**(2): p. 267-288.
414. Elliott, M., S. Nedwell, N.V. Jones, S.J. Read, N.D. Cutts, and K.L. Hemingway, Intertidal Sand and Mudflats & Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. 1998, Scottish Association for Marine Science (UK Marine SACs Project). 151 Pages.
415. Hall, S.J., 1994 Physical disturbance and marine benthic communities - life in unconsolidated sediments*.* Oceanography and Marine Biology. **32**: p. 179-239.
416. Da Costa, F., S. Darriba, and D. Martínez-Patiño, 2008 Embyonic and larval development of *Ensis arcuatus* (Jeffryes, 1865) (Bivalvia: Pharidae)*.* Journal of Molluscan Studies. **74**(2): p. 103-109.
417. Farke, H. and E.M. Berghuis, 1979 Spawning, larval development and migration behaviour of *Arenicola marina* in the laboratory*.* Netherlands Journal of Sea Research **13**: p. 512-528.
418. Newell, G.E., 1949 The later larval life of *Arenicola marina* L*.* Journal of the Marine Biological Association of the United Kingdom **28**: p. 635-639.
419. Newell, G.E., 1948 A contribution to our knowledge of the life history of *Arenicola marina* L*.* Journal of the Marine Biological Association of the United Kingdom **28**: p. 554-580.
420. Kahle, J., G. Liebezeit, and G. Gerdes, 2003 Growth aspects of *Flustra foliacea* (Bryozoa, Cheilostomata) in laboratory culture*.* Hydrobiologia. **503**: p. 237-244.
421. Loosanoff, V.L. and H.C. Davis, 1963 Rearing of bivalve mollusks*.* Advances in Marine Biology. **1**: p. 1-136.

422. Gilbert, M.A., 1978 Aspects of the reproductive cycle in *Macoma baltica* (Bivalvia). The Nautilus **29**: p. 21-24.
423. Lammens, J.J., 1967 Growth and reproduction in a tidal flat population of *Macoma balthica.* Netherlands Journal of Sea Research **3**: p. 315-382.
424. Chapman, M.G., 2003 The use of sandstone blocks to test hypotheses about colonization of intertidal boulders. Journal of the Marine Biological Association of the United Kingdom. **83**(2): p. 415-423.
425. Johannesson, B. and K. Johannesson, 1996 Population differences in behaviour and morphology in the snail *Littorina saxatilis*: Phenotypic plasticity or genetic differentiation? Journal of Zoology. **240**: p. 475-493.
426. Le Hir, M. and C. Hily, 2005 Macrofaunal diversity and habitat structure in intertidal boulder fields. Biodiversity and Conservation. **14**(1): p. 233-250.
427. Chapman, M.G., 2002 Patterns of spatial and temporal variation of macrofauna under boulders in a sheltered boulder field. Austral Ecology. **27**(2): p. 211-228.
428. Sousa, W.P., 1979 Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. Ecological Monographs. **49**(3): p. 227-254.
429. Kuklinski, P. and D.K.A. Barnes, 2008 Structure of intertidal and subtidal assemblages in Arctic vs temperate boulder shores. Polish Polar Research. **29**(3): p. 203-218.
430. Foster-Smith, R.L., 1989 A survey of boulder habitats on the Northumberland coast with a discussion on survey methods for boulder habitats. Nature Conservancy Council, Peterborough, unpub. NCC CSD Rep. 921, 76pp.
431. Foster-Smith, R.L., A boulder survey of the Isles of Scilly, September 5th to 9th, 1990. 1991, Nature Conservancy Council, Peterborough, unpub. NCC CSD Rep. 1226, 27pp.
432. James, R.J. and A.J. Underwood, 1994 Influence of color of substratum on recruitment of spirorbid tubeworms to different types of intertidal boulders. Journal of Experimental Marine Biology and Ecology. **181**(1): p. 105-115.
433. Sousa, W.P., 1979 Disturbance in marine intertidal boulder fields - the non-equilibrium maintenance of species diversity. Ecology. **60**(6): p. 1225-1239.
434. Hiscock, K., 2008 *Botryllus schlosseri.* Star ascidian. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. . (Plymouth: Marine Biological Association of the United Kingdom. [cited 11/01/2010]. Available from: www.marlin.ac.uk/reproduction.php?speciesID=2793).
435. Underwood, A.J., 1972 Spawning, larval development and settlement behaviour of *Gibbula cineraria* (Gastropoda: Prosobranchia) with a reappraisal of torsion in gastropods. Marine Biology. **17**: p. 341-349.
436. Borowsky, B., 1983 Reproductive behavior of three tube-building peracarid crustaceans: the amphipods *Jassa falcata* and *Ampithoe valida* and the tanaid *Tanais cavolinii.* Marine Biology. **77**(3): p. 257-263.
437. Hayward, P.J. and J.S. Ryland, Handbook of the marine fauna of North-West Europe. 1995: Oxford University Press.
438. Fowler, S.L. and I. Tittley, The marine nature conservation importance of British coastal chalk cliff habitats. 1993, English Nature Research Report No.32. English Nature, Peterborough.
439. Pinn, E.H., R.C. Thompson, and S.J. Hawkins, 2008 Piddocks (Mollusca : Bivalvia : Pholadidae) increase topographical complexity and species diversity in the intertidal. Marine Ecology-Progress Series. **355**: p. 173-182.
440. George, J.D. and A.A. Fincham, 1989 Macro-invertebrate communities of chalk shores in southeastern England UK. Scientia Marina. **53**(2-3): p. 373-386.
441. Knight, J.H., Studies on the biology and biochemistry of *Pholas dactylus* L., in unpublished Thesis, University of London. 1984.

442. Pinn, E.H., C.A. Richardson, R.C. Thompson, and S.J. Hawkins, 2005 Burrow morphology, biometry, age and growth of piddocks (Mollusca : Bivalvia : Pholadidae) on the south coast of England. Marine Biology. **147**(4): p. 943-953.
443. Ng, B., A.S.H. Tan, and Z. Yasin, 2009 Developmental stages, larval and post-larval growth of angelwing clam *Pholas orientalis.* Aquaculture Research. **40**(7): p. 845-851.
444. Daro, M.H. and P. Polk, 1973 The autecology of *Polydora ciliata* along the Belgian coast. Netherlands Journal of Sea Research **6**(1-2): p. 130-140.
445. Anger, K., V. Anger, and E. Hagmeier, 1986 Laboratory studies on larval growth of *Polydora ligni*, *Polydora ciliata*, and *Pygospio elegans* (Polychaeta, Spionidae). Helgolander Meeresunters. **40**: p. 377-395.
446. Grall, J. and M. Glémarec, 1997 Biodiversity of maerl beds in Brittany: Functional approach and anthropogenic impact. Vie Milieu. **47**(4): p. 339-349.
447. Kamenos, N.A., P.G. Moore, and J.M. Hall-Spencer, 2003 Substratum heterogeneity of dredged vs un-dredged maerl grounds. Journal of the Marine Biological Association of the United Kingdom. **83**(2): p. 411-413.
448. Jackson, C.M., N.A. Kamenos, P.G. Moore, and M. Young, 2004 Meiofaunal bivalves in maerl and other substrata; Their diversity and community structure. Ophelia. **58**(1): p. 49-60.
449. Bosence, D.W.J., 1980 Sedimentary facies, production rates and facies models for recent coralline algal gravels, Co. Galway, Ireland. Geological Journal. **15**(2): p. 91-111.
450. Hall-Spencer, J.M. and R.J.A. Atkinson, 1999 *Upogebia deltaura* (Crustacea : Thalassinidea) in Clyde Sea maerl beds, Scotland. Journal of the Marine Biological Association of the United Kingdom. **79**(5): p. 871-880.
451. Kamenos, N.A., P.G. Moore, and J.M. Hall-Spencer, 2004 Attachment of the juvenile queen scallop (*Aequipecten opercularis* (L.)) to Maerl in mesocosm conditions; juvenile habitat selection. Journal of Experimental Marine Biology and Ecology. **306**(2): p. 139-155.
452. Hall-Spencer, J., 1998 Conservation issues relating to maerl beds as habitats for molluscs. Journal of Conchology. p. 271-285.
453. Hinojosa-Arango, G., C.A. Maggs, and M.P. Johnson, 2009 Like a rolling stone: the mobility of maerl (Corallinaceae) and the neutrality of the associated assemblages. Ecology. **90**(2): p. 517-528.
454. Maggs, C.A., A phenological study of two maerl beds in Galway Bay, Ireland. 1983: PhD thesis, National University of Ireland, Galway.
455. Grall, J. and J.M. Hall-Spencer. Problems facing maerl conservation in Brittany. in International Workshop on the Conservation and Management of Maerl. 2001. Millport, Scotland: John Wiley & Sons Ltd.
456. Brodie, J., D.M. John, I. Tittley, M.J. Holmes, and D.B. Williamson, Important areas for algae: a provisional review of sites and areas of importance for algae in the United Kingdom. 2007, Plantlife International Salisbury p. 81pp.
457. Jackson, E., O. Langmead, J. Evans, R. Ellis, and H. Tyler Walters, Protecting nationally important marine Biodiversity in Wales., in Report to the Wales Environment Link form the Marine Life Information Network (MarLIN). 2008, The Marine Biological Association of the UK Plymouth. p. 78 pp.
458. Brodie, J., Report from the Biodiversitry and Conservation Committee, in The Phycologist. The Newsletter of the British Phycological Society J. Krokowski, Editor. 2008, The British Phycological Society p. 12-12.
459. Korringa, P., 1952 Recent advances in oyster biology. Quarterly Review of Biology. **27**(4): p. 539-65.
460. Newkirk, G.F. and L.E. Haley, 1982 Phenotypic analysis of the European oyster *Ostrea edulis* L. - relationships between length of larval period and postsettting growth rate. Journal of Experimental Marine Biology and Ecology. **59**(2-3): p. 177-184.

461. Le Pennec, M., A. Paugam, and G. Le Pennec, The pelagic life of the pectinid *Pecten maximus*-a review. 2003. p. 211-233.

462. Navarro, J.M. and R.J. Thompson, 1996 Physiological energetics of the horse mussel *Modiolus modiolus* in a cold ocean environment. Marine Ecology Progress Series. **138**(1-3): p. 135-148.

463. Witman, J.D., 1980 Community structure of subtital *Modiolus modiolus* (L) beds. American Zoologist. **20**(4): p. 807-807.

464. Sanderson, W.G., R.H.F. Holt, L. Kay, K. Ramsay, J. Perrins, A.J. McMath, and E.I.S. Rees, 2008 Small-scale variation within a *Modiolus modiolus* (Mollusca : Bivalvia) reef in the Irish Sea. II. Epifauna recorded by divers and cameras. Journal of the Marine Biological Association of the United Kingdom. **88**(1): p. 143-149.

465. Comely, C.A., 1978 *Modiolus modiolus* (L) from Scottish west coast. 1. Biology. Ophelia. **17**(2): p. 167-193.

466. Rees, E.I.S., W.G. Sanderson, A.S.Y. Mackie, and R.H.F. Holt, 2008 Small-scale variation within a *Modiolus modiolus* (Mollusca : Bivalvia) reef in the Irish Sea. III. Crevice, sediment infauna and epifauna from targeted cores. Journal of the Marine Biological Association of the United Kingdom. **88**(1): p. 151-156.

467. Anwar, N.A., C.A. Richardson, and R. Seed, 1990 Age determination, growth rate and population structure of the horse mussel *Modiolus modiolus.* Journal of the Marine Biological Association of the United Kingdom. **70**(2): p. 441-457.

468. Seed, R. and R.A. Brown, The influence of reproductive cycle, growth and mortality on population structure in *Modiolus modiolus* (L.), *Cerastoderma edule* (L.), and *Mytilus edulis* (L.) (Mollusca:Bivalvia), in Proceedings of the 9th European Marine Biology Symposium. 1975, Aberdeen University Press. p. 257-274.

469. Seed, R. and R.A. Brown, 1978 Growth as a strategy for survival in 2 marine bivalves, *Cerastoderma edule* and *Modiolus modiolus.* Journal of Animal Ecology. **47**(1): p. 283-292.

470. Seed, R. and R.A. Brown, 1977 A comparison of reproductive cycles of *Modiolus modiolus* (L), *Cerastoderma* (*cardium*) *edule* (L), and *Mytilus edulis* L in Strangford Lough, Northern-Ireland. Oecologia. **30**(2): p. 173-188.

471. Ocklemann, K.W., Developmental types in marine bivalves and their distribution along the Atlantic coast of Europe. 1965, In: Proceedings of the first European Malacological Congress, London 1962. London: Conchological Society of Great Britain and Ireland and Malacological Society of London. 25-35.

472. Jasim, A.K. and A.R. Brand, 1989 Observations on the reproduction of *Modiolus modiolus* in Isle of Man waters. Journal of the Marine Biological Association of the United Kingdom. **69**(2): p. 373-385.

473. Schweinitz, E.H.D. and R.A. Lutz, 1976 Larval development of northern horse mussel, *Modiolus modiolus* (L.) including a comparison with larvae of *Mytilus edulis* (L.) as an aid in planktonic identification. Biological Bulletin. **150**(3): p. 348-360.

474. Holt, T.J., E.I. Rees, S.J. Hawkins, and R. Seed, Biogenic Reefs: An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. 1998, University of Liverpool Port Erin Marine Laboratory, University of Liverpool

475. Brown, R.A., 1984 Geographical variations in the reproduction of the horse mussel, *Modiolus modiolus* (Mollusca, Bivalvia). Journal of the Marine Biological Association of the United Kingdom. **64**(4): p. 751-770.

476. Brown, R.A. and R. Seed, *Modiolus modiolus* (L.). An autoecological study, in Biology of Benthic Organisims, B.K. Keegan, P.O. Cleidigh, and P.J.S. Boddin, Editors. 1977, Pergamon Press: Oxford.

477. Hayward, P.J. and J.S. Ryland, Cheilostomatous Bryozoa: 1. Aeteoidea - Cribrilinoidea: notes for the identification of British species. 2nd ed. Synopses of the British fauna (new series), 10. 1998: Field Studies Council: Shrewsbury, UK. ISBN 1-85153-261-7. VII, 366 pp.

478. Giangrande, A., Polychaete reproductive patterns, life cycles and life histories: An overview. Oceanography and Marine Biology Vol. 35. 1997: Aberdeen University Press, ROYAUME-UNI (1963). 323-386

479. Witbaard, R. and G.C.A. Duineveld, 1989 Some aspects on the biology and ecology of the burrowing shrimp *Callianassa subterranea* (Montagu) (Thalassinidea) from the southern North Sea. Sarsia. **74**(3): p. 209-219.

480. Hall, S.J., 1994 Physical disturbance and marine benthic communities: life in unconsolidated sediments. Oceanography and Marine Biology Annual Review. **32**: p. 179-239.

481. Posey, M.H., 1986 Changes in a benthic community associated with dense beds of a burrowing deposit feeder, *Callianassa californiensis.* Marine Ecology Progress Series. **31**: p. 15-22.

482. Birkeland, C., Consequences of differening reproductive and feeding strategies for the dynamics and structure of an association based on the single prey species, *Ptilosarcus guerneyi* (Gray). PhD Thesis, in University of Washington. 1969.

483. Soong, K., 2005 Reproduction and colony integration of the sea pen *Virgularia juncea.* Marine Biology. **146**(6): p. 1103-1109.

484. Tremblay, M.T., J. Henry, and M. Anctil, 2004 Spawning and gamete follicle rupture in the cnidarian *Renilla koellikeri*: effects of putative neurohormones. General and Comparative Endocrinology. **137**(1): p. 9-18.

485. Eckelbarger, K.J., P.A. Tyler, and R.W. Langton, 1998 Gonadal morphology and gametogenesis in the sea pen *Pennatula aculeata* (Anthozoa : Pennatulacea) from the Gulf of Maine. Marine Biology. **132**(4): p. 677-690.

486. Edwards, D.C.B. and C.G. Moore, 2008 Reproduction in the sea pen *Pennatula phosphorea* (Anthozoa : Pennatulacea) from the west coast of Scotland. Marine Biology. **155**(3): p. 303-314.

487. Davis, N. and G.R. Van Blaricom, 1978 Spatial and temporal heterogeneity in a sand bottom epifaunal community of invertebrates in shallow water. Limnology and Oceanography. **23**: p. 417-427.

488. Birkeland, C., 1974 Interactions between a sea pen and seven of its predators. Ecological Monographs. **44**: p. 211-232.

489. Chia, F.S. and B.J. Crawford, 1973 Some observations on gametogenesis, larval development and substratum selection of the sea pen *Ptilosarcus guerneyi.* Marine Biology. **23**: p. 73-82.

490. Fenaux, L., 1970 Maturation of the gonads and seasonal cycle of the planktonic larvae of the ophiuroid *Amphiura chiajei* Forbes. Biological Bulletin. **138**: p. 262-271.

491. Rowden, A.A. and M.B. Jones, 1994 A contribution to the biology of the burrowing mud shrimp, Callianassa subterranea (Decapoda: Thalassinidea). Journal of the Marine Biological Association of the United Kingdom. **74**: p. 623-635.

492. Manuel, R.L., British Anthozoa. Synopses of the British Fauna No. 18 1988, Avon: The Bath Press.

493. Thorson, G., Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the Sound (Øresund). Meddelelser fra Kommissionen for Danmarks Fiskeri- Og Havundersögelser. Serie: Plankton, 4, 1-523. 1946.

494. Farmer, A.S.D., 1975 Synopsis of biological data on the Norway lobster *Nephrops norvegicus* (Linnaeus, 1758). FAO Fisheries Synopsis. **112**: p. 78-97.

495. Dickey-Collas, M., N. McQuaid, M.J. Armstrong, M. Allen, and R.P. Briggs, 2000 Temperature-dependent stage durations of Irish sea *Nephrops* larvae. Journal of Plankton Research. **22**(4): p. 749-760.

496. Dickey-Collas, M., R.P. Briggs, M.J. Armstrong, and S.P. Milligan, 2000 Production of *Nephrops norvegicus* larvae in the Irish Sea. Marine Biology. **137**(5-6): p. 973-981.

497. Hansen, B., 1991 Feeding behaviour in larvae of the opisthobranch *Philine aperta*. II. Food size spectra and particle selectivity in relation to larval behaviour and morphology of the velar structures. Marine Biology, . **111**: p. 263-270.
498. Barnes, R.S.K., 1973 A preliminary survey of the macroscopic bottom fauna of the Solent, with particular reference to *Crepidula fornicata* and *Ostrea edulis.* Proceedings of Molluscan Journal. **40**: p. 253-275.
499. Barnes, R.S.K. and J. Coughlan, 1971 A survey of the bottom fauna of the Blackwater Estuary. Essex Naturalis. **32**: p. 263-276.
500. Dame, R.F., R.G. Zingmark, and E. Haskin, 1984 Oyster reefs as processors of estuarine materials. Journal of Experimental Marine Biology and Ecology. **83**(3): p. 239-247.
501. Coen, I.D., M.W. Luckenbach, and D.I. Breitburg, The role of oyster reefs as essential fish habitat: A review of current knowledge and some new perspectives, in Proceedings of the Sea Grant Symposium 22 on Fish Habitat: 'Essential Fish Habitat' and Rehabilitation, held at Hartford, Connecticut, USA, 26-27 August 1998, L.R. Benaka, Editor. 1998. p. 438-454.
502. Dame, R.F. and B.C. Patten, 1981 Analysis of energy flows in an intertidal oyster reef. Marine Ecology Progress Series. **5**(2): p. 115-124.
503. Berghahn, R. and M. Ruth, 2005 The disappearance of oysters from the Wadden Sea: a cautionary tale for no-take zones. Aquatic Conservation-Marine and Freshwater Ecosystems. **15**(1): p. 91-104.
504. Key, D. and P.E. Davidson, A Review of the Development of the Solent Oyster Fishery 1972-80, in Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Laboratory Leaflet No.52. 1981: Lowestoft
505. Yonge, C.M., Oysters. 1960: London: Collins.
506. Cole, H.A., 1942 Primary sex-phases in *Ostrea edulis.* Quarterly Journal of the Microscopical Science. **83**: p. 317-356.
507. Labarta, U., M.J. Fernandez-Reiriz, and A. Perez-Camacho, 1999 Energy, biochemical substrates and growth in the larval development, metamorphosis and postlarvae of *Ostrea edulis* (L.). Journal of Experimental Marine Biology and Ecology. **238**(2): p. 225-242.
508. Duval, D.M., 1963 The biology of *Petricola pholadiformis* Lamarck (Lammellibranchiata: Petricolidae). Proceedings of the Malacological Society. **35**: p. 89-100.
509. Murphy, J.P., 1981 Marine Algae on Peat. Irish Naturalists' Journal. **20**: p. 254.
510. Wood, C., Sussex sublittoral survey. Selsey Bill to Beachy Head. 1984, Nature Conservancy Council, Peterborough (United Kingdom).
511. Wood, E. and C. Wood, Channel Tunnel Sublittoral survey. 1986, NCC CSD Report #674. Report to the Nature Conservancy Council. Marine Conservation Society, Ross-on-Wye.
512. Bhaud, M. Two contradictory elements determine invertebrate recruitment: dispersion of larvae and spatial restrictions on adults. in 4th Symposium of the National Programme on the Determinism of Recruitment. 1998. Nantes, France.
513. McHugh, D., 1993 A comparative study of reproduction and development in the polychaete family Terebellidae. Biological Bulletin. **185**: p. 153-167.
514. Smith, R., 1989 Notes on gamete production in *Lanice conchiega* (Annelida, Polychaeta, Terebellidae). Invertebrate Reproduction and Development. **15**: p. 7-12.
515. Mathivat-Lallier, M.H. and C. Cazaux, 1990 Larval exchange and dispersal of polychaetes between a bay and the ocean. Journal of Plankton Research. **12**(6): p. 1163-1172.
516. Caline, B., Y. Gruet, C. Legendre, J. Le Rhun, A. L'Homer, R. Mathieu, and R. Zbinden, The Sabellariid Reefs in the Bay of Mont Saint-Michel, France; Ecology, Geomorphology, Sedimentology and Geologic Implications. Florida Oceanographic

Society, Contributions to Marine Science - Volume 1 Number 1, ed. D.W. Kirtley. 1992: Florida Oceanographic Society (Stuart, Fla)

517. Holt, T.J., E.I. Rees, S.J. Hawkins, and R. Seed, Biogenic Reefs (volume IX). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. 1998, Scottish Association for Marine Science (UK Marine SACs Project). 170 Pages.
518. Dubois, S., C. Retiere, and F. Olivier, 2002 Biodiversity associated with *Sabellaria alveolata* (Polychaeta : Sabellariidae) reefs: effects of human disturbances. Journal of the Marine Biological Association of the United Kingdom. **82**(5): p. 817-826.
519. Dias, A.S. and J. Paula, 2001 Associated fauna of *Sabellaria alveolata* colonies on the central coast of Portugal. Journal of the Marine Biological Association of the United Kingdom. **81**(1): p. 169-170.
520. Gruet, Y., Recherches sur l'ecologie des recifs d'hermelles edifies par l'annelide polychaete *Sabellaria alveolata* (Linne), in Sciences Biologiques. 1982, l'Universite de Nantes: Nantes. p. 238.
521. Wilson, D.P., 1974 *Sabellaria* Colonies at Duckpool, North Cornwall, 1971-1972, with a Note for May 1973. Journal of the Marine Biological Association of the United Kingdom. **54**(2): p. 393-&.
522. Wilson, D.P., 1976 *Sabellaria alveolata* at Duckpool, North Cornwall, 1975. Journal of the Marine Biological Association of the United Kingdom. **56**: p. 305-310.
523. Wilson, D.P., 1971 *Sabellaria* colonies at Duckpool, North Cornwall, 1961-1970. Journal of the Marine Biological Association of the United Kingdom. **51**: p. 509-580.
524. Gruet, Y., 1985 Ecology of sabellarian reefs built by the Annelida Polychaeta *Sabellaria alveolata* (Linne). Journal de Recherches Oceanographique. **10**: p. 32-35.
525. Ayata, S., C. Ellien, F. Dumas, S. Dubois, and E. Thiebaut, 2009 Modelling larval dispersal and settlement of the reef-building polychaete *Sabellaria alveolata*: Role of hydroclimatic processes on the sustainability of biogenic reefs. Continental Shelf Research **29**(13): p. 1605-1623.
526. de Gruet, Y., & Lassus, P., 1983 Contribution a letude de la biologie reproductive d'une population naturelle de l'annelide polychaete *Sabellaria alveolata* (Linne). Annales de L'Institut Oceanographique. **59**(2): p. 127-140.
527. Wilson, D.P., 1968 The settlement behaviour of the larvae of *Sabellaria alveolata* (L.). Journal of the Marine Biological Association of the U.K. **48**: p. 387-435.
528. Wilson, D.P., 1968 Some aspects of the development of eggs and larvae of *Sabellaria alveolata* (L.). Journal of the Marine Biological Association of the United Kingdom. **48**: p. 367-386.
529. Dubois, S., T. Comtet, C. Retiere, and E. Thiebaut, 2007 Distribution and retention of *Sabellaria alveolata* larvae (Polychaeta : Sabellariidae) in the Bay of Mont-Saint-Michel, France. Marine Ecology Progress Series. **346**: p. 243-254.
530. Pawlick, J.R., 1988 Larval settlement and metamorphosis of two gregarious sabellariid polycahetes: *Sabellaria alveolata* compared with *Phragnatopoma cilifornica*. Journal of The Marine Biological Association of the United Kingdom. **68**: p. 101-124.
531. Ayata, S., C. Ellien, F. Dumas, S. Dubois, and E. Thiebaut, 2009 Modelling larval dispersal and settlement of the reef-building polychaete *Sabellaria alveolata*: Role of hydroclimatic processes on the sustainability of biogenic reefs. Continental Shelf Research. **29**(13): p. 1605-1623.
532. Wilson, D.P., 1929 The larvae of the British Sabellarians. Journal of the Marine Biological Association of the United Kingdom. p. 221-270.
533. Wilson, D.P., 1970 Additional Observations on Larval Growth and Settlement of Sabellaria-Alveolata. Journal of the Marine Biological Association of the United Kingdom. **50**(1): p. 1-&.
534. Gruet, Y. Sabellarian reefs built by the polychaete *Sabellaria alveolata* (Linne) in a tidal delta (Noirmoutier, France): Spatio-temporal changes. in Third International Polychaete

Conference Held At California State University, Long Beach, California, August, 48, 587-588. 1989.

535. Foster-Smith, R.L., *Sabellaria spinulosa* reef in The Wash and North Norfolk Coast cSAC and its approaches: Part II, fine scale mapping of the spatial and temporal distribution of reefs and the development of tecniques for monitoing condition, in English Nature Research Report 544. 2001, English Nature. p. 51.
536. Foster-Smith, R.L.H., V.J., *Sabellaria spinulosa* reef in The Wash and North Norfolk cSAC and its approaches: Part III, Summary of knowledge, reccomended monitoring strategies and outstanding research requirements, in English Nature Research Report 543. 2003, English Nature. p. 62.
537. Foster-Smith, R.L.W., W.H., *Sabellaria spinulosa* reef in The Wash and North Norfolk Coast cSAC and its approaches: Part I, Mapping techniques and ecological assessment, in English Nature Research Report 545. 2001, English Nature. p. 52.
538. Hendrick, V.J.F.-S., R.L., 2006 *Sabellaria spinulosa* reef: a scoring system for evaluating 'reefiness' in the context of the Habitats Directive. Journal of The Marine Biological Association of the United Kingdom. **86**: p. 655-677.
539. McIntosh, W.C., A mongraph of British Marine Annelids Volume IV, Parte I. Polychaeta - Hermellidae to Sabellidae. 1922, London: The Ray Society 247.
540. Unicomarine, Results of the biological sampling of the areas around the Deep Water Approach Channel to Harwich and Felixstowe Docks; 1992 and 1996. 1998, Unicomarine Report to Harwich Haven Authority
541. George, C.L. and R.M. Warwick, 1985 Annual macrofauna production in a hard-bottom reef community. Journal of the Marine Biological Association of the United Kingdom. **65**(3): p. 713-735.
542. Pearce, B., The ecology of *Sabellaria spinulosa* reefs, in The Marine Institute. 2009, University of Plymouth.
543. Warren, P.J. and R.W. Sheldon, 1967 Feeding and migration patterns of the pink shrimp, *Pandalus montagui*, in the estuary of the River Crouch, Essex, England. Journal of the Fisheries Research Board of Canada. **24**(3): p. 569-580.
544. MESL, Distribution of *Sabellaria spinulosa*: Licence Areas 401/1 & 401/2. August 2000. 2001: St. Ives, Cornwall. p. 25 pp.
545. MESL, Benthic Biological Resources In & Adjacent to Production Licence Area 401/1 & 402/1 Off Lowestoft. 2000: St. Ives, Cornwall. p. 59 pp.
546. MESL, Marine Aggregate Extraction Application Area 106 East (480): Environmental Statement, in Environmental Statement. 2003: St. Ives, Cornwall. p. 199 pp.
547. Pearce, B., J.A. Taylor, and L.J. Seiderer, Recoverability of *Sabellaria spinulosa* Following Aggregate Extraction. Aggregate Levy Sustainability Fund MAL0027. 2007: Marine Ecological Surveys Limited, 24a Monmouth Place, Bath, BA1 2AY. 87.
548. Schafer, W., Ecology and Paleoecology of Marine Environments. 1972: Oliver & Boyd. Edinburgh. 568.
549. Wilson, D.P., 1929 The Larvae of the British Sabellarians. p. 50 pp.
550. Wilson, D.P., 1970 Larvae of *Sabellaria spinulosa* and their settlement behaviour. Journal of the Marine Biological Association of the United Kingdom. **50**(1): p. 33-&.
551. Dubois, S., T. Comtet, C. Retiere, and E. Thiebaut, 2007 Distribution and retention of Sabellaria alveolata larvae (Polychaeta : Sabellariidae) in the Bay of Mont-Saint-Michel, France. Marine Ecology-Progress Series. **346**: p. 243-254.
552. MBA, Plymouth Marine Fauna. 3rd ed. 1957: Marine Biological Association of the UK
553. Garwood, P.R., Polychaeta - Sedentaria and Archianellida, in Report of the Dove Marine Laboratory Third Series 1982. p. 350.
554. Zhang, J.Z., Further studies of scallop spay settlement and early survival in Isle of Man coastal waters. 1996, Liverpool University.
555. MESL, Marine Macrofauna Genus Traits Handbook. 2008, Bath: Marine Ecological Surveys Ltd.

556. MESL, Thanet Offshore Wind Farm: Preliminary report on the presence of *Sabellaria spinulosa* in the Survery Area. 2005, Marine Ecological Surveys Ltd: Bath. p. 12 pp.
557. Bamber, R.N., S.D. Batten, M. Sheader, and N.D. Bridgwater, 1992 On the ecology of brackish water lagoon in Great Britain. Aquatic Conservation-Marine and Freshwater Ecosystems. **2**(1): p. 65-94.
558. Barnes, R.S.K., 1988 The faunas of land-locked lagoons: Chance differences and the problems of dispersal Estuarine, Coastal and Shelf Science. **26**: p. 309-318.
559. Joyce, C.B., C. Vina-Herbon, and D.J. Metcalfe, 2005 Biotic variation in coastal water bodies in Sussex, England: Implications for saline lagoons. Estuarine Coastal and Shelf Science. **65**(4): p. 633-644.
560. Bamber, R.N., 1998 Conservation of brackish lagoonal faunas. Journal of Conchology. p. 265-269.
561. Gordon, C., Y. Ntiamoa-Baidu, and J.M. Ryan, 2000 The Muni-Pomadze Ramsar site. Biodiversity and Conservation. **9**(4): p. 447-464.
562. Healy, B., 1997 Long-term changes in a brackish lagoon, Lady's Island Lake, south-east Ireland. Biology and Environment, Proceedings of the Royal Irish Academy. **97B**(1): p. 33-51.
563. Jones, P.J.S. and A. Carpenter, 2009 Crossing the divide: The challenges of designing an ecologically coherent and representative network of MPAs for the UK. Marine Policy. **33**(5): p. 737-743.
564. Pain, C., S. Wilkinson, and J. Light, 2009 Two further UK sites for *Caecum armoricum*, De Folin, 1989, formerly known only in The Fleet, Dorset, as a member of the interstitial 'springs community. Journal of Conchology. **39**: p. 779-780.
565. Graham, A., Molluscs: Prosobranch and Pyramidellid Gastropods: Keys and Notes for Identification of the Species (Synopses of the British Fauna No 2). Published for the Linnean Society of London and the Estuarine and Brackish-water Sciences Association, ed. E.J. Brill and W. Backhuys. 1988: Leiden; New York.
566. Barnes, R.S.K., Coastal lagoons: the natural history of a neglected habitat. Cambridge Studies in Modern Biology. Vol. 1. 1980. 106.
567. Barnes, R.S.K., Investment in eggs in lagoonal *Hydrobia ventrosa* and life-history strategies in north-west European *Hydrobia* species. 1994, Cambridge Journals Online. p. 637-650.
568. Fish, J.D. and S. Fish, The early life-cycle stages of *Hydrobia ventrosa* and *Hydrobia neglecta* with observations on *Potamophyrgus jenkinsi*. 1981. p. 89-98.
569. Little, C. and W. Nix, 1976 The burrowing and floating behaviour of the gastropod *Hydrobia ulvae*. Estuarine and Coastal Marine Science. **4**(5): p. 537-544.
570. Healy, B. and M. O'Neill, 1984 The life cycle and population dynamics of *Idotea pelagica* and *I. granulosa* (Isopoda: Valvifera) In South-East Ireland. Journal of the Marine Biological Association of the United Kingdom. **64**(1): p. 21-33.
571. Guero, G. and C. Ribera, 1995 Growth and reproductive ecology of *Palaemon adspersus* in the Western Mediterranean. Ophelia. **43**(3): p. 205-213.
572. Barnes, R.S.K., The brackish-water fauna of Northwestern Europe. 1994: Cambridge University Press.
573. Jolly, M.T., A.D. Rogers, and M. Sheader, 2003 Microgeographic genetic variation of populations of *Idotea chelipes* (Crustacea: Isopoda) in lagoons of the southern English coast. Cahiers de Biologie Marine **44**: p. 319–327.
574. Allen, J.R., S.B. Wilkinson, and S.J. Hawkins, 1995 Redeveloped docks as artificial lagoons: The development of brackish-water communities and potential for conservation of lagoonal species. Aquatic Conservation: Marine and Freshwater Ecosystems. **5**(4): p. 299-309.
575. Stewart, A., D.A. Pearman, and C.D. Preston, Scarce Plants in Britain. 1994, JNCC, Peterborough.

576. Attrill, M.J., J.A. Strong, and A.A. Rowden, 2000 Are macroinvertebrate communities influenced by seagrass structural complexity? Ecography. **23**: p. 114-121.
577. Boström, C. and E. Bonsdorff, 1997 Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L) beds in the northern Baltic Sea. Journal of Sea Research. **37**(1-2): p. 153-166.
578. Philippart, C.J.M., 1995 Seasonal variation in growth and biomass of an intertidal *Zostera noltii* stand in the Dutch Wadden Sea. Netherlands Journal of Sea Research. **33**(2): p. 205-218.
579. Frost, M.T., A.A. Rowden, and M.J. Attrill, 1999 Effect of habitat fragmentation on the macroinvertebrate infaunal communities associated with the seagrass *Zostera marina* L. Aquatic Conservation Marine and Freshwater Ecosystems. **9**(3): p. 255-263.
580. Davison, D.M. and D.J. Hughes, *Zostera* biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs, Vol. 1. 1998, Scottish Association for Marine Science, (UK Marine SACs Project)., Scottish Association for Marine Science, (UK Marine SACs Project).
581. Denhartog, C., 1987 Wasting disease and other dynamic phenomena in *Zostera* beds. Aquatic Botany. **27**(1): p. 3-14.
582. Duarte, C.M., 1989 Temporal biomass variability and production/biomass relationships of seagrass communities. Marine Ecology Progress Series **51** (3): p. 269–276.
583. Duarte, C.M. and H. Kirkman, Methods for the measurement of seagrass abundance and depth distribution. 2001, In: Short, F.T., Coles, R.G. (Eds.), Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam, pp. 141–153.
584. Vermaat, J.E. and F.C.A. Verhagen, 1996 Seasonal variation in the intertidal seagrass *Zostera noltii* Hornem: Coupling demographic and physiological patterns. Aquatic Botany. **52**(4): p. 259-281.
585. Nacken, M. and K. Reise, 2000 Effects of herbivorous birds on intertidal seagrass beds in the northern Wadden Sea. Helgoland Marine Research. **54** p. 87-94.
586. Fowler, S.L., Marine monitoring in the Isles of Scilly, 1991. 1992, English Nature Research Report No. 9., Peterborough. (Contractor: Nature Conservation Bureau Ltd).
587. Short, F.T. and S. Wyllie-Echeverria, 1996 Natural and human-induced disturbance of seagrasses. Environmental Conservation. **23**(1): p. 17-27.
588. Frederiksen, M., D. Krause-Jensen, M. Holmer, and J.S. Laursen, 2004 Spatial and temporal variation in eelgrass (*Zostera marina*) landscapes: influence of physical setting. Aquatic Botany. **78**(2): p. 147-165.
589. Olesen, B. and K. Sandjensen, 1994 Patch dynamics of eelgrass *Zostera marina*. Marine Ecology Progress Series. **106**(1-2): p. 147-156.
590. Foden, J. and D.P. Brazier, 2007 Angiosperms (seagrass) within the EU water framework directive: A UK perspective Aquatic Toxicology. **85**(3): p. 184-191.
591. Reusch, T.B.H., W.T. Stam, and J.L. Olsen, 1999 Size and estimated age of genets in eelgrass *Zostera marina* L. assessed with microsatellite markers. Marine Biology. **133**: p. 519–525.
592. Reusch, T.B.H., W.T. Stam, and J.C. Olsen, 1998 Size and estimated age of genets in eelgrass, *Zostera marina*, assessed with microsatellite markers. Marine Biology. **133**: p. 519-525.
593. Orth, R.J., M. Luckenbach, and K.A. Moore, 1994 Seed dispersal in a marine macrophyte: implications for colonization and restoration. Ecology. **75**(7): p. 1927-1939.
594. Reusch, T.B.H., 2002 Microsatellites reveal high population connectivity in eelgrass (*Zostera marina*) in two contrasting coastal areas. Limnology and Oceanography. **47**(1): p. 78-85.
595. de Kluijver, M.J., S.S. Ingalsuo, A.J.L. van Nieuwenhuijzen, and H.H. Veldhuijzen van Zanten, Macrobenthos of the North Sea (Vol.2):Keys to Polychaeta, Nemertina, Sipuncula and Platyhelminthes (World Biodiversity Database CD-ROM Series) (v. 2). 2001.

596. Gibbs, P.E., A comparative study of reproductive cycles in four polychaete species belonging to the family Cirratulidae. 1971, Cambridge Journals Online. p. 745-769.

597. Stephenson, T.A., On Methods of Reproduction as Specific Characters. 1929, Cambridge Journals Online. p. 131-172.

598. Jara-Jara, R., M. Abad, A.J. Pazos, M.L. Perez-Paralle, and J.L. Sanchez, 2000 Growth and reproductive patterns in *Venerupis pullastra* seed reared in waste water effluent from a fish farm in Galicia (N.W. Spain). Journal of Shellfish Research. **19**: p. 949-956.

599. Anon (2009) Subtidal rocky reefs including sublittoral chalk. The Solent Habitat Information Pack,

600. Picton, B.E. and C.E. Goodwin, 2007 Sponge biodiversity of Rathlin Island, Northern Ireland. Journal of the Marine Biological Association of the United Kingdom. **87**(6): p. 1441-1458.

601. Ungfors, A., H. Hallback, and P.G. Nilsson, 2007 Movement of adult edible crab (*Cancer pagurus* L.) at the Swedish West Coast by mark-recapture and acoustic tracking. Fisheries Research. **84**(3): p. 345-357.

602. Ungfors, A., N.J. McKeown, P.W. Shaw, and C. Andre, 2009 Lack of spatial genetic variation in the edible crab (*Cancer pagurus*) in the Kattegat-Skagerrak area. ICES Journal of Marine Science. **66**(3): p. 462-469.

603. Eaton, D.R., J. Brown, J.T. Addison, and L.J. Milligan, 2003 Edible crab (*Cancer pagurus*) larvae surveys off the east coast of England: implications for stock structure. Fisheries Research. **65**: p. 191-199.

604. Kunitzer, A., D. Basford, J.A. Craeymeersch, J.M. Dewarumez, J. Dorjes, G.C.A. Duineveld, A. Eleftheriou, C. Heip, P. Herman, P. Kingston, U. Niermann, H. Rachor, and P.A.J. de Wilde, 1992 The benthic infauna of the North Sea; species distribution and assemblages. ICES Journal of Marine Science. **49**: p. 127-143.

605. Kaiser, M.J., D. Edwards, P. Armstrong, K. Radford, N. Lough, R. Flatt, and H. Jones, 1998 Changes in megafaunal benthic communities in different habitats after trawling disturbance. ICES Journal of Marine Science. **55**(3): p. 353-361.

606. MESL, Bristol Deep Sea Container Terminal Biological Resource Assessment : Analysis of Survey Data for 2007/8. 2008.

607. MESL, Biological Resources of the Tay Estuary 1998: St. Ives, Cornwall

608. MESL, London Gateway Port Project; Benthic Biological Resources of the Lower Thames Estuary: Analysis of Survey Data for 2007. 2008.

609. Wilson, D.P., 1970 The larvae of *Sabellaria spinulosa* and their settlement behaviour. Journal of the Marine Biological Association of the United Kingdom. **50**(33-52).

610. Bellamy, A.G., The UK marine sand and gravel dredging industry: an application of Quaternary geology, in Advances in Aggregates and Armourstone Evaluation, J.P. Latham, Editor. 1998, Geological Society, London, Engineering Geology Special Publications. p. 33-45.

611. Newell, R.C., L.J. Seiderer, and J.E. Robinson, 2001 Animal : sediment relationships in coastal deposits of the eastern English Channel. Journal of the Marine Biological Association of the United Kingdom. **81**(1): p. 1-9.

612. Newell, R.C., L.J. Seiderer, N.M. Simpson, and J.E. Robinson, 2004 Impacts of marine aggregate dredging on benthic macrofauna off the south coast of the United Kingdom. Journal of Coastal Research. **20**(1): p. 115-125.

613. Glemarec, M., 1973 The benthic communities of the European Atlantic continental shelf. Oceanography and Marine Biology: An annual Review. **11**: p. 263-289.

614. Smith, J.E., 1932 The shell gravel and the infauna of the Eddystone Grounds. Journal of the Marine Biological Association of the United Kingdom. **18**(1): p. 243-278.

615. Hitchcock, D.R., R.C. Newell, and L.J. Seiderer, Integrated Report on the Impact of Marine Aggregate Dredging on Physical and Biological Resources of the Seabed 2002, U.S. Department of the Interior Minerals Management Service, International Activities and Marine Minerals Division (INTERMAR): Washington, D.C.,.

616. Galap C., L.F. and J.P. Grillot, 1997 Seasonal variations in biochemical constituents during the reproductive cycle of the female dog cockle *Glycymeris glycymeris.* Marine Biology **129** p. 625-634.

617. Kaiser, M.J. and F.E. Spence, 2002 Inconsistent temporal changes in the megabenthos of the English Channel. Marine Biology. **141**(2): p. 321-331.

618. Graham, A., Molluscs: prosobranchs and pyramellid gastropods (2nd ed.). Synopses of the British Fauna (New Series). Synopses of the British Fauna ed. D.M. Kermack and R.S.K. Barnes. Vol. No. 2. 1988: The Linnean Society of London.

619. Lancaster, I., 1990 Reproduction and life history strategy of the hermit crab *Pagurus bernhardus.* Journal of the Marine Biological Association of the United Kingdom. **70**(129-142).

620. Tirado, C., C. Salas, and I. Marquez, 2003 Reproduction of *Venus verrucosa* in the littoral of Malaga. Fisheries Research. **63**(437-445).

621. Kenny, A.J. and H.L. Rees, 1996 The effects of marine gravel extraction on the macrobenthos: Results 2 years post-dredging. Marine Pollution Bulletin. **32**(8-9): p. 615-622.

622. MESL, Predictive Framework for Assessment of Recoverability of Marine Benthic Communities Following Cessation of Aggregate Dredging in Technical report to the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and Department for Environment, Food and Rural Affairs (Defra). 2007: . p. 115pp.

623. MESL., Marine Macrofauna Genus Trait Handbook. 2008, Bath Marine Ecological Surveys Limited

624. James, J.W.C., R.A. Coggan, V.J. Blythe-Skyrme, A. Morando, S.N.R. Birchenough, E. Bee, D.S. Limpenny, E. Verling, K. Vanstaen, B. Pearce, C.M. Johnston, K.F. Rocks, S.L. Philpot, and H.L. Rees, Eastern English Channel Marine Habitat Map, in Science Series Technical Report Cefas, Editor. 2007, Centre for Environment, Fisheries and Aquaculture Science (Cefas): Lowestoft. p. 191.

625. Foster-Smith, J., The marine fauna and flora of the Cullercoats District. Marine species records for the North East Coast of England., ed. U.o.N.u.T. Dove Marine Laboratory. 2000, Sunderland: Penshaw Press.

626. Webb, C.M. and P.A. Tyler, 1985 Post-larval development of the common north-west European brittle stars *Ophiura ophiura, O. albida* and *Acrocnidabranchiata* (Echinodermata: Ophiuroidea). Marine Biology. **89**(3): p. 281-292.

627. Cardoso, J.F.M.F., J.I.J. Witte, and H.W. Van de Veer, 2006 Growth and reproduction of the bivalve *Spisula subtruncata* (da Costa) in Dutch coastal waters. Journal of Sea Research. **57**: p. 316-324.

628. Gaspar, M.B. and C.C. Monteiro, 1999 Gametogenesis and spawning in the subtidal white clam *Spisula solida*, in relation to temperature. Journal of the Marine Biological Association of the United Kingdom. **79**: p. 753-755.

629. Soulsby, R., Dynamics of marine sands 1997, London: Thomas Telford Publications.

630. Warwick, R.M., C.L. George, and J.R. Davies, 1978 Annual macrofauna production in a Venus community. Estuarine and Coastal Marine Science. **7**(3): p. 215-241.

631. Boyden, C.R. and C. Little, 1973 Faunal distributions in soft sediments of the Severn estuary. Estuarine and Coastal Marine Science. **1**: p. 203-223.

632. MESL, Bivalve Resources in the Scottish Solway Firth. An Assessment of: 1. The food resources available to wading birds, 2. Cockle Stocks at Carse Sands and Barnhourie Bank 2007.

633. MESL., Cockle Stock Assessment in the Scottish Solway Firth, Carse Sands. 2006. p. 30 pp.

634. Elliot, M. and K. Hemingway, Fishes in Estuaries. 2002, Oxford: Blackwell Science Limited.

635. Mente, E., Reproductive Biology of Crustaceans: case studies of decapod crustaceans. 2008: U.S.: Science Publishers.

636. Crothers, J. and M. Crothers, A key to the crabs and crab-like animals of British inshore waters. Somerset, England. Field Studies Council. 1988: [AIDGAP guide, no. 155.].
637. Kashenko, S.D., 1994 Larval development of the heart urchin *Echinocardium cordatum* feeding on different macroalgae. . Biologiya Morya. **20**: p. 385-389.
638. Dauvin, J.C., D. Bellansantini, and G. Bellan, 1993 The genera *Ophelia* and *Ampelisca* of the Roscoff region - examples of allotopy and syntopy in marine communities of the loost substratum
Cahiers De Biologie Marine. **34**(1): p. 1-15.
639. Rabaut, M., U. Braeckman, F. Hendrickx, M. Vincx, and S. Degraer, 2008 Experimental beam-trawling in *Lanice conchilega* reefs: Impact on the associated fauna. Fisheries Research. **90**: p. 209-216.
640. Chardy, P. and J.C. Dauvin, 1992 Carbon flows in a subtidal fine sand community from the wester English Channel - a simulation analysis. Marine Ecology Progress Series. **81**(2): p. 147-161.
641. Hall, S.J., D.J. Basford, M.R. Robertson, D.G. Raffaelli, and I. Tuck, 1991 Patterns of recolonization and the importance of pit-digging by the crab *Cancer pagurus* in a subtidal sand habitat. Marine Ecology Progress Series. **72**(1-2): p. 93-102.
642. Dauvin, J., E. Thiebaut, J.L.G. Gesteira, K. Ghrtsos, F. Gentil, M. Ropert, and B. Sylvand, 2004 Spatial structure of a subtidal macrobenthic community in the Bay of Veys (western Bay of Seine, English Channel). Journal of Experimental Marine Biology and Ecology. **307**: p. 217-235.
643. MESL., Benthic Ecology of Licence Area 457 - Liverpool Bay. Pre-Dredge Benthic and Epibenthic Resources, in Prepared for Westminster Gravels Limited. 2009, Marine Ecological Surveys, Bath.
644. Dauvin, J.C., E. Thiebaut, J.L.G. Gesteira, K. Ghertsosa, F. Gentil, M. Ropert, and B. Sylvand, 2004 Spatial structure of a subtidal macrobenthic community in the Bay of Veys (western Bay of Seine, English Channel). Journal of Experimental Marine Biology and Ecology. **307**(2): p. 217-235.
645. Dauvin, J.C. and F. Gentil, 1989 Long-term changes in populations of subtidal bivalves (*Abra alba* and *Abra prismatica*) from the Bay of Morlaix (Western English Channel). . Marine Biology. **103**: p. 63-73.
646. Fishbase. FishBase. World Wide Web electronic publication 2009 [cited; 07.10.09:[Available from: www.fishbase.org.
647. Prevedelli, D. and R. Simonini, 2003 Life cycles in brackish habitats: adaptive strategies of some polychaetes from the Venice lagoon. Oceanologica Acta **26**: p. 77-78.
648. Hansen, B., 1993 Aspects of feeding, growth and stage development by trochophore larvae of the boreal polychaete *Mediomastus fragile* (Rasmussen) (Capitellidae). Journal of Experimental Marine Biology and Ecology **166**: p. 273-288.
649. Coe, W.R., 1930 Asexual reproduction in Nemerteans. Physiological Zoology. **3**: p. 297-308.
650. Menard, F., F. Gentil, and J.C. Dauvin, 1990 Population dynamics and secondary production of *Owenia fusiformis* Delle Chiaje (Polychaeta) from the Bay of Seine (eastern English Channel). Journal of Experimental Marine Biology and Ecology **133**: p. 151-167.
651. Holland, G.J., S.P.R. Greenstreet, I.M. Gibb, H.M. Fraser, and M.R. Robertson, 2005 Identifying sandeel *Ammodytes marinus* sediment habitat preferences in the marine environment. Marine Ecology-Progress Series. **303**: p. 269-282.
652. Proctor, R., P.J. Wright, and A. Everitt, 1998 Modelling the transport of larval sandeels on the north-west European shelf. Fisheries Oceanography. **7**(3-4): p. 347-354.
653. Buchanan, J.B., 1964 A comparative study of some of the features of the biology of *Amphiura filiformis* and *Amphiura chiajei* (Ophiuroidea) considered in relation to their distribution. Journal of the Marine Biological Association of the United Kingdom. **44**: p. 565-576.

654. Mauchline, J., 1970 The biology of *Schistomysis ornata.* Journal of the Marine Biological Association of the United Kingdom **50**: p. 169-175.

655. Peattie, M.E. and R. Hoare, 1981 The sublittoral ecology of the Menai Strait: II. The sponge *Halichondria panicea* (Pallas) and its associated fauna. Estuarine, Coastal and Shelf Science. **13**(6): p. 621-635.

656. Seed, R. and V. Wood, 1994 Recruitment and mortality of *Alcyonidium hirsutum* (Fleming) and *Flustrellidra hispida* (Fabricius) (Bryzona, Ctenostomata) within a *Fucus serratus* L. community. Cahiers De Biologie Marine. **35**(3): p. 305-326.

657. Seed, R., R.J. O'Connor, and P.J.S. Boaden, 1983 The spatial niche of *Dynamena pumila* (L.) and *Gonothryaea loveni* (Allman) (Hydrozoa) within a *Fucus serratus* L. community. Cahiers De Biologie Marine. **24**: p. 391-419.

658. Wood, V. and R. Seed, 1980 The effect of shore level on the epifaunal communities associated with *Fucus serratus* (L) in the Menai Strait, North Wales. Cahiers De Biologie Marine. **21**: p. 155-167.

659. Seed, R. and S. Harris, 1980 The epifauna of the fronds of *Laminaria digitata* Lamour in Strangford Lough, Northern Ireland. Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science. **80B**: p. 91-106.

660. Hoare, R. and M.E. Peattie, 1979 Sublittoral ecology of the Menai Strait. 1. Temporal and spatial variation in the fauna and flora along a transect. Estuarine and Coastal Marine Science. **9**(6): p. 663-675.

661. Hayward, P.J. and J.S. Ryland, Growth, reproduction and larval dispersal in *Alcyonidium hirsutum* (Fleming) and some other Bryozoa, in 8th European Marine Biology Symposium Sorrento. Pubblicazioni della Stazione Zoologica di Napoli, G. Bonaduce and G.C. Carrada, Editors. 1975, European Marine Biology Symposia: Naples. p. 226-241

662. Irving, R., 2004 *Leptosammia pruvoti* at Lundy - teetering on the brink? Porcupine Marine Natural History Newsletter **15**: p. 29-34.

663. Thorson, G., 1949 Reproductive and Larval Ecology of marine Bottom Invertebrates. Biological Reviews. **25**(1): p. 1 - 45.

664. Sainte-Marie, B., 1983 Differences in life history and success between suprabenthic shelf populations of *Arrhis phyllonyx* (Amphipoda Gammaridea) in two ecosystems of the Gulf of St. Lawrence. Journal of Crustacean Biology **3**: p. 45-67.

665. Barnes, M., Pedunculate Cirripedes of the genus *Pollicipes*, in Oceanography and Marine Biology. 1996, U C L Press Ltd: London. p. 303-394.

666. Butler, A., N. Vicente, and B. de Gaulejac, 1993 Ecology of the pterioid bivalves *Pinna bicolor* Gmelin and *Pinna nobilis* L. Mar. Life. **3**(1-2): p. 37-45.

667. Maeno, Y., K. Suzuki, Yurimoto T, Fuseya R, Kiyomoto S, O. S, and O. H, 2009 Maturation Process of Broodstock of the Pen Shell *Atrina pectinata* (Linnaeus, 1767) in Suspension Culture. Journal of Shellfish Research. **28**(3): p. 561-568. .

668. Thorson, G., Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the Sound (Øresund). Meddelelser fra Kommissionen for Danmarks Fiskeri- Og Havundersögelser, Serie: Plankton. Vol. 4. 1946. 1-523.

669. Ayling, a.L., 1980 Patterns of sexuality, asexual reproduction and recruitment in some subtidal marine Demospongiae. Biological Bulletin. **158**(3): p. 271-282.

670. Elvin, D.W., 1976 Seasonal Growth and Reproduction of an Intertidal Sponge, *Haliclona permollis* (Bowerbank). Biological Bulletin. **151**(1): p. 108-125.

671. Ereskovsky, A.V., Reproduction cycles and strategies of the cold-water sponges *Halisarca dujardini* (Demospongiae, Halisarcida), *Myxilla incrustans* and *Lophon piceus* (Demospongiae, Poecilosclerida) from the White Sea. 2000. p. 77-87.

Appendix 1

Table 6-1 Species population density data from a number of surveys (see Appendix Table Table 6-2) used to calculate the area (in m^2) for a minimum viable population number of 5000

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Abra alba	988	163	31
Abra tenuis	8	191	26
ACTINIARIA	919	119	42
Aequipecten opercularis	150	24	208
Alcyonidium diaphanum	Colonial		
Alcyonidium hirsutum	Colonial		
Alcyonium digitatum	Colonial		
Alkmaria romijni	No data – Rare Species		
Ammodytes tobianus	Highly Mobile Species		
Ampelisca	360	50	100
Amphianthus dohrnii	No data		
Amphiura chiajei	18	47	107
Amphiura filiformis	56	164	30
Anotrichium barbatum	No data		
Antedon bifida	2	10	500
Aonides paucibranchiata	1415	32	156
Aphelochaeta marioni	456	773	6
Arca	No data		
Arctica islandica	No data		
Arenicola marina	42	27	188
Armandia cirrhosa	48	106	47
Arrhis phyllonyx	No data		
Asbestopluma	No data		
ASCIDIACEA	190	77	65
Ascidiella aspersa	11	16	306
Asterias rubens	73	17	294
Atelecyclus rotundatus	85	12	421
Atrina fragillis	No data		

Table continued...

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Axinella	Colonial		
Balanus balanus	14	67	74
Balanus crenatus	632	932	5
Balanus improvisus	50	1733	3
Barnea candida	10	165	30
Bathyporeia elegans	392	86	58
Bonellia viridis	No data		
Botryllus schlosseri	Colonial		
Brissopsis lyrifera	No data		
BRYOZOA	Colonial		
Buccinum undatum	45	12	433
Bugula neritina	No data		
Caecum armoricum	No data		
Callianassa subterranea	137	19	257
Calocaris macandreae	No data		
Cancer pagarus	Mobile		
Carcinus maenas	Mobile		
Caryophyllia smithii	No data		
Caulleriella alata	931	30	165
Cerastoderma edule	191	986	5
Cerastoderma glaucum	No data		
Cereus pedunculatus	No data		
Cerianthus lloydii	150	26	190
CHRYSOPHYCEAE	No data		
Ciona intestinalis	1	10	500
Cladorhiza	No data		
Clavelina lepadiformis	No data		
Cliona celata	17	91	55
Corophium volutator	320	4040	1
Corynactis viridis	No data		
Corystes cassivelaunus	43	10	478
Cruoria cruoriaeformis	No data		
Dendrodoa grossularia	373	312	16

Table continued...

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Dermocorynus montagnei	No data		
Distomus variolosus	No data		
Echiichthys vipera	Mobile		
Echinocardium cordatum	93	21	235
Echinocyamus pusillus	888	50	99
Edwardsia ivelli	No data		
Edwardsia timida	No data		
Elminius modestus	143	2936	2
Ensis	218	135	37
Eteone longa	789	53	95
Eulalia viridis	40	19	260
Eumida	341	57	88
Eumida sanguinea	512	46	109
Eunice norvegica	No data		
Eunicella verrucosa	No data		
Exogone hebes	336	47	106
Fabulina fabula	76	20	252
Flustra foliacea	Colonial		
Funiculina quadrangularis	No data		
Gammaropsis	124	50	99
Gammarus	12	16	316
Gammarus insensibilis	No data		
Geodia	No data		
Gibbula cineraria	45	17	292
Gitanopsis bispinosa	No data		
Glycera	781	25	202
Glycymeris glycymeris	226	33	153
Halichondria panicea	Colonial		
Haliclystus auricula	No data		
HAPTOPHYCEAE	No data		
Harmothoe	1115	49	103
Hediste diversicolor	264	317	16
Hippocampus guttulatus	No data		

Table continued...

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Hippocampus hippocampus	No data		
Hydrobia neglecta	No data		
Hydrobia ulvae	174	796	6
Hydrobia ventrosa	No data		
HYDROZOA	Colonial		
Idotea chelipes	2	10	500
Lagis koreni	858	85	59
Lanice conchilega	998	105	48
Lepidonotus	125	22	230
Lepidonotus squamatus	584	34	149
Leptopsammia pruvoti	No data		
Limaria hians	No data		
Lithothamnion corallioides	No data		
Littorina littorea	3	23	214
Littorina mariae	No data		
Littorina obtusata	No data		
Littorina tenbrosa	No data		
Lophelia pertusa	No data		
Lucernariopsis campanulata	No data		
Lucernariopsis cruxmelitensis	No data		
Lumbrineris	163	37	135
Macoma balthica	561	271	18
Madrepora oculata	No data		
Magelona	46	56	90
Marphysa	56	14	368
Mediomastus	75	45	110
Melinna palmata	114	481	10
Metridium senile	1	10	500
Mitella pollicipes	No data		
Modiolus modiolus	40	19	267
Munida rugosa	No data		
Mya arenaria	29	32	158
Mya truncata	40	18	278

Table continued...

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Mysella bidentata	541	77	65
Mytilus edulis	126	174	29
Nematostella vectensis	No data		
Nemertea	2409	38	131
Nemertesia	Colonial		
Nephrops norvegicus	No data		
Nephtys	1238	62	81
Notomastus	460	37	137
Notomastus latericeus	1248	41	122
Nucella lapillus	1	10	500
Nucula	93	42	118
Ophelia	84	50	99
Ophiactis balli	No data		
Ophiothrix fragilis	185	53	95
Ophiura	179	45	112
Ostrea edulis	1	10	500
Owenia fusiformis	293	19	263
Pachycerianthus multiplicatus	No data		
Padina pavonica	No data		
Pagurus bernhardus	202	12	423
Palaemon	1	10	500
Palinurus elephas	No data		
Paludinella litorina	No data		
Pandalus	1	10	500
Patella vulgata	No data		
Pennatula phosphorea	No data		
Pentapora foliacea	Colonial		
Petricola pholadiformis	74	36	138
Phakellia	No data		
Philine aperta	31	18	272
Pholas dactylus	4	25	200
Pholoe baltica	785	30	167
Phymatolithon calcareum	No data		

Table continued...

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Pionosyllis	93	17	302
Pisidia longicornis	1050	272	18
Pliobothrus	No data		
Poecilochaetus serpens	867	44	113
Polydora ciliata	105	5198	1
Polynoidae	158	33	152
Pomatoceros lamarcki	874	217	23
Pomatoceros triqueter	463	85	59
Porcellana platycheles	No data		
Porella	Colonial		
PORIFERA	Colonial		
Psammechinus miliaris	459	17	299
Ptilosarcus gurneyi	No data		
Puccinella maritima	No data		
Pygospio elegans	426	549	9
Pyura microcosmos	7	27	184
Sabella pavonina	65	82	61
Sabellaria alveolata	37	1621	3
Sabellaria spinulosa	1399	670	7
Salicornia	No data		
Scalibregma inflatum	867	52	96
Schistomeringos rudolphi	233	18	270
Schistomysis	8	19	267
Scoloplos armiger	1055	56	89
Scrobicularia plana	170	46	109
Semibalanus balanoides	5	422	12
Serpula vermicularis	No data		
Sertularia	Colonial		
Spartina alterniflora	No data		
Spartina anglica	No data		
Spartina maritima	No data		
Spiophanes bombyx	1456	107	47
Spisula	70	18	282

Table continued...

SPECIES	NO. RECORDS	MEAN DENSITY (m^{-2})	AREA (m^2) FOR VIABLE POPULATION (N=5000)
Stelletta	No data		
Sthenalais boa	275	29	170
Stryphnus	No data		
Suada	No data		
Swiftia pallida	No data		
Tenellia adspersa	5	156	32
Terebellides stroemi	252	17	303
Tharyx	281	721	7
Tubificoides benedii	816	2042	2
Urothoe	88	54	92
Urticina felina	37	29	173
Venerupis senegalensis	22	15	344
Venus	2	15	333
Virgularia mirabilis	Colonial		

Table 6-2 MESL survey reports; studies of species around the UK coastline. References are available from MESL if required

Emu Environmental Ltd (2002). *Cross Sands Licence Area 436 / 202 Baseline Benthic Ecology Study* in *Prepared for Hanson Aggregates Marine Ltd*. 2000: Hayling Island
Emu Ltd (2002). *Area 254 CROSS SANDS Benthic Ecology Study: Final Report*. 2002: Durley, Hampshire.
Emu Ltd (2002). *Area 254 CROSS SANDS Benthic Ecology Study: Final Report*. 2002: Durley, Hampshire.
Emu Ltd (2003). *Area 436/202 CROSS SANDS Benthic Ecology Monitoring Study 2003*. Durley, Hampshire.
Emu Ltd (2005). *Lincs Offshore Wind Farm, Baseline Benthic Survey, 2005*, E. Ltd., Editor. Emu Ltd.: Southampton.
Emu Ltd (2005). *Lynn and Inner Dowsing Offshore Wind Farm Monitoring Programme (inc.) Lincs Baseline Surveys)*, in *Fisheries and Epibenthos Surveys: Draft Report* Southampton.
English Nature and H.L.T. Essex (2003). *London Gateway HEO-Council Directive 92/42/EEC (the Habitats Directive) and the Conservation (Natural Habitats &c.) Regulations 1994 (the Habitats Regulaions)*: Essex.
Environmental Resource Management Limited (2007). *Marine Aggregate Regional Environmental Assessment, Scoping Report: Thames Estuary Dredging Association (TEDA)*. 2007.
Gardline Lankelma. and MESL (2007). T*hames Regional Environmental Characterisation: Seabed Imagery* Bath
MESL (1998). *Biological Resources of the Tay Estuary* : St. Ives, Cornwall
MESL (1999). *Benthic ecology South West Of The Isle Of Wight* St. Ives
MESL (2000). Benthic Biological Resources In & Adjacent to Production Licence Area 401/1 & 402/1 Off Lowestoft. St. Ives, Cornwall**:** 59 pp.
MESL (2000). *Benthic Biological Resources In & Adjacent to Production Licence Area 240, South Cross Sand*. St. Ives, Cornwall. p. 47 pp.
MESL (2000). *Benthic Biological Resources In & Adjacent to Production Licence Area 401/1 & 402/1 Off Lowestoft.* 2000: St. Ives, Cornwall. p. 59 pp.
MESL (2002). *Area 480: Benthic Biological Survey. Analysis of Survey Data for 2008 and Comparison with 2002 Survey Data*. Bath p. 166 pp.
MESL (2002). *Benthic Biological Resources in the Eastern English Channel*. St. Ives.
MESL (2002). Benthic Biological Resources in the Eastern English Channel. St. Ives.
MESL (2002). *Environmental Resource Appraisal, Princes Channel, Outer Thames Estuary. February 2002.* 2002: St. Ives.
MESL (2002). *London Gateway Port Project Benthic Intertidal Biology of the Lower Thames Estuary.July 2002.*, in *July 2002*. St. Ives, Cornwall.
MESL (2002). *Thanet Offshore Wind Farm, Ancillary Intertidal Resource Survey: Proposel Cable Routes in Pegwell Bay* 2007, Marine Ecological Surveys Ltd.,: Bath. p. 20 pp.
MESL (2003). *Dredging International (UK) Limited Licence Application Area 483: Benthic and Epibenthic Report* R.C. Newell, et al., Editors. St. Ives, Cornwall.
MESL (2003). *Environmental Impact Assessment of Marine Sand and Gravel Extraction: Area 106 East (Area 480): Report on the Scoping Exercise for Dredging Application Area 480*. St. Ives, Cornwall. p. 25 pp.
MESL (2003). Hanson Licence Application Area 439 (Inner Dowsing) and Sub-Area 439 (95) Benthic and Epibenthic Report St. Ives, Cornwall. **1:** 72 pp.
MESL (2004). Impacts of Overboard Screening on Seabed & Associated Benthic Biological Community Structure in Relation to Marine Aggregate Extraction St. Ives, Cornwall.
MESL (2004). Impacts of Overboard Screening on Seabed & Associated Benthic Biological Community Structure in Relation to Marine Aggregate Extraction St. Ives, Cornwall.
MESL (2004). *Impacts of Overboard Screening on Seabed & Associated Benthic Biological Community Structure in Relation to Marine Aggregate Extraction*: St. Ives, Cornwall.
MESL (2005), *Benthic Ecology of Licemce Area 407 (St. Catherines) Sept-Nov 2004*. Bath.
MESL (2005), *Thanet Offshore Wind Farm, Benthic & Intertidal Resource Survey* 2005: Bath. p. 131 pp.

Table continued...

MESL (2005). *Marine ALSF Science Review: Aggregate Research in UK Waters; Research Summary for the Period 01.04.05 - 30.09.05*, R.C. Newell and H.L. Jenkins, Editors. Bath.

MESL (2005). *Marine ALSF Science Review: Aggregate Research in UK Waters*, in *Annual Research Review: Marine Aggregate Levy Sustainability Fund*, R.C. Newell and K.A. Reeds, Editors. Bath. p. 111 pp.

MESL (2005). *QINETIQ BINCLEAVES MARINA PORTLAND HARBOUR. BIOLOGICAL RESOURCE ASSESSMENT*. Bath.

MESL (2006). *Aggregate Licence area 430- Southwold East, Biological Monitoring Proposal, Scoping Document.* Bath.

MESL (2006). Benthic Biological Assessment of Ashlett Creek. Bath

MESL (2006). *Benthic Biological Assessment of Ashlett Creek*. Bath

MESL (2006). *Hastings Shingle Bank, Licence Application Area 460. Benthic Baseline Report*. Bath. p. 127 pp.

MESL (2006). *Marine ALSF Science Review: Aggregate Research in UK Waters* in *Prepared for The Department for Environment, Food and Rural Affairs (Defra).* R.C. Newell, Editor: Bath. p. 60 pp.

MESL (2007). CEMEX UK Marine Limited, Licence Area 407 (St. Catherines). Benthic Biological Monitoring Report. July 2007. Bath.

MESL (2007). *Licence Area 451 (St Catherines) Benthic Biological Monitoring Survey, July 2007/ Revised October 2007*. Bath.

MESL (2007). Predictive Framework for Assessment of Recoverability of Marine Benthic Communities Following Cessation of Aggregate Dredging <u>Technical report to the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and Department for Environment, Food and Rural Affairs (Defra)</u>. Bath 115pp. + electronic appendices 466pp.

MESL (2007). Recoverability of *Sabellaria spinulosa* Following Aggregate Extraction B. Pearce and L. J. Seiderer. Bath

MESL (2007). *Recoverability of Sabellaria spinulosa Following Aggregate Extraction* B. Pearce and L.J. Seiderer, Editors. Bath

MESL (2007). *Thanet Offshore Wind Farm, Ancillary Intertidal Resource Survey: Proposed Cable Routes in Pegwell Bay* 2007, Marine Ecological Surveys Ltd. Bath. p. 20 pp.

MESL (2008). *Benthic Ecology of Licence Area 407 (St. Catherines) Proposed terms of Reference for Benthic Survey to be carried out in October 2008*. Bath.

MESL (2008). *Benthic Ecology of Licence Area 480: Proposed terms of Reference for benthic Survey to be carried out in June-July* Bath.

MESL (2008). *Benthic Ecology of Licence Area 481. Proposed Terms of reference for Pre-dredge Benthic & Geophysical Survey to be carried out in November/December 2008*, in *Prepared for United Marine Dredging Limited & Van Oord Limited*. 2008, Marine Ecological Surveys Ltd.: Bath.

MESL (2008). *Licence Area 447 - Cutline: Pre-Dredge Report* Bath

MESL (2008). *London Gateway Port Project; Benthic Biological Resources of the Lower Thames Estuary: Analysis of Survey Data for 2007*, in *2007*. Bath.

MESL (2008). *London Gateway Port Project; Benthic Biological Resources of the Lower Thames Estuary: Analysis of Survey Data for 2006* in *2006*. Bath.

MESL (2008). *London Gateway Port Project; Benthic Biological Resources of the Lower Thames Estuary: Analysis of Survey Data for 2004*, in Bath.

MESL (2008). Marine Aggregate Extraction, Area 202: Cross Sands Extension. Summary of Consultation Bath

MESL (2009). *Benthic Ecology of Licence Area 457 - Liverpool Bay. Pre-Dredge Benthic and Epibenthic Resources*, in *Prepared for Westminster Gravels Limited*. 2009, MES, Bath.

MESL (2009). *Licence Area 351: Benthic Biological Resources: Analysis of August 2008 Survey Data* 2009: Bath p. 1-107.

MESL (2009). *Wells-next-the-sea: Benthic Biological Resource Assessment: Analysis of Survey Data for 2009.* Bath p. 38pp.

MESL(2006). *Benthic Ecology of Licence Area 407 (St. Catherines). Proposed Terms of Reference for Benthic Survey to be Carried out in September 2006*. Bath.

MESL(2008). *London Gateway Port Project Benthic Biological Resources of the Lower Thames estuary: Analysis of Survey Data for 2004.*: Bath

Table continued...

MESL(2008). *London Gateway Port Project; Benthic Biological Resources of the Lower Thames Estuary: Analysis of Survey Data for 2005*, Bath

MESL (2003). Dredging International (UK) Limited Licence Application Area 483: Benthic and Epibenthic Report R. C. Newell, L. J. Seiderer, J. E. Robinsonet al. St. Ives, Cornwall.

MESL (2007). Thanet Offshore Wind Farm, Ancillary Intertidal Resource Survey: Proposed Cable Routes in Pegwell Bay Bath, Marine Ecological Surveys Ltd.,**:** 20 pp.

MESL (2009). Benthic Ecology of Licence Area 407 (St. Catherines) Analysis of October-November 2008 Survey Data. Bath.

UMD Ltd (2004). *Benthic Ecology of the Outer Bristol Channel based on Modelling of Existing Data*. 2004.

Table 6-3 All viability data for species of conservation importance

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Anotrichium barbatum	0		AV + S	-	<10	[11, 13]
Cruoria cruoriaeformis	0		AV + S	-	<1	[13, 20, 22, 456]
Dermocorynus montagnei	0		AV + S	-	<1	[13, 457, 458]
Lithothamnion corallioides	0		AV	0	<1	[41, 43, 44]
Padina pavonica	0		S	-	<10	[47, 51, 53]
Phymatolithon calcareum	0		V	0	0	[41, 43, 44]
Armandia cirrhosa **Armandia* spp.	< 1	47	*FS-L-PLK	*21-180	*15-1000	[62, 563]
Alkmaria romijni	0		BR-DIR-J	20	10-100	[70-72]
Gobius cobitis	1-10		Spawn (Embryos attached at nest site)-J	35	40-49	[74, 76]
Gobius couchi **Gobius cobitis*	1-10		Spawn (Embryos attached at nest site)-J	35*	40-49	[74, 76]
Hippocampus guttulatus	0.005 - 67 m^2		BR-J-PLK	42-56	>49	[90, 93]
Hippocampus hippocampus	0.7 – 18.1 m^2		BR-J-PLK	42-56	>49	[90, 94]
Victorella pavida	0		S	0	0	[103, 104]
Amphianthus dohrnii	0		A	0	0	[384]
Edwardsia ivelli	0		BR-L-LEC	60	>49	[49, 113, 384]
Edwardsia timida	0		BR-L-LEC	60	>49	[49, 113, 384]
Eunicella verrucosa	0		FS-L-LEC	3-5	4-10	[121, 123]
Funiculina quadrangularis **Ptilosarcus gurneyi*	0		FS-L-LEC	7-14*	4-40	[126, 489]
Haliclystus auricula **H. salpinx* and *H. stejnegeri*	0		FS-L (Crawling stage)	1-3*	<0.5	[136-138]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Leptopsammia pruvoti	0		BR-L-LEC	1	4	[662]
Lucernariopis campanulata	0		FS-L (Crawling stage)	1-3	<0.5	[136-138, 149]
Lucernariopis cruxmelitensis **L. campanulata*	0		FS-L (Crawling stage)	1-3*	<0.5	[136, 138]
Nematostella vectensis	0		A	0	0	[155, 156]
Pachycerianthus multiplicatus	0		FS-L-LEC	<1	7	[163, 663]
Swiftia pallida	0		FS-L-LEC	<1	<4	[121]
Arrhis phyllonyx	0 – 10		BR-DIR	0	0	[168, 664]
Gammarus insensibilis	0-10	316	BR-DIR	0	0	[171, 175, 176]
Mitella pollicipes	0		BR-L-PLK	11-24	10-40	[186, 665]
Palinurus elephas	2 - 20		BR-L-PLK	300-360	>49	[190, 194]
Gitanopsis bispinosa	<1		BR-DIR	0	0	[168]
Arctica islandica	0		FS-L-PLK	55	>49	[211]
Atrina pectinata	0		FS-L-PLK	7-10	4-10	[666, 667]
Caecum armoricum **Truncatella subcylindrica*	< 1		BR-DIR*	0	0	[224, 564, 565]
Nucella lapillus	< 1	500	BR-DIR	0	0	[234]
Ostrea edulis	0	29	FS-L-PLK	11-30	10-40	[239, 241]
Paludinella littorina	< 1		BR-DIR	0	<0.5	[245]
Tenellia adspersa	< 1		DIR + BR-L-LEC or PLK	5	4-9.8	[246, 249]

Table 6-4 Viability data for all characteristic species in habitat viability assessments

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Abra alba	< 1	31	FS-L-PLK	30	40	[645]
Abra tenuis	< 1	26	DIR	0	0	[347]
Aequipecten opercularis	< 1	208	FS-L-PLK	11-30	10-40	[402, 554]
Alcyonidium diaphanum	0		FS-L-LEC	<1	<0.1	[403]
Alcyonidium hirsutum	0		FS-L-LEC	<1	<0.1	[661]
Alcyonium digitatum	0		FS-L-PLK	>180	>50	[374], [375]
Alkmaria romijni	< 1		BR-DIR	20	10-100	[70-72]
Ammodytes marinus	< 1		FS-L	70	>50	[646, 652]
Ampelisca spp.	1 - 10	100	BR-DIR	0	0	[437, 555]
Amphiura chiajei	< 1	107	FS-L-PLK	8-14	10-40	[490]
Amphiura filiformis	< 1	30	FS-L-PLK	30-360	>50	[276, 653]
Antedon bifida	< 1	500	BR-L-PLK	5	10	[392]
Aonides paucibranchiata	< 1	156	FS-L-LEC	2-10	4-10	[277, 555]
Aphelochaeta marioni	< 1	6	FS-L-LEC	10	10-40	[277] [596]
Apistonema spp.	0		A + S		>50$^{\#}$	[27]
Arca spp.	0		FS-L			[308]
Arenicola marina	< 1	188	E-B-J	0	1-10	[417-419]
Armandia cirrhosa *Armandia spp.	< 1	47	FS-L-PLK	21-180	15-1000	[62, 563]
Ascidians	0	65	FS-L-LEC	<1	<0.25	[44]
Ascidiella aspersa	0	306	FS-L-LEC	1-2	4	[313]
Ascophyllum nodosum	0		S	-	<10	[274]
Asterias rubens	1 – 10	294	FS-L-PLK	<90	>50	[393], [394]

Table continued...

SPECIES	**HOME RANGE (km)**	**AREA FOR MVP (m^2)**	**MODE OF REPRODUCTION**	**LARVAL DISPERSAL**		**REFERENCES**
				(days)	**(km)**	
Atelecyclus rotundatus		421	BR-L-PLK	<30	40	[625]
Axinella spp. *Deep sea sponges	0		A + FS-L-LEC	2	5	[309, 310]
Balanus crenatus	0	5	BR-L-PLK	30	40	[279]
Balanus improvisus	0	5	BR-L-PLK	30	40	[279]
Bathyporeia elegans	< 1	58	BR-DIR	0	0	[348, 555]
Bathyporeia spp.	< 1	58	BR-DIR	0	0	[348, 555]
Bonellia viridis	< 1		BR-L	0-7	0-10	[311], [312]
Botryllus schlosseri	0		E-L-LEC	1	<4	[434]
Bryozoans	0		EB- L-LEC	2	0-4	[402, 477]
Buccinum undatum	1 – 10	433	E-DIR	0	0	[437, 618]
Bugula neritina	0		L-LEC	0-1.5	<0.1	[44]
Caecum armoricum **Truncatella subcylindrica*	< 1		BR-DIR	0	0	[224, 564, 565]
Callianassa subterranea	< 1	257	BR-L-PLK	30-60	>50	[491]
Calocaris macandreae	< 1		DIR	0	0	[348]
Cancer pagurus	1 - 10		BR-L-PLK	23-30	40	[601, 602], [603]
Carcinus maenas	1 – 10		BR-L-PLK	80	12-300	[44, 376]
Caryophyllia smithii	0		A + FS-L-PLK	56-70	>50	[404, 405], [406]
Cerastoderma edule	< 1	5	FS-L-PLK	14-21	25-40	[420]
Cerastoderma glaucum	<1		FS-L-PLK	7	10	[566]
Cereus pedunculatus	0		A + B	0	0	[384, 402, 597]
Cerianthus lloydii	0	190	FS-L-PLK	90	>50	[492], [379], [493]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Chrysotila lamellose	0		A + S		$>50^{\#}$	[27]
Ciona intestinalis	0	500	FS-L-LEC	0-6	10	[313], [314], [315], [316]
*Cirratulidae *Tharyx*	0	7	BR-DIR	0	0	[277]
Clavelina lepadiformis	0		FS-L-LEC	0.2	<1	[118], [407], [408]
Cliona celata	0	55	A + FS-L-LEC	2	5	[409, 410]
Corophium spp.	< 1	1	DIR	0	<1	[270-272]
Corophium volutator	< 1	1	DIR	0	<1	[270-273]
Corystes cassivelaunus	< 1	478	BR-L-PLK	11-30	10-40	[635, 636]
Cruoria cruoriaeformis	0		AV + S	0	<10	[13, 20, 22, 456].
Deep sea sponges	0		AB + FS-L-LEC	0-2	0-10	[309, 310]
Dendrodoa grossularia	0	16	A + BR-L-LEC	2-3 hrs	<1	[313], [377]
Dermocorynus montagnei	0		AV + S	0	<10	[13, 457, 458]
Echiichthys vipera			FS-L			[646]
Echinocardium cordatum	< 1	235	FS-L-PLK	39	50	[637]
Echinocyamus pusillus	< 1	99	FS-L-PLK	30-60	>40	[276]
Elminius modestus	0	2	BR-L-PLK	17-34	41±33	[378], [379], [44, 380]
Ensis spp.	< 1	37	FS-L-PLK	20-30	40	[416]
Enteromorpha spp.	0		S	-	<10	[274]
Eteone longa	< 1	95	FS-L-PLK	2-10	4-10	[277, 348]
Eumida sanguinea	<1	109	FS-L-PLK	56	>50	[60, 493]
Eunice norvegicus	0		FS-L-PLK	$11\text{-}30^{\#}$	$10\text{-}40^{\#}$	[277]
Eunicella verrucosa	0		FS-L-LEC	3-5	4-10	[121] [123]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	LARVAL DISPERSAL (km)	REFERENCES
Exogone hebes		106	BR-DIR	0	0	[277, 555]
Flustra foliacea	0		A + FS-L-LEC	Few hrs	<1	[420, 477]
Fucus serratus	0		S	-	<10	[274]
Fucus vesiculosus	0		S	-	<10	[274]
Funiculina quadrangularis **Ptilosarcus gurneyi*	0		FS-L-LEC	7-30	10-40	[126, 489]
Gammaropsis spp.	< 1	99	BR-DIR	0	0	[275]
Gammarus insensibilis	0-10		BR–DIR	0	0	[171, 175, 176]
Gammarus spp.	< 1	316	BR-DIR	0	0	[275]
Gibbula cineraria	< 1	292	FS-L-PLK	8-9	10	[316, 435]
Glycera spp.	< 1	202	FS-L-PLK	11-30	10-40	[350, 421]
Glycymeris glycymeris	< 1	153	FS-L-LEC	1-10$^{\#}$	4-10$^{\#}$	[616]
Halichondria panicea	0		BR-L-LEC	2 hrs	<1	[381], [382]
Harmothoe spp.	< 1	103	BR + FS-L-PLK	11-30$^{\#}$	10-40$^{\#}$	[276], [277]
Nereis (Hediste) diversicolor	< 1	16	FS-DIR	0	0	[276] [277, 278]
Hydrobia neglecta	< 1		E-DIR	0	0	[567, 568]
Hydrobia ulvae	< 1	6	BR-L-PLK or DIR	20-30	40	[349] [569]
Hydrobia ventrosa	< 1		E-DIR	0	0	[276, 567, 568]
Hydroids	0		FS-L-PLK/LEC or BR-L-PLK + AV	0-1	0-4	[317-319]
Idotea chelipes	< 1	500	BR-DIR	0	0	[570]
Jassa spp.	< 1		DIR	0	0	[436]
Laminaria digitata	0		S	-	<10	[274]
Laminaria spp.	0		S	-	<10	[274]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Lanice conchilega	0	48	FS-L-PLK	57	>50	[512], [513], [514], [514], [515]
Lepidonotus squamata	< 1	149	FS-L-PLK	11-30#	10-40#	[277] [478]
Limaria hians	< 1		FS-L-PLK	21	40	[391]
Lithothamnion corallioides	0		AV	0	0	[41, 43, 44]
Lithothamnion glaciale	0		AV	0	0	[44, 395]
Littorina littorea	< 1	214	BR-L-PLK	30	0-80	[44]
Littorina obtusata/mariae	< 1		E-DIR	0	0	[379], [383]
Littorina tenebrosa	< 1		BR-DIR	0	0	[668]
Lophelia pertusa	0		A + L-PLK	42-56	>50	[293]
Lumbrineris spp.	< 1	135	BR-DIR	0	0	[277, 555]
Lumbrineris gracilis	< 1	135	BR-DIR	0	0	[277, 555]
Macoma baltica	< 1	18	FS-L-PLK	30-360	>40	[422, 423]
*Madrepora oculata * Lophelia*	0		A + L-PLK	42-56	>50	[293]
Marphysa spp.	< 1	368	A + L-LEC	<1	<1	[277, 647]
Mediomastus spp.	1 - 10	110	E-L-PLK	<1	<1	[277, 648]
Metridium senile	0		AB	0	0	[384]
Modiolus modiolus	0	267	FS-L-PLK	30	40	[396]
*Munida rugosa *Galathea*			BR-L			[320]
Mya arenaria	<1	158	FS-L-PLK	11-30	11-40	[421]
Mya truncata	< 1	278	FS-L			[276]
Mysella bidentata	< 1	65	L-PLK	11-30#	10-40#	[397]
Mytilus edulis	0	29	FS-L-PLK	20-30	40	[269]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL (days)	LARVAL DISPERSAL (km)	REFERENCES
Nematostella vectensis	0		AB	0	0	[155, 156]
Nemertea	< 1	131	A-DIR	0	0	[649]
Nephrops norvegicus	< 1	500	FS-L-PLK	50-60	>50	[494-496]
Nephtys spp.	< 1	81	FS-L-PLK	49-56	>50	[277, 278]
Nereis (Hediste) diversicolor	< 1	16	FS-DIR	0	0	[277] [350]
Nucella lapillus	< 1	500	BR-DIR	0	0	[234]
Nucula spp.	< 1	118	FS-L-LEC + DIR	10-14	10-40	[321-324]
Ophelia spp.	1 - 10	99	FS-L-LEC	2-10	4-10	[60, 276]
Ophiactis balli	< 1		FS-L-PLK	120-210	<50	[162, 325]
Ophiothrix fragilis	< 1	95	FS-L-PLK	21-26	40	[162, 398, 399]
Ophiura spp.	< 1	112	FS-L-PLK	300	>50	[555, 626]
Ostrea edulis	0	500	BR-L-PLK	10-30	10-40	[241, 459, 460]
Owenia fusiformis	< 1	263	FS-L-PLK	11-30#	10-40#	[276, 650]
Pagurus bernhardus	1 - 10	423	BR-L-PLK	11-30#	10-40#	[437, 619]
Palaemon spp.	0 - 10	500	BR-L-PLK	30-60	>40	[571]
Pandalus spp.	< 1	500	BR-L-LEC	60-90	0-330	[162]
Patella vulgata	< 1		FS-L-PLK	14	25	[326], [327], [349]
Pecten maximus	0		FS-L-LEC	18-48	10-30	[36, 461]
Pennatula phosphorea **Virgularia mirabilis*	0		FS-L-LEC	7-30	10-40	[126, 489]
Petricola pholadiformis	0	138	FS-L-LEC	14	25	[409]
Philine aperta	< 1	272	E-L-PLK	11-30#	10-40#	[497]
Pholas dactylus	0	200	FS-L-PLK	45	>50	[442]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Phymatolithon calcareum	0		AV	0	0	[41, 43, 44]
*Phyollodocidae *Eumida*		88	FS-L-PLK	56	>50	[60, 493]
Pionosyllis spp.	< 1	302	BR-L-LEC	1-10$^{\#}$	4-10$^{\#}$	[60]
Pisidia longicornis	< 1	18	BR-L-PLK	30-60	>50	[400, 401]
Pleurochrysis carterae	0		A + S		>50$^{\#}$	[27]
Polydora ciliata	0	1	BR-L-LEC	21	40	[277]
Pomatoceros spp.	0	59	FS-L-PLK	14-60	>40	[444, 445], [277, 437]
Pomatoceros triqueter	0	59	FS-L-PLK	14-60	>40	[277, 437]
Porcellana platycheles	<1		BR-L-PLK	30-60	>50	[401]
Psammechinus miliaris	< 1	299	FS-L-PLK	14-21	<30	[276, 555]
Puccinella maritima	0		AV + S	0-50	0->50	[344-346]
Pygospio elegans	< 1	9	DIR or L-PLK / LEC	11-30$^{\#}$	10-40$^{\#}$	[277]
Sabella pavonina	0	61	FS-L-PLK	11-30$^{\#}$	10-40$^{\#}$	[276, 402]
Sabellaria alveolata	0	3	FS-L-PLK	42-228	>50	[528, 531-533]
Sabellaria spinulosa	0	7	L-FS-PLK	42-112	>40	[550]
Salicornia spp.	0		AV + S	0-50	0->50	[344-346]
Schistomysis spp.	< 1	267	BR-DIR	0	0	[654]
Scoloplos armiger	1 – 10	89	E-DIR	0	0	[277]
Semibalanus balanoides	0	12	BR-L-PLK	14-21	25-40	[279]
Serpula vermicularis	0		FS-L-PLK	6-60	>10	[328, 329]
Spartina alterniflora	0		AV + S	0-30	0->40	[344-346]

Table continued...

SPECIES	HOME RANGE (km)	AREA FOR MVP (m^2)	MODE OF REPRODUCTION	LARVAL DISPERSAL		REFERENCES
				(days)	(km)	
Spartina anglica	0		AV + S	0-50	0->50	[344-346]
Spartina maritima	0		AV + S	0-50	0->50	[344-346]
Spiophanes bombyx	< 1	47	FS-L-PLK	56	>50	[277, 555]
Spisula spp.	< 1	282	FS-L-PLK	30	40	[627, 628]
Sponges	0		A + L-LEC	0-1	<4	[669-671]
Suaeda maritima	0		AV + S	0-50	0->50	[344-346]
Swiftia pallida	0		FS-L-LEC	3-5$^{\#}$	4-10$^{\#}$	[123]
Syllidae **Exogone hebes*		106	BR-DIR	0	0	[121], [277, 555]
Tenellia adspersa	< 1	32	DIR + BR-L-LEC or PLK	*5*	<10	[246, 249]
Terebellides stroemi	< 1	303	DIR	0	0	[277]
Thallochrysis spp.	0		A + S		>50$^{\#}$	[27]
Tharyx spp.	0	7	BR-DIR	0	0	[277]
Urothoe spp.	< 1	92	BR-DIR	0	0	[402, 625]
Urticina felina	0	173	FS-L-PLK	11-30$^{\#}$	10-40$^{\#}$	[598]
Venerupis senegalensis	<1	344	L-PLK	11-30$^{\#}$	11-40$^{\#}$	(Fish and Fish 1996)
Venus spp.	< 1	333	FS-L-LEC			[620]
Virgularia mirabilis ** Ptilosarcus guerneyi*	0		FS-L-LEC	7-30	10-40	[126, 489]
Zostera spp.	0		AV + Seeds	-	0.05-60	[593, 594]