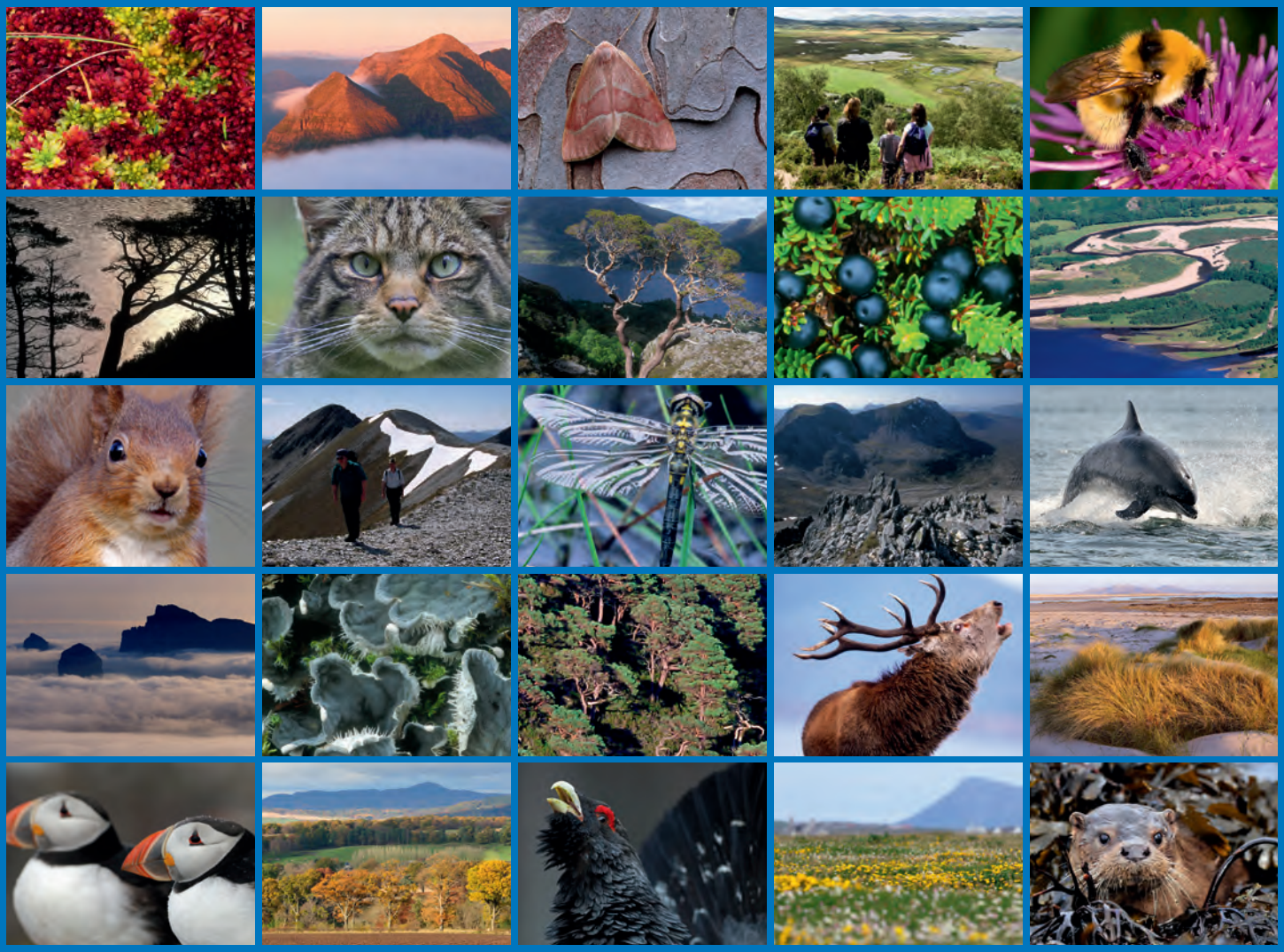
Scottish Natural Heritage
Commissioned Report No. 600

Predictive mapping of proposed protected features within selected possible Nature Conservation MPAs in Scottish territorial waters using available datasets



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COMMISSIONED REPORT

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Predictive mapping of proposed protected features within selected possible Nature Conservation MPAs in Scottish territorial waters using available datasets

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COMMISSIONED REPORT

Summary

Predictive mapping of proposed protected features within selected possible Nature Conservation MPAs in Scottish territorial waters using available datasets

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Background

The Marine (Scotland) Act 2010 and the UK Marine and Coastal Access Act 2009 include new powers for Scottish Ministers to designate Marine Protected Areas (MPAs). Thirty-three Nature Conservation possible MPAs have been developed and a further four MPA search locations remain to be fully evaluated.

The aim of this study was to derive predictive polygon maps of specified sea bed proposed protected features in 10 possible Nature Conservation MPAs within Scottish territorial waters. The main objectives were to: (1) generate protected feature maps on the basis of the best available information (existing remote sensing and ground-truthing data holdings); (2) determine the confidence ascribed to the mapping products; and (3) undertake a preliminary appraisal of all existing data holdings for each possible Nature Conservation MPA to determine their suitability for underpinning the development of full coverage sea bed habitat maps in due course.

Main findings

- Issues associated with mapping the distribution and extent of the proposed protected features as polygons from point records have been identified and discussed.
- A systematic approach to drawing polygons has been developed and implemented and the guidelines for this approach have been stated.
- The data available for mapping for each possible Nature Conservation MPA have been reviewed and the gaps in knowledge that could be usefully filled by further work have been identified.
- The confidence assigned to the polygons has been discussed and a method for scoring the polygons to “High”, “Moderate” and “Low” levels of confidence has been explained.
- A summary of the distribution of the proposed protected features is presented for each possible Nature Conservation MPA and confidence levels assigned.
- Some features remain as point distributions as the evidence to support polygon construction was not considered sufficiently strong.
- The polygon shape files in the accompanying Arc GIS Project give more details on the evidence upon which the polygons are based.

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Table of Contents **Page**

List of Figures **Page**

List of Tables **Page**

1. INTRODUCTION

1.1 Background and objectives

The Marine (Scotland) Act 2010 and the UK Marine and Coastal Access Act 2009 include new powers for Scottish Ministers to designate Marine Protected Areas (MPAs) in the seas around Scotland as part of a range of measures to manage and protect Scotland's seas for current and future generations. Work to identify these new MPAs is coordinated through the Scottish MPA Project, a joint project between Marine Scotland (MS), Scottish Natural Heritage (SNH), the Joint Nature Conservation Committee (JNCC) and Historic Scotland. SNH and JNCC submitted formal advice to Scottish Ministers on the identification of Nature Conservation MPAs in Scotland's seas in December 2012 (SNH and JNCC, 2012). In total, 33 Nature Conservation possible MPAs have been developed and a further four MPA search locations remain to be fully evaluated.

The aim of this study was to derive predictive maps of proposed protected features within 10 of the possible MPAs in Scottish territorial waters. The main objectives were to:

- generate proposed protected feature maps on the basis of the best available information (i.e. existing remote sensing and ground-truthing data holdings);
- determine the confidence ascribed to the mapping products;
- undertake a preliminary appraisal of all existing data holdings for each possible MPA to determine their suitability for underpinning the development of full coverage seabed habitat maps in due course.

In addition to the mapping of the proposed protected features within their respective possible MPAs, additional work focused on delineating polygons for the components of burrowed mud within six sites; North-west sea lochs and Summer Isles, Small Isles, Lochs Duich, Long and Alsh, Upper Loch Fyne and Loch Goil, South Arran and Loch Sween.

1.2 The Study Areas

The 10 possible Nature Conservation MPAs are listed in Table 1 and illustrated in Figure 1. Data of the proposed protected features within these areas are variable but GIS analysis of existing (and geo-referenced) biological data combined with data on bathymetry, sediments, topography and other physical parameters has allowed the generation of predictive polygon maps.

Table 1: *The 10 possible Nature Conservation MPAs included within this project*

Possible MPA	Size (km^2)	Possible MPA	Size (km^2)
Clyde Sea Sill	712	North-west sea lochs & Summer Isles	769
Fetlar to Haroldswick	219	Small Isles	808
Loch Sunart	49	South Arran	283
Loch Sween	38	Upper Loch Fyne and Loch Goil	87
Lochs Duich, Long and Alsh	37	Wyre and Rousay Sounds	16

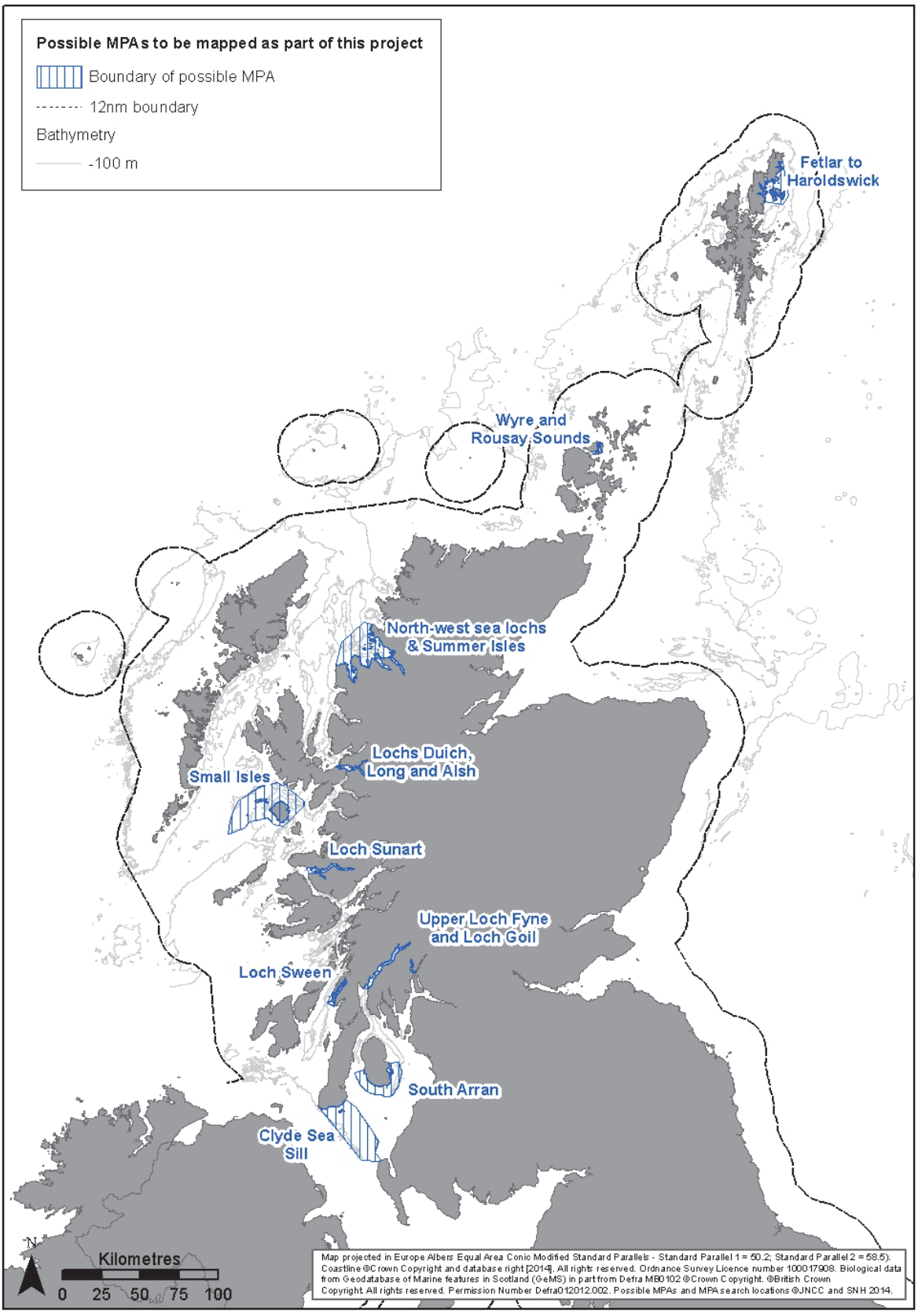

Figure 1. The 10 possible Nature Conservation MPAs included within this project

2. METHODS

2.1 Data sources

The data available for mapping the distribution of features consist mostly of point records (diver, video, ROV and grabs) that either had been assigned to a proposed protected feature class, biotope (at varying levels in the MNCR classification) or habitat class (e.g. sediment type, Folks class) and/or are associated with particular species. Many of the feature records have been collated into a database and provided as layers within a GIS project. However, these and other feature and non-feature records (the latter being useful to constrain polygons) are also located in the following sources:-

- BGS particle size analysis (PSA)
- MSS *Nephrops* database (PSA, burrowed mud)
- 2012 MSS and JNCC video surveys
- Marine Recorder

Other sources of data were specific to the possible MPAs and have been acknowledged in each section accordingly.

Acoustic survey data (bathymetry and backscatter/side scan) were available for the following possible MPAs: Fetlar to Haroldswick, Loch Sunart, Lochs Duich, Long and Alsh, North-west sea lochs, and Summer Isles and the Small Isles. However, most of these datasets are incomplete and so a background, low resolution, bathymetry dataset was useful for filling gaps and providing data for the other sites. The Defra bathymetry dataset was available for this purpose.

Aerial photography was also available for Fetlar to Haroldswick, Wyre and Rousay Sounds, North-west sea lochs and Summer Isles, and South Arran. These images were potentially useful for inshore areas, but were often incomplete or light penetration was not sufficient for polygon drawing. Google images were also available for inshore areas.

2.2 General considerations for mapping methodology

Habitat distribution maps should be founded on a confident assessment of observations of the sea floor. Available records are often few in number, clustered in some areas with many gaps with no coverage and have often been made many years apart. Mapping the distribution of features from point sample data alone suffers from the limitations of the sampling process (apart from the inherent low spatial resolution of direct observations). In particular, sampling may be biased towards certain features of interest, to certain geographic areas and be more abundant in easily accessible areas and depths. In other words, the apparent distribution of a feature may be due to sampling bias and there is no guarantee that the feature may not be distributed more widely. Negative records (feature not present) can help constrain the distribution. However, the problem of sampling bias can be a very difficult issue for mapping distribution of features based on point data alone.

Another issue is spatial heterogeneity and the scale at which maps are to be produced. Even in apparently densely sampled areas, records might indicate a high degree of spatial heterogeneity and drawing boundaries between features may not be possible with any certainty.

Many of these problems can be partially addressed using supporting full coverage data. These data must be of a higher spatial resolution and be spatially comprehensive throughout the area of interest. The estimation of the extent and boundaries of features relies on interpolation between points using inferences about associations between the biological

community and environmental variables: Depth, acoustic “hardness” of the sea floor (backscatter strength), topography and physiography were available for some sites for this project, but exposure (other than implications from physiography) was not readily available.

Use of these additional data sources can take the form of drawing boundaries based on obvious seabed characteristics (e.g. hard, rough ground may be interpreted as rocky sea floor, soft ground as mud), depth zones and physiographic features (e.g. “narrows”; sheltered deep “basin”). At its simplest, mapping can take the form of segmentation of the full coverage data ‘by eye’ so that polygons drawn around obvious features enclose records of one habitat class and exclude other classes. More exhaustive analysis could make use of image processing techniques to derive more detail about sea floor features.

2.3 Methodological options for deriving polygons

A systematic approach to drawing boundaries “by eye” was adopted for most sites. This used a set of procedures that were justified by the particular needs of each site. These procedures had to be flexible enough to cope with the different datasets available for the different sites (e.g. the number of proposed protected features present, the density of point records, the availability of acoustic coverage, size of the sites and their complexity and heterogeneity). However, there are a number of issues for mapping features from point data that are common to all of the sites. Section 2.6 summarises these and discusses the issues encountered when applying them to the datasets available.

2.4 Collating proposed protected feature records

The point data provided have been organised into a small number of groups with component subsets that needed to be inspected to find relevant records of the proposed protected features. Many of the records for the proposed protected features have been collected together for each of the possible Nature Conservation MPAs in the GIS project, provided alongside this report, and the records were checked against other records in the GIS project to verify if the records have or have not been duplicated. In addition, some of the proposed protected features that are defined by sediment type do not necessarily appear as proposed protected features (as in Marine Scotland, 2011, Howson *et al.,* 2012) and so these were searched for within Marine Recorder. Some records could also be considered similar enough to proposed protected features to warrant flagging up as supporting evidence for their distribution.

Some records had multiple habitat categories for the same location. This was particularly the case for older records in Marine Recorder and it is assumed that the location was central to a wider search area and the biotope records were attributed to a nominal location. The positional information in these cases may have been compromised (e.g. where shore biotopes and sublittoral biotopes have been attributed to the same point). Records with dubious positional accuracy may have been excluded if their position was critical (e.g. sublittoral records that were recorded on the shore or even on land).

This required careful searching through the data and inspection of plotted records. It should be noted that it was beyond the scope of this contract to collate all the records of relevant features into a single dataset. However, the complexity of examining the dataset required a relatively rapid solution to summarise the data and it was decided to create a new point dataset for each feature for each site that could overlay all the other data layers. This simply consisted of point objects tagged with their feature name, but not other attributes. The purpose was to create a simple summary to aid polygon construction and for display purposes. If the user of the GIS requires more detailed information for that record, then the underlying data from the full database must be scrutinized.

2.5 Environmental coverages

Many of the possible Nature Conservation MPAs in this project do not have acoustic data available at present, whilst the remainder have partial coverage, with some sites better covered than others. The use of low resolution, comprehensive datasets for bathymetry has been beneficial in supporting the mapping to cover these gaps in the data. The Defra bathymetry data were processed to provide bathymetric contours of the sites and, in some instances, digital elevation models of physiographic features were created where this was considered to be of benefit for interpretation.

A set of aerial photographs were made available during the course of this study for some of the sites, and images from Google Earth also provided useful background information. However, the aerial photographs were often not comprehensive and the light penetration limited their usefulness to very shallow, inshore water.

2.6 Drawing polygons

Most of the proposed protected feature polygons have been drawn “by eye” guided by the existing evidence, using a systematic and consistent approach throughout. No automated processes (such as classification) have been used. The following guidelines have been followed:-

a. Where possible, boundaries have been drawn around point records using features from full coverage data to interpolate between points (e.g. depth contours, hard/soft ground, slope and other topographic boundaries). These boundaries are considered well supported and confidence of these is therefore high.

b. Wherever possible, polygons for features have been drawn non-overlapping. In other words, the polygons have been exclusive to the particular feature. However, the overlapping of polygons has been necessary where there is evidence that a mosaic of features is present on the sea bed. For example, the proposed protected features shallow tide-swept coarse sands with burrowing bivalves, maerl or coarse shell gravel with burrowing sea cucumbers and maerl beds may all share similar environmental conditions with gravelly habitats and are often found in very close proximity. This has necessitated either drawing very small polygons or larger overlapping polygons. This may not be an ideal solution and an alternative may be to combine the boundaries into one embracing feature. This solution has been adopted, for example, with maerl beds and maerl or coarse shell gravel with burrowing sea cucumbers in the proposed North-west sea lochs and Summer Isles possible MPA.

c. Drawing polygons around single points or widely scattered points where there were few supporting full coverage data was avoided. Clusters of points could be encompassed by a polygon if the point records were sufficiently dense. The definition of what constitutes “dense” is subjective, but there should be more than three records within a radius of 500m. Otherwise, the records remained as points.

d. Some areas may have been sparsely sampled, however, environmental data might give a reasonable expectation that conditions are favourable and therefore the distribution of the proposed protected feature can be based on the distribution of the environmental characteristics.

e. When drawing polygons around point data, there is a temptation to create complex shapes to fit the points or to draw small polygons around isolated points. This can lead to a problem termed “over-fitting the data”. What constitutes an over-fitted polygon is somewhat subjective. However, in some cases simple but overlapping polygons were

considered preferable to complex but exclusive polygons (for example, the polygons for the proposed protected features burrowed mud and sublittoral mud and mixed sediment communities overlap within the Upper Loch Fyne and Loch Goil possible MPA). In other cases, isolated points were left outside any corresponding polygon or might even be located in a polygon for some other feature. For example, a few of the records for fan mussel aggregations are outside of the polygon that encompasses the majority of the records in the Small Isles possible MPA because they are isolated.

f. Polygons have been drawn to encompass widely separated records only if there is sufficient reason to assume some continuity because of collateral environmental data. The confidence of these polygons must be judged on the basis of this justification and will either be moderate or low confidence as a result.

g. In many instances records for a particular feature are interspersed by records of similar features. For example, records for “burrowed mud” might be interspersed by records of “mud” or “sandy mud”. The view has been taken that these latter records may not necessarily mean that burrowing fauna was absent: the records may have been made for reasons other than biological. In these cases, the non-burrowed mud records have been regarded as supporting and not contradicting the feature polygon.

h. In other instances, relating to ‘g’ above, the neighbouring point data may logically preclude the presence of the feature (e.g. a bedrock record must exclude burrowed mud at that location) and these neighbouring points have been useful in constraining the boundary for the feature. The use of constraining data increases the confidence of the feature polygon.

i. The complexity of the boundary may appear somewhat arbitrary. Simple boundaries have been drawn around points where there are no constraining features or records. More convoluted boundaries arise when there are neighbouring feature polygons to take into consideration and when boundaries have followed environmental features (e.g. depth contours). These constraints can be thought of as subtracting areas from a simple polygon.

j. In some instances the use of constraining features has resulted in very complex polygons. For example, rocky outcrops can be mapped in fine spatial resolution from multibeam data and these can then be “subtracted” from an area to reveal the remaining ground as potentially one of the soft sediment features. The level of complexity of polygon boundaries is a matter of choice. Where possible, these have been simplified to show the predominant feature.

2.7 Probability distribution maps

In order to map the components of the burrowed mud proposed protected feature within some of the sites probability distributions maps were drawn. These were derived from the point records alone without the use of collateral environmental data. This procedure was feasible only where there were plentiful records that were fairly evenly distributed across a site and was used to assist in the mapping of component biotopes of the burrowed mud proposed protected feature within selected possible MPAs.

A new set of point records was created for each proposed protected feature in turn. Every record was assigned a value of 1 if the particular proposed protected feature was present and a value of 0 if it was absent. Each of the new present/absent datasets was then imported into Surfer™ for interpolation using inverse distance square algorithm and a simple radius search of 2 km. The resulting grid gives the probability of a particular habitat occurring

in a grid square (pixel) from a maximum of 1 (presence is certainty) to a minimum of 0 (absence is certain).

The complete set of probability images were imported into Idrisi™ and image processing used to find the habitat with the maximum probability for each pixel. The raster image of maximum probability was then converted to a polygon and exported into the ArcGIS project.

This approach was used in conjunction with "by-eye" polygon mapping. The polygons derived from probability analysis extrapolated to create "predicted" habitat distributions throughout the whole of the site. However, these predicted distributions were often unsupported by records and even contrary to known environmental constraints. For this reason, the predictions based on probability maps were trimmed using "by-eye" polygon drawing procedures described in Section 2.6.

2.8 Predictive modelling: supervised classification

Statistical classification procedures predict habitat distribution using ground truth datasets to interpret geophysical and other environmental coverages (usually termed "supervised classification"). Such predictive modelling techniques can only be used where the data available are suitable and agree with the following:-

- The success of statistical classification is dependent on the quality, consistency and comprehensiveness of the data available. Acoustic datasets were not available for many sites and for others the coverage was incomplete and often lacked definition in the shallow inshore areas where many features occur.
- The spatial relationship between the samples and the coverage should be clear and unequivocal. However, the records for features often indicated a heterogeneous sea floor and the statistical overlap between the different ground truth classes would have led to considerable uncertainty in the outcome of statistical analysis.
- The ground truth data are representative of the whole area and range of habitat classes present. However, the records for most of the sites clearly suffered from sampling bias. These biases have a hugely detrimental effect on the results of statistical analyses.

Supervised classification was used for the interpretation of burrowed mud component biotopes in the Lochs Duich, Long and Alsh possible MPA where the ground truth data were adequate and the acoustic data comprehensive and of high quality.

Supervised classification proceeds by using good quality ground truth data (the point records) to derive statistical signatures from the acoustic images of the area. Small polygons were drawn around the records to enclose relatively homogeneous acoustic data in the proximity of the point records. These polygons were used to extract data from the acoustic images and these data analysed statistically to derive acoustic "signatures" for each habitat class. The signatures were then applied to the complete area covered by the images and each pixel matched to the signatures and assigned to the most likely habitats class to which it belonged. IDRISI™ image processing and GIS software was used for the modelling process.

2.9 Confidence assessment

It is important that confidence must not be confused with the degree of expression of the feature (concentration of distribution, density of records or likelihood of occurrence). It is a statement of the confidence of how well the boundary represents the distribution of the

feature. The term “confidence” has been applied in this report to the validity of the polygon drawn from the data.

Each polygon has been assigned a level of confidence based on a systematic appraisal of the evidence supporting the polygons. However, the use of the MESH Confidence Assessment Tool was not easy to apply to the criteria for the polygons and so a simple “High, Moderate or Low” confidence was assigned to each polygon.

Confidence assessment remains a difficult area: The polygons can be assigned to a confidence level using systematic guidance and attempts can try to get these assessments as consistent as possible. However, there will always be a subjective element as the guidance criteria are difficult to quantify. For example, the level of certainty might depend on the density of point samples. But what should be considered dense records as compared with moderately dense? That would necessarily depend on size (area), heterogeneity of the habitats and complexity of the sea floor and coastline. What would be dense records in one context may not be in another.

The guidance given is designed to suit the 10 sites that have been reviewed and will undoubtedly need modification based on experience from other sites. A comprehensive and complete guidance is beyond the scope of this report and the suggestions should be regarded as “work in progress” for this type of assessment.

The assessment followed the guidance for constructing the polygons (see Section 2.5 above) and the criteria are summarised in Table 2.

Table 2: Confidence levels and their justification

Confidence level	Justification
High	Clusters of homogeneous points or more scattered points directly linked to underlying full coverage habitat feature data (e.g. bathymetry, topography, backscatter) that can be used to interpolate between points. There is strong evidence from sample data that the area is predominantly occupied by a particular proposed protected feature; the boundary is very likely to be within 50m of the polygon boundary for small polygons, 100m or perhaps greater for large polygons.
Moderate	Reasonably well sampled areas, often large, for which there is supporting full coverage data and where the data are not too heterogeneous (more than three records of the same habitat). This is a form of interpolation between points that are some distance from each other. An example is the offshore burrowed mud polygon within the North-west sea lochs and Summer Isles possible MPA. Also in the "moderate" category are overlapping polygons in well sampled areas where there may be some confusion between features from similar habitats. This is the situation for many of the polygons in the Sound of Canna in the Small Isles possible MPA. The area is predominantly occupied by the particular proposed protected feature although other habitats (not necessarily protected features) may also occur; the boundaries are estimated.
Low	Sparsely sampled areas where the major justification rest with the evidence from the full coverage data using extrapolation, OR extrapolation from a neighbouring area with a high or moderate confidence with very similar habitat features to a polygon, OR the point data are from old records of features that might have changed over time. The distribution is tentative and flags up the possible distribution of a proposed protected feature. The boundaries are indicative only.
Point data only	No polygons have been drawn where there is little data available, i.e., where the records are scattered over large areas and are not easily linked to particular full coverage features. This is particularly the case where the feature may be under-recorded and any attempt to map the distribution could be misleading.

Cautionary note: High or moderate confidence polygons do not necessarily mean that the complete distribution of the feature has been established and reference should be made to other statements about distribution of the proposed protected features in the whole of the possible Nature Conservation MPA. For example, small isolated polygons of high confidence may be accompanied by statements pointing out the lack of knowledge of the distribution of the feature throughout the area and so may not represent the proposed protected feature in its entirety.

The use of terms such as "likely" and "probable" in the text not related to polygons reflects that whilst it is possible to assign a certainty level to a polygon, this cannot be extended to areas for which the data cannot support drawing boundaries demarking feature distribution. Often it is useful to make a statement about the composition of an area in order to provide some context for the polygons that have been drawn. For example, it may be possible to draw boundaries around a collection of records and assign a high certainty that this polygon contains the particular habitat. However, we might not be able to say that other un-sampled areas also contain this feature, but it is very likely that they do. This statement provides a useful caveat that the polygons may not represent a true picture of the distribution of the feature. Clearly, it is impossible to be more precise about the likelihood.

3. RESULTS

3.1 Clyde Sea Sill possible Nature Conservation MPA

The Clyde Sea Sill possible Nature Conservation MPA was identified for two MPA search features, which are now referred to as proposed protected features; the black guillemot and fronts and one geodiversity feature (Marine Geomorphology of the Scottish Shelf Seabed). Circalittoral sand and coarse sediment communities (CCS) is not an MPA search feature but has been recommended as a proposed protected feature as it is considered to add to the broader representativity of the Scottish MPA network (i.e. is a representative feature). CCS communities are the only proposed protected feature mapped for this project (Table 3).

Details of the supporting evidence are provided in the Clyde Sea Sill possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1032176.pdf], with the existing available data holdings displayed in Figure 2.

Table 3: *Proposed protected features to be mapped within the Clyde Sea Sill possible MPA*

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes
Clyde Sea Sill	Circalittoral sand and coarse sediment communities (CCS)	SS.SCS.CCS[MedLumVen] SS.SCS.OCS SS.SSa.CFiSa SS.SSa.OSa

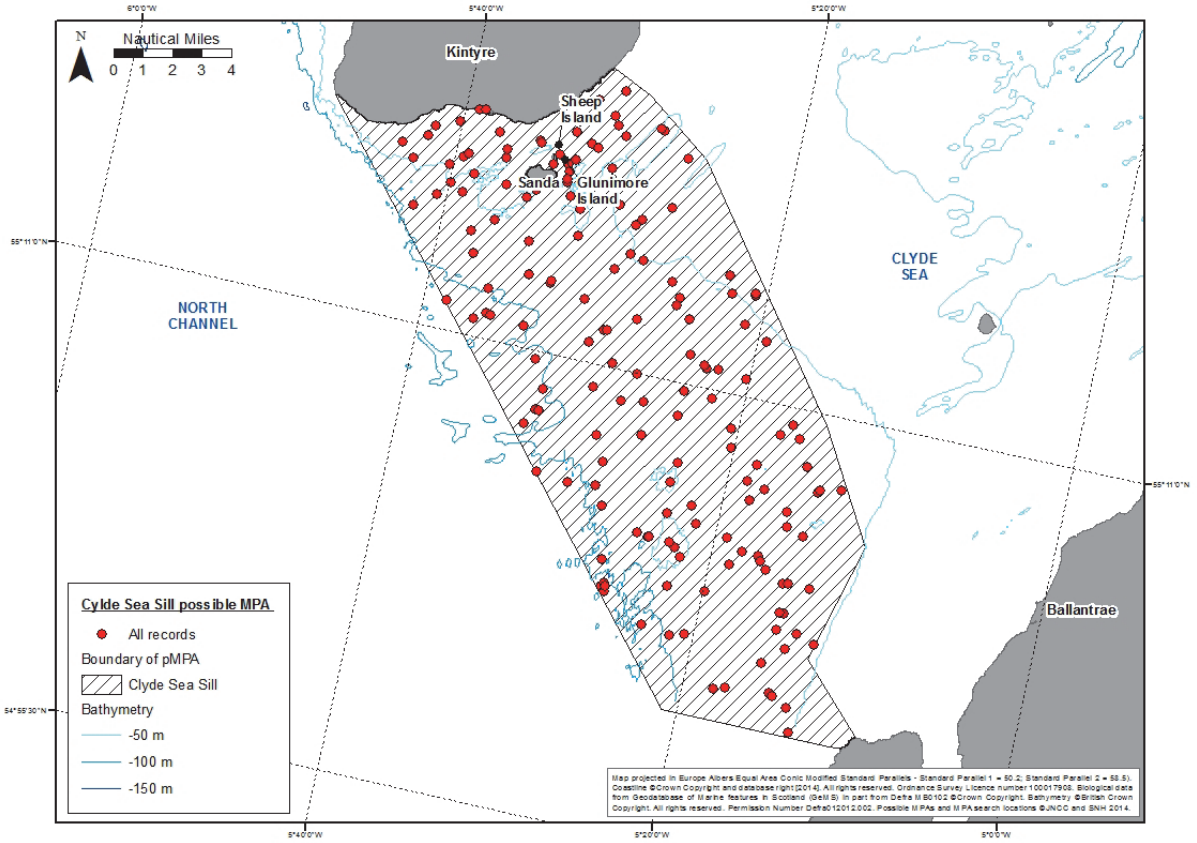

Figure 2. Existing data holdings within the Clyde Sea Sill possible MPA

3.1.1 Data assessment and requirements for more comprehensive mapping

Although there are currently no acoustic data available for the Clyde Sea Sill possible Nature Conservation MPA, the coverage of point data is comprehensive, especially when the BGS PSA data are taken into consideration. Many of the proposed protected feature records are quite broadly defined in terms of their sediment characteristics which facilitated boundary definition and the area is not physiographically very diverse or heterogeneous. The Defra bathymetry data set was referenced to delineate the polygon boundaries.

Unless there is a requirement to distinguish between the component sediments and biotopes listed in Table 3, it is unlikely that further survey work would be required to refine boundaries of the proposed protected feature.

3.1.2 Proposed protected features

3.1.2.1 Circalittoral sand and coarse sediment communities

The density of sample points with habitat information is high (relative to many other sites in this study) and comprehensive. Whilst there are no dedicated acoustic data for the area, the Defra bathymetry dataset is more than adequate to indicate the general topographic nature within the possible MPA.

The distribution of sea bed sediments follows a general trend from coarse to muddy sediment from the Mull of Kintyre to the mainland. The BGS substrate map (included within the GeMS database layers as Geodiversity; Physiography & Substrate) shows these trends in distribution although it may be that this map underemphasises the coarse sediment component when compared to the point samples.

The point sample data from all sources (including the BGS PSA data) have been combined into one dataset and samples reclassified into the proposed protected feature circalittoral coarse sediment (CCS) or other habitat types. Apart from those samples already classified as CCS, gravelly sand and slightly gravelly sand samples were also classed as CCS. However, mixed sediment and sandy gravel were excluded at the coarse end of the continuum. Any sediment records with a muddy component (such as muddy sandy gravels) were also excluded. Records labelled as “sand” could have been coarse or medium fine sand and could be regarded as possible CCS. Two polygons have been drawn for the predicted distribution of CCS. The first encompasses the samples that could be confidently assigned to CCS with few outliers from other sediments within the boundary (particularly fine sand in the north-east sector of the polygon). The boundary with mixed sediment and gravel to the west appears to be quite well defined and coincides with a change from varied and moderately steep topography to level or gently sloping seabed to the east.

The second polygon is an eastwards extension to the first polygon and encompasses samples where the records were assigned to “sand”, but excludes any muddy sand records. It is difficult to justify a precise boundary separating areas into CCS and “sand” because there is a continuum from coarse to muddy sediments.

Figure 3 shows the distribution of the sediment classes overlaying the predictive polygons for CCS. There is some confusion about the nature of a topographic rise in the south-east quarter that coincides with an area of bedrock (according to the BGS Substrate map which is included in the GeMS layers as Geodiversity Data; Physiography & Substrate and also included in the layer “Hard Substrates”). However, there may also be a sandbank at this location (according to Block Data, Block 6: Marine Geomorphology of the Scottish Shelf Seabed also in Geodiversity Data in the GIS project). There are no records to substantiate

bedrock and it is presumed the evidence comes from other sources available to BGS, such as side scan. Further clarification may be required to establish the nature of this feature. The exclusion of this polygon from the CCS polygon may be considered if the rock is confirmed by BGS, in which case the CCS records may be isolated patches where grab sampling was successful.

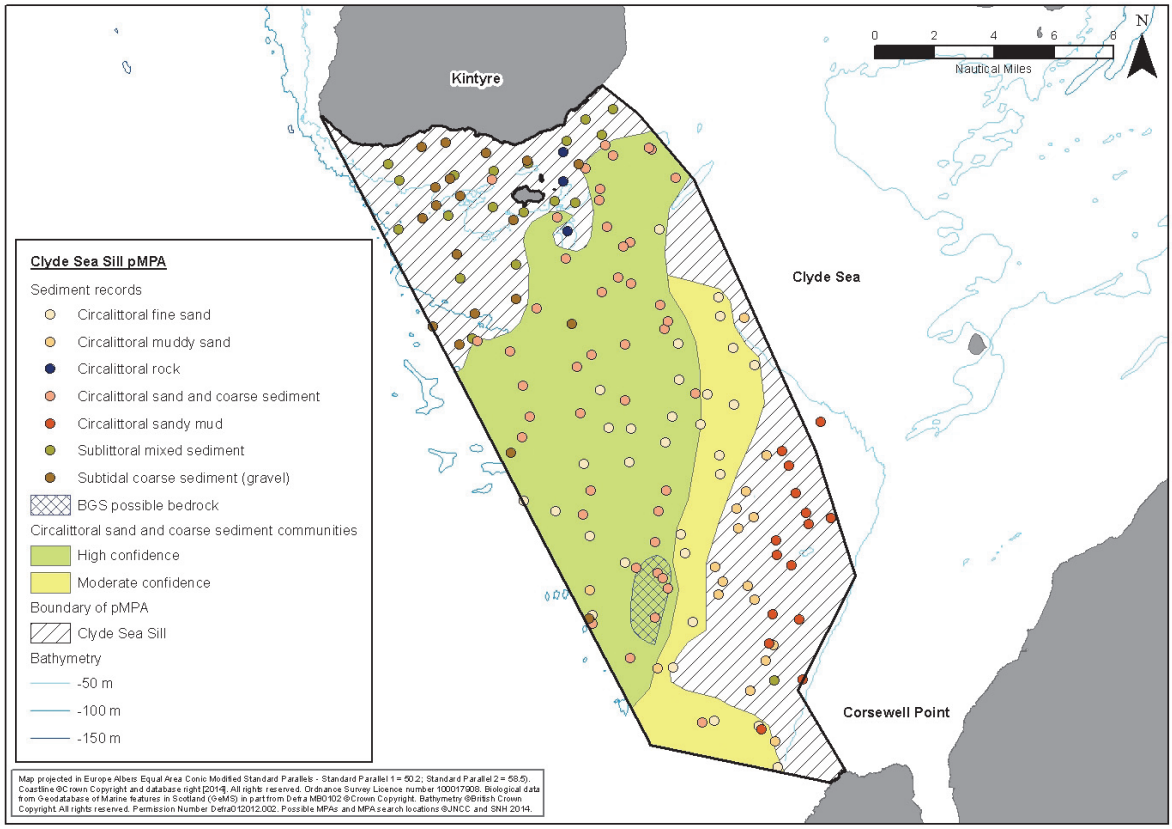

Figure 3. The distribution of circalittoral sand and coarse sediment communities within the Clyde Sea Sill possible MPA coded with confidence.

3.2 Fetlar to Haroldswick possible Nature Conservation MPA

The Fetlar to Haroldswick possible Nature Conservation MPA was identified for five MPA search features, all of which are now referred to as proposed protected features; black guillemot, horse mussel beds, kelp and seaweed communities on sublittoral sediment, maerl beds, and shallow tide-swept coarse sands with burrowing bivalves, and one geodiversity feature (Marine Geomorphology of the Scottish Shelf Seabed). Circalittoral sand and coarse sediment communities is not an MPA search feature but has been recommended as a proposed protected feature as it adds to the broader representativity of the Scottish MPA network (i.e. a representative feature). The proposed protected features to be mapped are listed in Table 4.

Details of supporting evidence are provided in the Fetlar to Haroldswick possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1031326.pdf] with the existing available data holdings displayed in Figure 4.

Table 4: *Proposed protected features to be mapped within the Fetlar to Haroldswick Possible MPA*

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes
Fetlar to Haroldswick	Circalittoral sand and coarse sediment communities (CCS)	SS.SCS.CCS[.MedLumVen] SS.SSa[.CFiSa]
	Horse mussel beds	SS.SBR.SMus.ModT SS.SBR.SMus.ModMx SS.SBR.SMus.ModHAs SS.SBR.SMus.ModCvar
	Kelp and seaweed communities on sublittoral sediment	SS.SMp.KSwSS
	Maerl beds	SS.SMp.Mrl
	Shallow tide-swept coarse sands with burrowing bivalves	SS.SCS.ICS.MoeVen

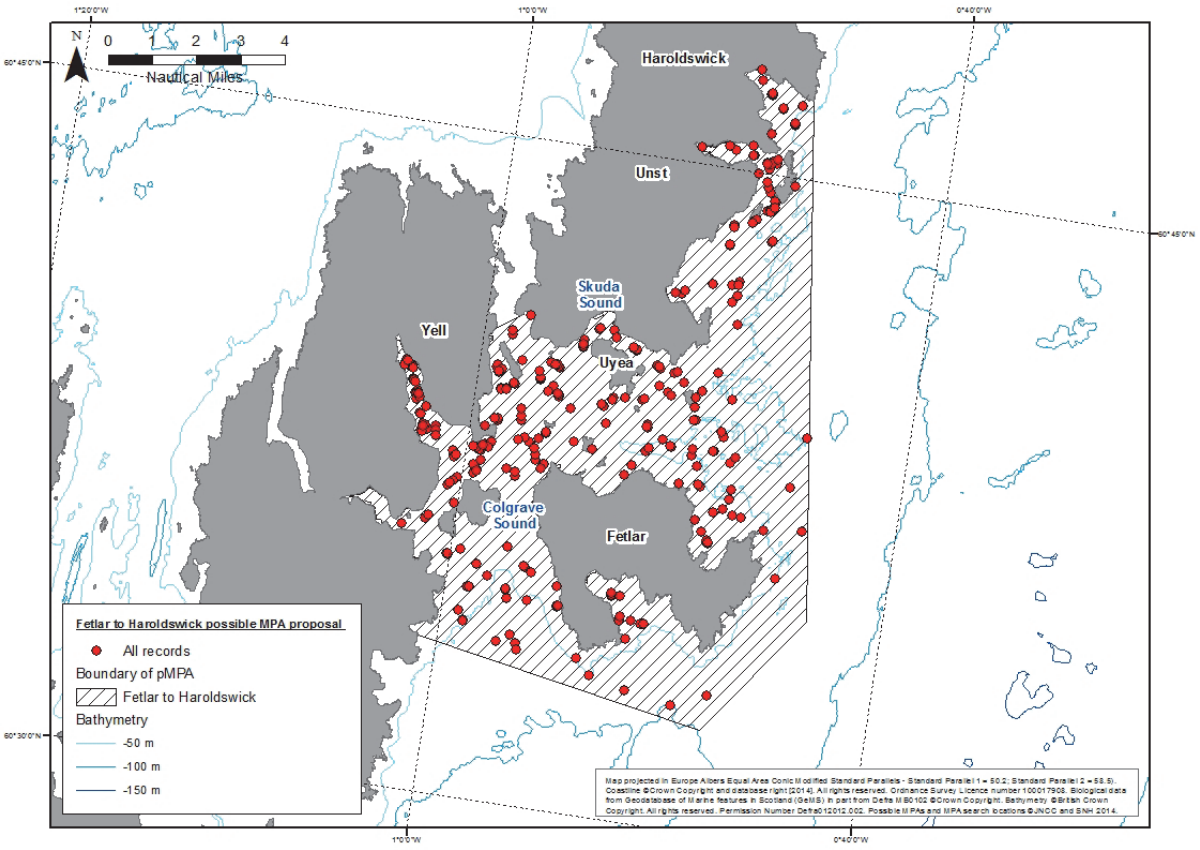

Figure 4. Existing data holdings within the Fetlar to Haroldswick possible MPA

3.2.1 Data assessment and requirements for more comprehensive mapping

The Fetlar to Haroldswick possible Nature Conservation MPA is large with a complex coastline and varied physiography. The coverage of point data for all of the proposed protected features are moderately comprehensive, although it is likely that many of the inshore features are more extensive than the point distribution would indicate. The acoustic data sets available are of high quality and were used as collateral habitat information to assist defining boundaries for some of the features. However, the acoustic data are not comprehensive, especially for inshore areas and much of the south-eastern sector and so gaps in bathymetry were supported with the Defra bathymetry contours. The 10 m contour was adopted for the upper limit for circalittoral sediment and the 30 m contour as the lower limit for the infralittoral kelp habitats (N.B. These depths do not correspond exactly to the depth limits set by the biotope classification. A certain flexibility of the depths was allowed in order to include as many infralittoral and circalittoral records as possible).

The hillshade rendering of the swath bathymetry data (available in the GIS project provided by SNH) shows topographic detail, collected by Marine Scotland Science (MSS) and the UK Hydrographic Office (UKHO). These images were used to derive the probable distribution of rocky outcrops. This was calculated using filtering techniques in image processing followed by reclassification. The process was as follows: The composite hillshade image file was split into three component colour bands with values ranging from 0 – 255. One band was used to calculate the standard deviation of values over a 3 x 3 cell moving window filter in order to highlight areas of greatest rugosity (taken to be an indication of rocky outcrops). The resulting image (Figure 5) was smoothed to reduce speckle by using a moving average 15 x 15 cell filter. (N.B. each cell equates to a square area of the sea floor of 5 x 5 m).

This image was re-classed into ground likely to be rock and non-rock. The value adopted for the cut-off point between the two ground types was selected with reference to specific features of the original image that were clearly rocky outcrops emerging from sediment. The resulting raster images were converted into polygons and these were used to constrain the sediment-based proposed protected features (Figure 6).

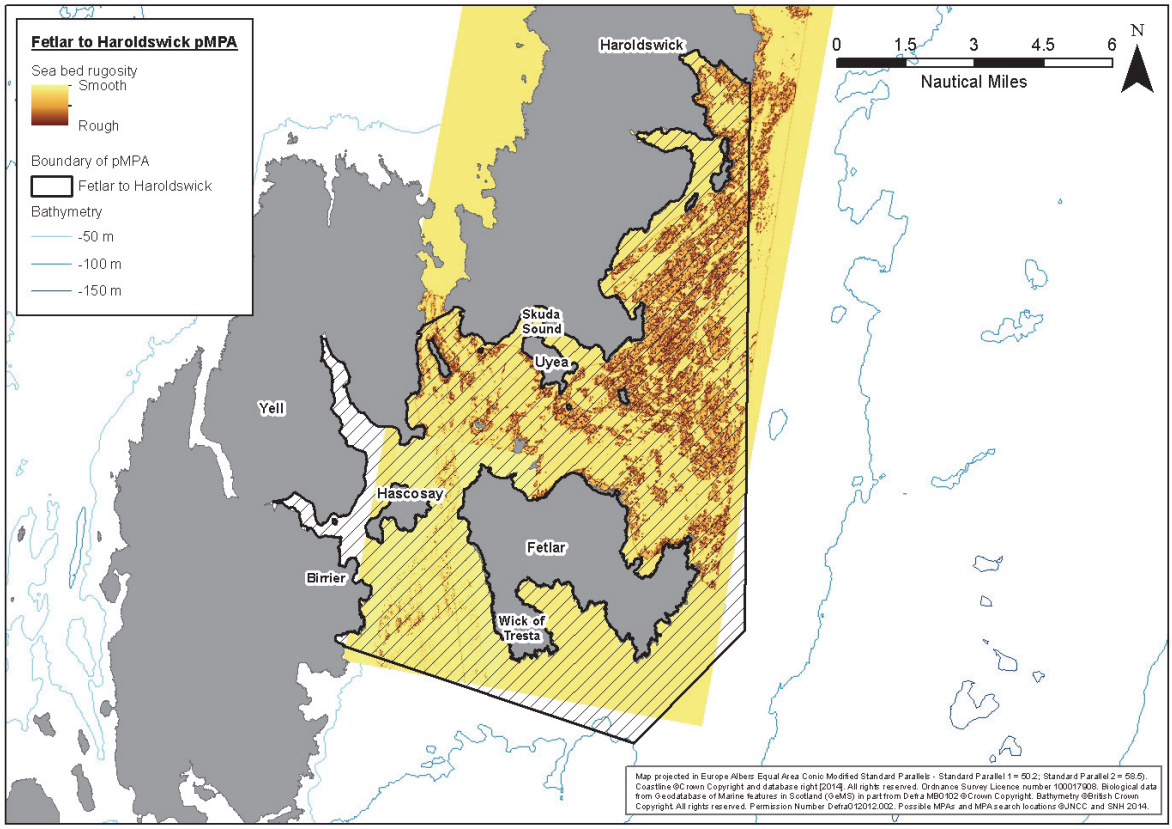

Figure 5. Rugosity image derived from swath bathymetry data as an intermediate step in defining rocky areas.

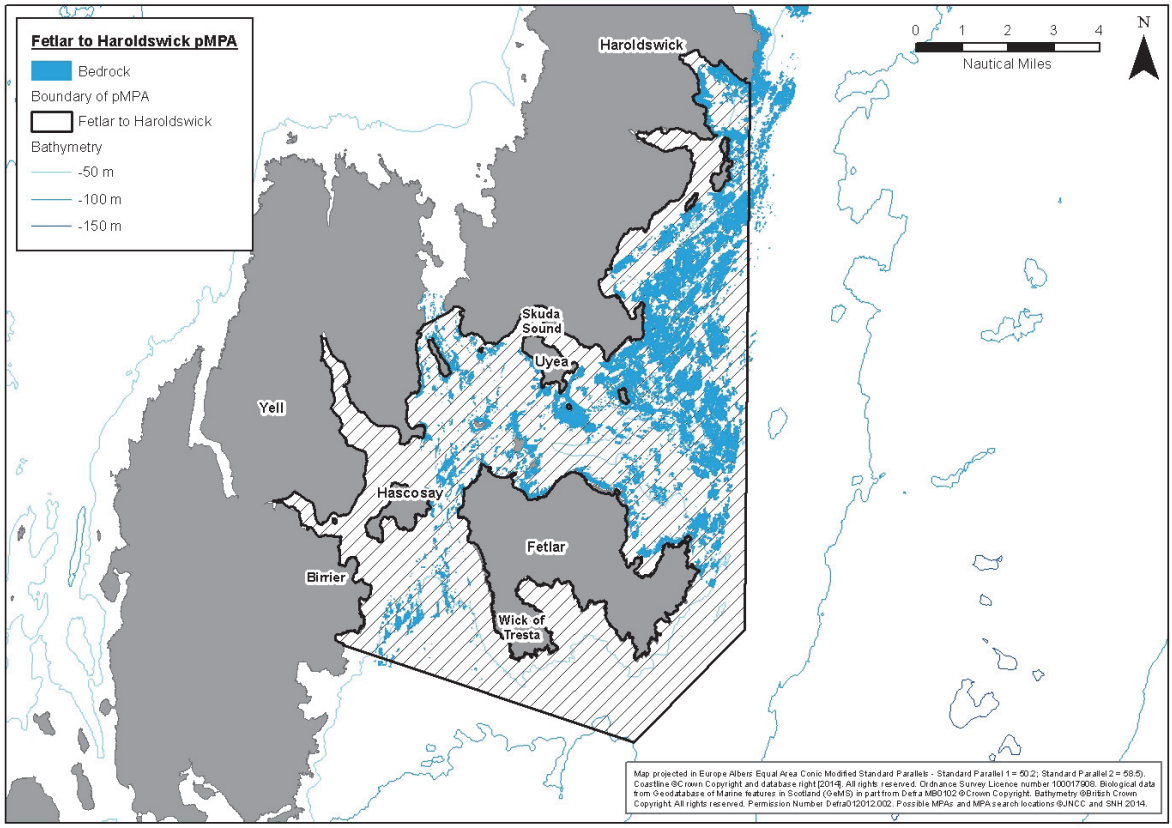

Figure 6. Rocky areas derived from the rugosity analysis presented in Figure 5.

Aerial photographs were provided and covered most, but not all, of the shallow water and coastline. They showed areas of kelp versus sand in shallow water, but it was unclear if the kelp was on rock or mixed substrata. Likewise, sandy areas may have graded into other habitats in deeper water where light penetration was weaker. Thus, the aerial photographs mainly were used to trim polygons where it was clear that the substratum was unlikely to support a particular feature.

However, the aerial photographs did show that the intertidal/very shallow subtidal zone extended from the coastline (Ordnance Survey). The coastline was, therefore, buffered to extend the landward margin for all feature polygons by 30 m. This buffer was then used to trim all feature polygons.

The proposed protected features listed in Table 4 could be considered to grade into each other in a set of overlapping habitats that map onto the sediment/depth zone framework of the biotope classification (Figure 7). Clearly, circalittoral sand and coarse sediment communities (CCS) is one of these major habitat types, whilst the remainder of the proposed protected features overlap this habitat category and each other. This continuum between proposed protected features in this possible Nature Conservation MPA means that it is likely that a very large proportion of the non-rock sea bed here may also be a proposed protected feature, particularly if mixed sediment and gravel habitats can be considered to be potential areas where maerl, horse mussels or the biotope **SS.SCS.ICS.MoeVen** could be located.

Without definite evidence for the non-occurrence of proposed protected features (given that records of mixed sediment and gravel could support proposed protected features), the issue for mapping is whether to draw conservative polygons around the positive records or to extrapolate into territory that is poorly supported by sparse records or has acoustic coverage only.

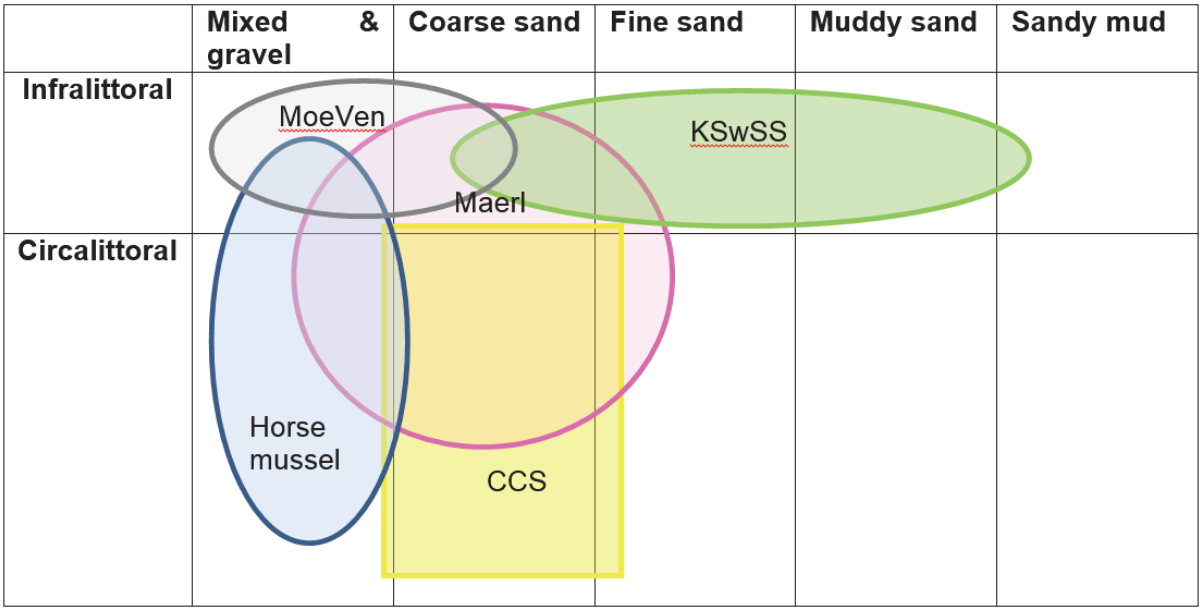

Figure 7. Schematic diagram indicating the distribution of proposed protected features on a sediment/depth plot.

Modelling the distribution of offshore features may be sufficient to define these boundaries adequately and it is recommended that this is tried and the predicted boundaries tested against limited targeted ground truth sampling. Mapping the proposed protected features of the shallow inshore areas around the complex coastline of the possible MPA presents more of a challenge. A dedicated survey of these areas by shallow multibeam or use of aerial photography or light detection and ranging (LIDAR) is a possibility. Without this, the components of many of the smaller inlets remain very uncertain.

3.2.2 Proposed protected features

3.2.2.1 Circalittoral sand and coarse sediment communities

Some of the inshore records of circalittoral coarse sediments (**SS.SCS.CCS**, **SS.SSa**) are shallower than 10 m and were discounted as being misidentified or having incorrect positions. Others lay between the 10-20 m contours and some flexibility was allowed and the records were accepted as circalittoral records for mapping. Although there was a large number of CCS records compared to other features within the site, the scale of the possible Nature Conservation MPA means that the separation between records was large (1-2 km). For mapping purposes the assumption was made that non-rocky areas around records were likely to be CCS, with the exception of where there were records of fine sand or muddy sand. This encompassed most of the offshore, east-facing area. However, much of the area in the northern section was predominantly rocky with non-rocky gullies between the outcrops (some quite extensive). Much of this area has been poorly sampled and subsequently has been assigned to CCS with low confidence.

Although there are scattered records of CCS within the more sheltered region to the west of Fetlar drawing polygons for CCS has not been attempted in this area and the records remain as points.

There are clear regions where CCS is indicated: (1) the non-rock areas well supported by point records; (2) the inshore area to the north that is moderately well supported by records and lies in a discrete non-rocky area. Figure 8 is an illustration of the result of subtracting constraining features (rock outcrops and infralittoral zone) from the possible extent of coarse

sand. The result is a series of complex polygons with varying degrees of support and confidence.

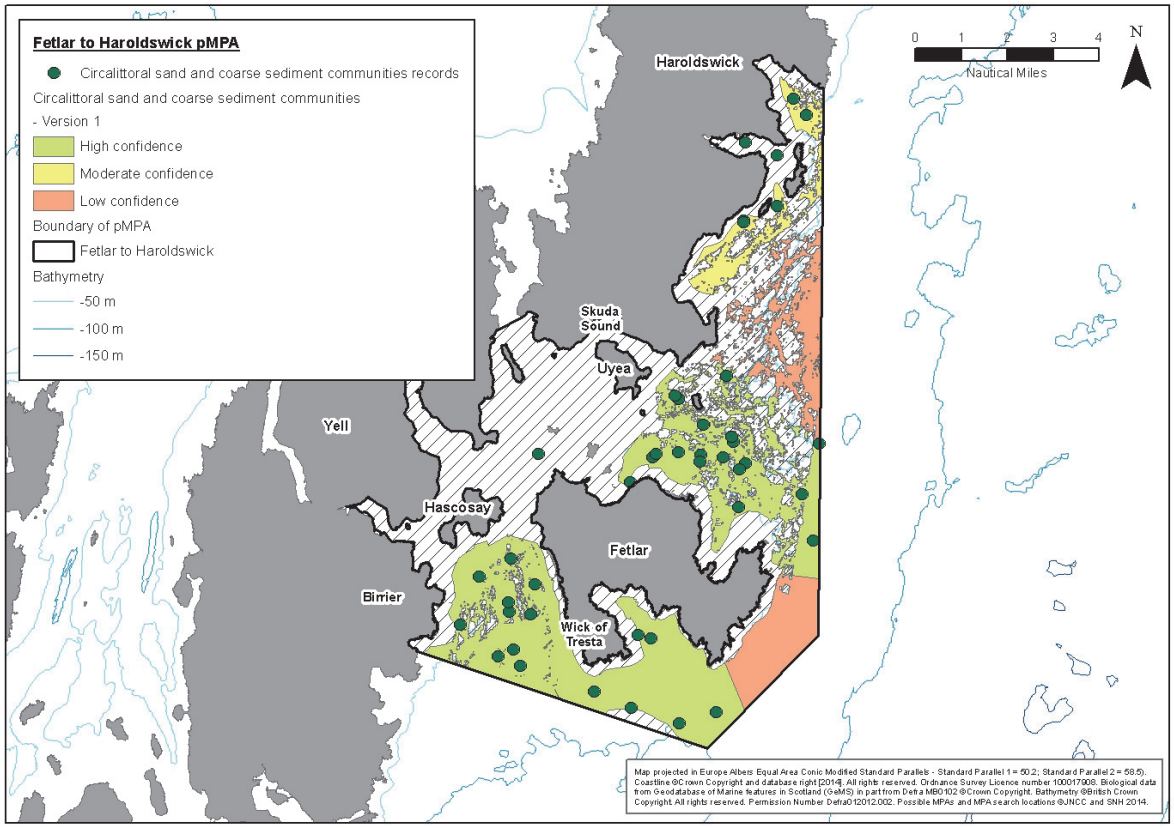

Figure 8. The distribution of circalittoral sand and coarse sediment communities for the Fetlar to Haroldswick possible MPA coded for confidence. This version shows the areas of possible CCS around the rocky outcrops

The extensive rocky area north of Fetlar, with possible sediment in gullies between the rocky outcrops, is particularly complex and given the lack of corroborating evidence, the inclusion of this area in the CCS feature may be contentious. It is suggested that the latter could be excluded until further evidence is collected of this small patchwork of sediment. Figure 9 presents an alternative, simplified series of polygons for CCS which ignores the rocky outcrop areas.

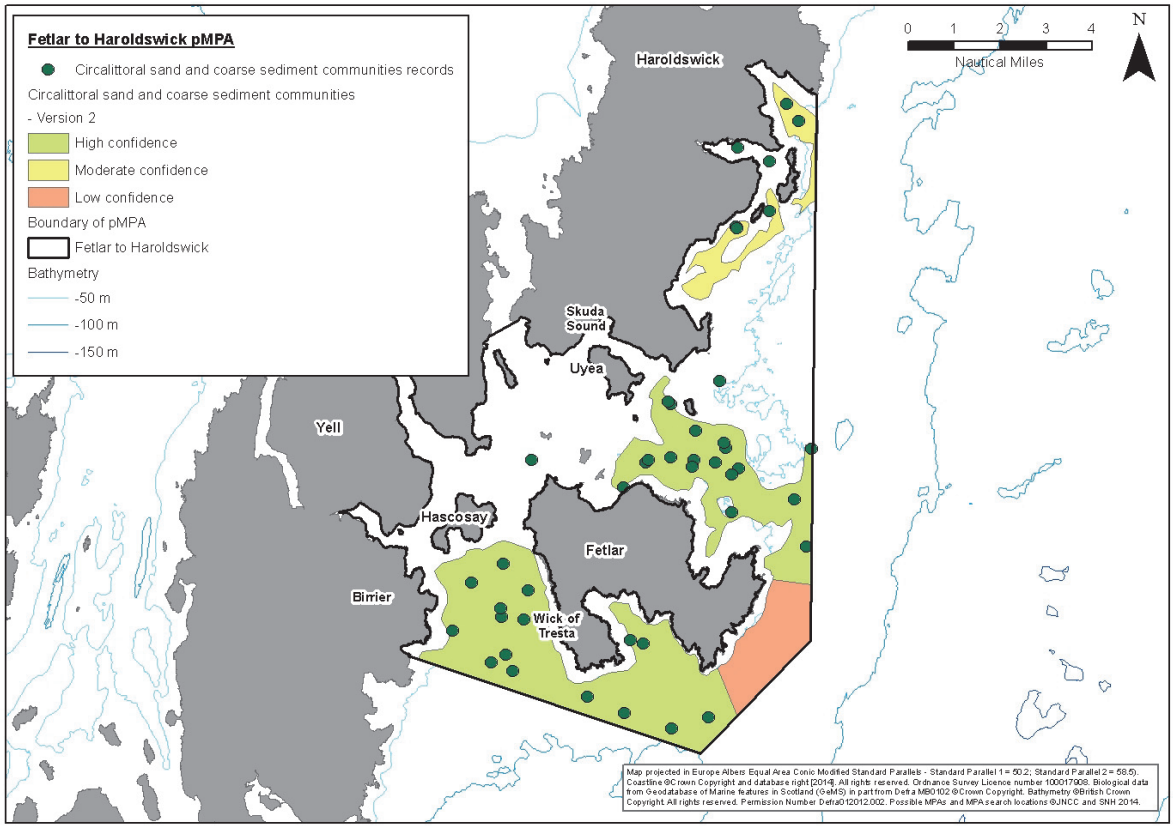

Figure 9. The distribution of circalittoral sand and coarse sediment communities for the Fetlar to Haroldswick possible MPA coded for confidence. This version shows a more simplified series of polygons than in 8.

3.2.2.2 Maerl beds

Maerl beds overlap with other sediment habitats ranging from gravelly sediments (**SS.SCS.ICS/CCS**) to sand. The point distribution of maerl beds are intermixed with other habitats (mixed sediment, horse mussels, tide-swept gravels and seaweed on sediment) and separation of these habitats into discrete polygons is problematic. The backscatter images show areas of rock very clearly. However, sediments (gravel and sand) are less easily distinguished and the images cannot be relied on to define the boundaries to the various gravel, maerl and coarse sediment habitats.

Records of maerl beds (**SS.SMp.Mrl**) are extensive around Hascosay, Burra Ness and Uyea (Figure 10). Although other habitats have been recorded in this area, maerl is the most commonly recorded habitat. The sea bed within Uyea and Skuda Sounds was also very heterogeneous and there is a degree of uncertainty whether the sea bed is composed of maerl, kelp and seaweed on sand or sand, as records for these habitats lie in close proximity to each other. Although some of the maerl records are not recent a survey in 2012 indicated that maerl is likely to be present beneath kelp in this area and so it is likely that these habitats are intermixed as a mosaic of habitats. Consequently, the maerl polygon overlaps the polygon for **KSwSS** (Figure 11) in this area and has been assigned a low confidence until further survey can confirm the presence and extent of the maerl there.

The approach adopted for mapping was to create a polygon that encompassed all of the maerl records and use constraints to subtract sections from this original polygon. The depth limit of the maerl records was generally -25 m and exceptionally -30 m. The -25 m contour was used to clip the polygon, except a small area with a record of maerl between -25 m and

-30 m. The rocky areas were then subtracted. Since the polygon created for the rocky areas was quite detailed, the resulting maerl polygons were also quite detailed (but only where the two polygons overlapped: the rocky polygon was not comprehensive). Further small areas of rock and sand that were clearly identifiable from the aerial photographs were also subtracted. Any isolated polygons unsupported by records that were created by this process were deleted.

In general, the maerl polygons are well supported by records and show the most probable distribution of maerl to a high level of confidence. However, the occurrence of other habitats cannot be ruled out. This is particularly the case at the limits to the polygons where there are indications that these merge into **SS.SCS.ICS.MoeVen** and horse mussel beds. It is also possible that maerl is more extensively distributed. However, it is felt that the polygons cannot be extended further without supporting records. Note that although the polygons that have been drawn can be assigned a high level of confidence that they contain the particular feature, this does not preclude the possibility that the feature extends beyond the polygon boundaries.

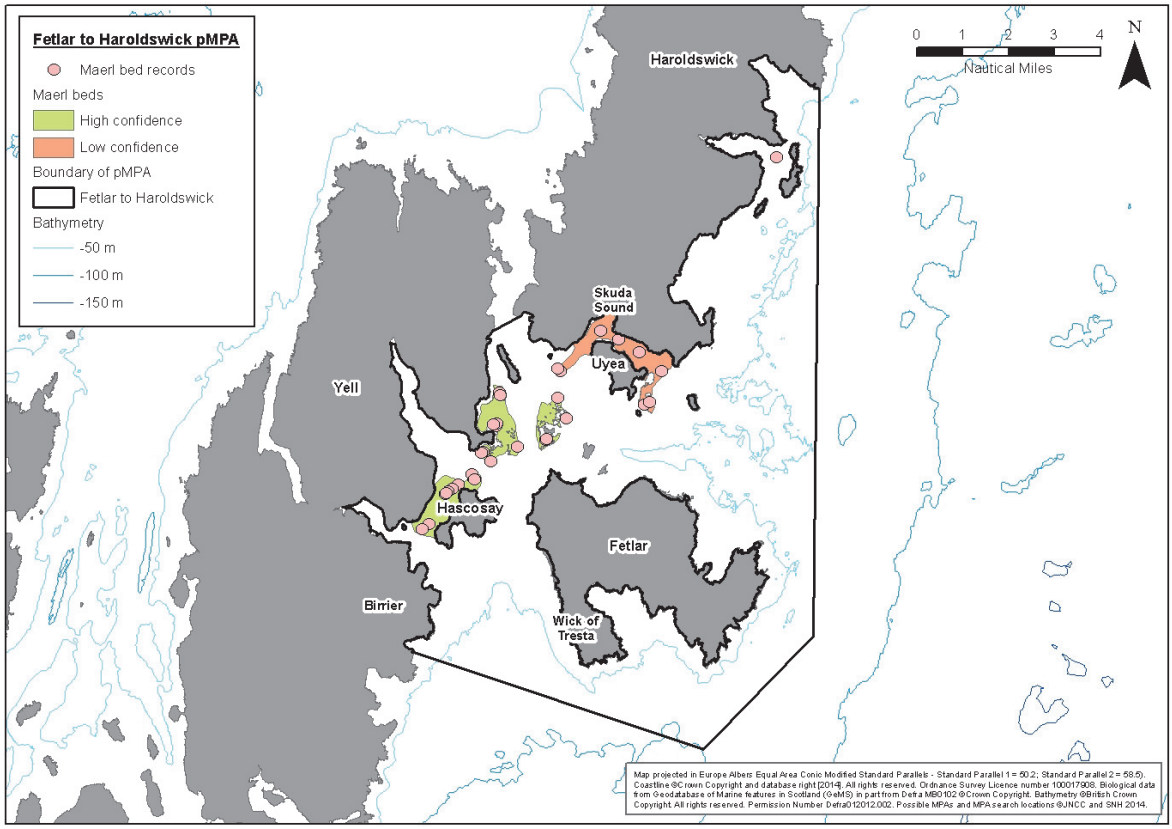

Figure 10. The distribution of maerl beds for the Fetlar to Haroldswick possible MPA coded for confidence

3.2.2.3 Kelp and seaweed communities on sublittoral sediment

Records of kelp and seaweed on sand habitats (**SS.SMp.KSwSS**) are scattered (Figure 11), with a few small patches supported by both the predicted sediment and the concentration of records. Other records are scattered and widely separated. As stated in the previous section, the area in Uyea and Skuda Sounds is probably shared by the maerl bed proposed protected feature. It is likely that the occurrence of **SS.SMp.KSwSS** is much more widespread than the present records suggest.

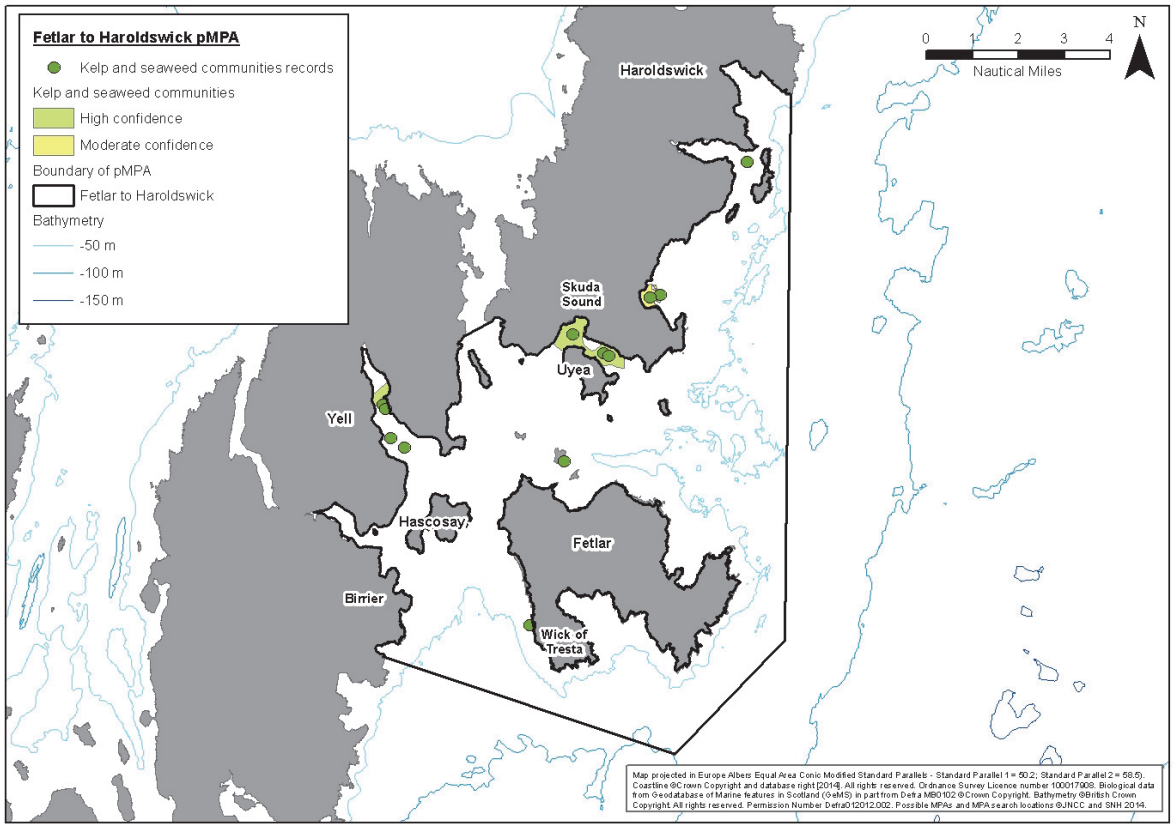

Figure 11. The distribution of kelp and seaweed communities on sublittoral sediments for the Fetlar to Haroldswick possible MPA coded for confidence.

3.2.2.4 Horse mussel beds

Horse mussel bed records (**SS.SBR.SMus.ModT**, **SS.SBR.SMus.ModMx**, **SS.SBR.SMus.ModHAs** and **SS.SBR.SMus.ModCvar**) within this proposed Nature Conservation MPA lie in the deeper water between Bluemull Sound and Fetlar. Here horse mussel records are interspersed with the more extensive records of mixed sediment and gravel, as well as maerl in the shallower areas. A conservative interpretation of the extent of horse mussel beds is given below (Figure 12) where the extrapolation based on acoustic data has been kept to a minimum. Other sites are scattered but often supported by video transects and small polygons have been drawn around these records.

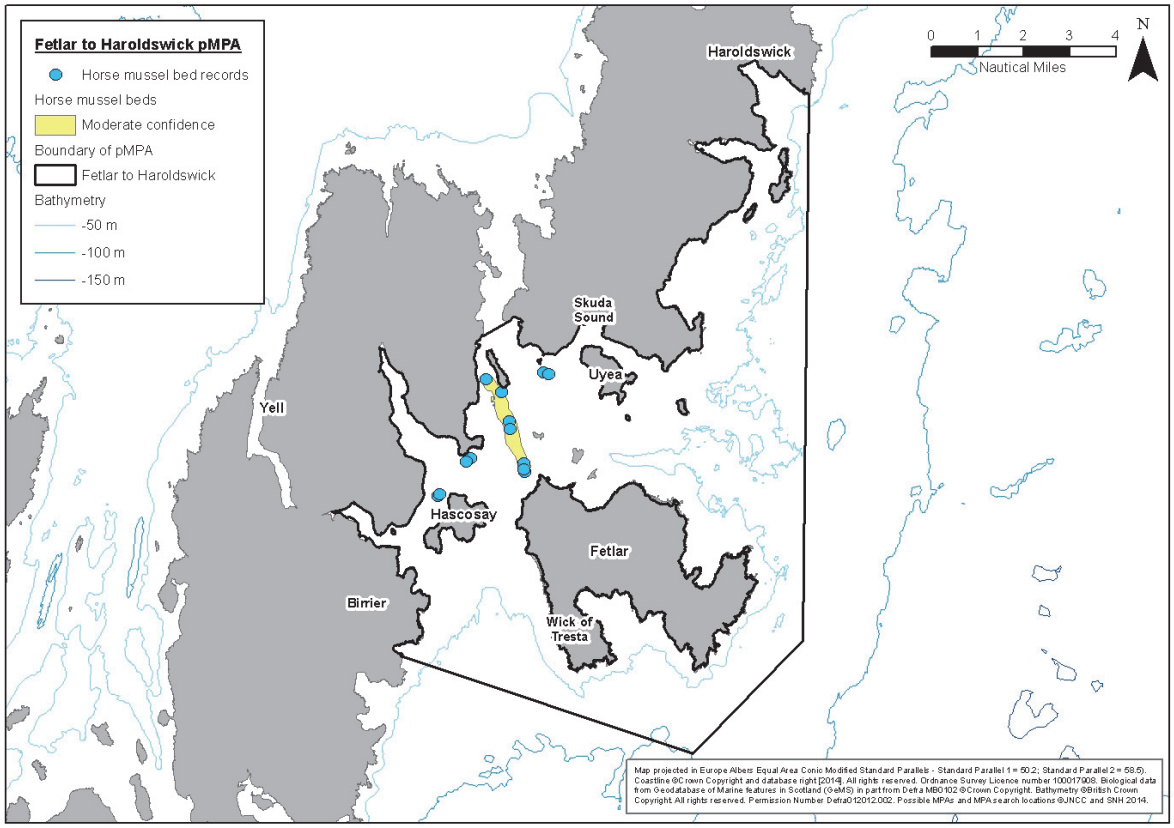

Figure 12. The distribution of horse mussel beds for the Fetlar to Haroldswick possible MPA coded for confidence

3.2.2.5 Shallow tide-swept coarse sands with burrowing bivalves

There are very few records of the shallow tide-swept coarse sands with burrowing bivalves proposed protected feature (**SS.SCS.ICS.MoeVen**), although this habitat may be more extensive than the records suggest in mixed sediment/gravel habitats in the infralittoral. It is possible that surveyors have assigned records up to a higher level habitat (Level 3) rather than commit to the Level 4 biotope. However, some polygons have been attempted: small patches have been digitised near Basta, Bluemull Sound and in the Wick of Tresta (Fetlar) (Figure 13).

Note that, as with CCS, surveyors do not appear to have abided by the depth zones that the records were located in. One record in Colgrave Sound is far too deep to be considered eligible for this feature and subsequently has not been used to delineate polygons within this possible MPA.

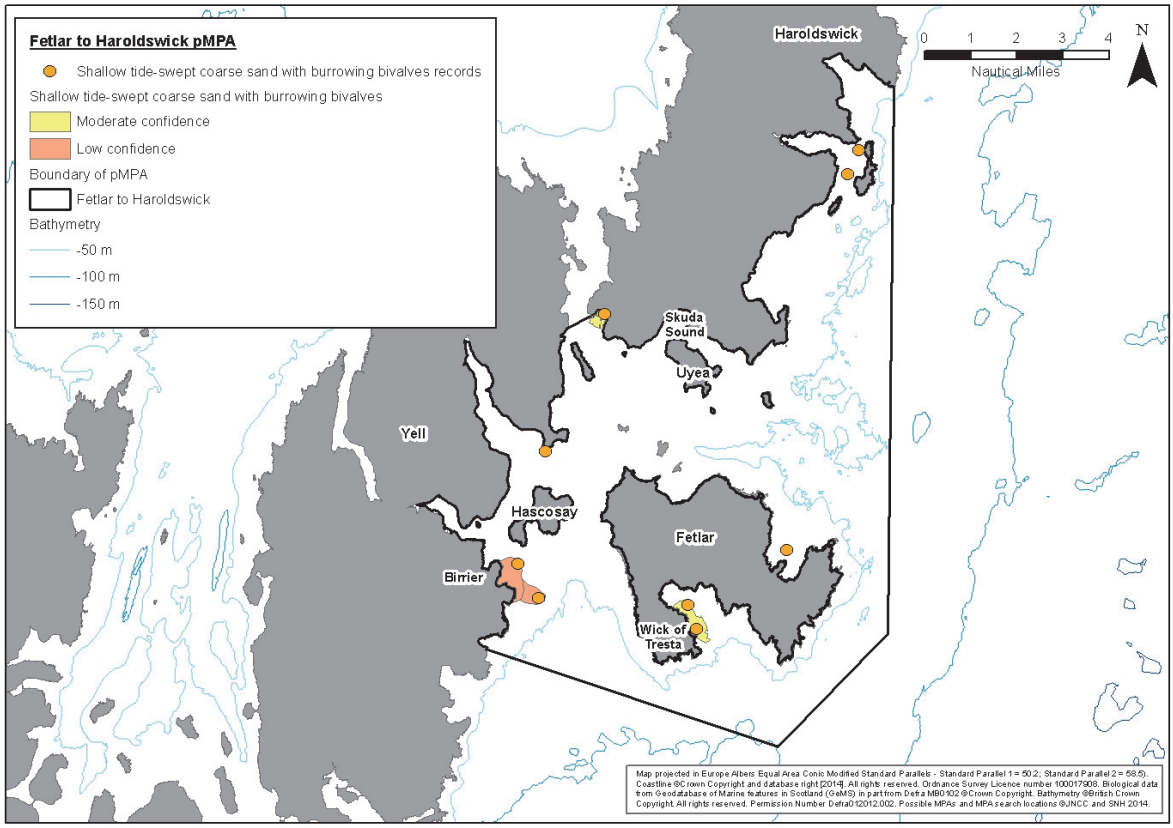

Figure 13. The distribution of shallow tide-swept coarse sand with burrowing bivalves for the Fetlar to Haroldswick possible MPA coded for confidence

3.2.2.5 Summary of proposed protected features for the Fetlar to Haroldswick possible Nature Conservation MPA

The predominant proposed protected feature circalittoral sand and coarse sediment communities (CCS) is widely distributed on the open coast from deep water up to the infralittoral zone. However, the distribution is less certain off the south-east coast of Fetlar due to lack of records here (Figure 4). The large area not assigned to any proposed protected feature east of Unst is a patchwork of rock and sediment. Lack of sampling here means that the composition of this large area is unknown.

The area of sea bed that has not currently been assigned to a biotope, between Unst, Fetlar and Yell, is likely to be predominantly gravel or sand/gravel and may support maerl beds, based on the composition of neighbouring areas of similar habitat. However, there is not enough evidence to draw polygons for the distribution of any of these habitats in this area.

Many of the sheltered, shallow areas support kelp and seaweed communities on sublittoral sediments. However, this feature is probably more widely distributed than existing records suggest.

The distribution of all the proposed protected features is summarised in Figure 14. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

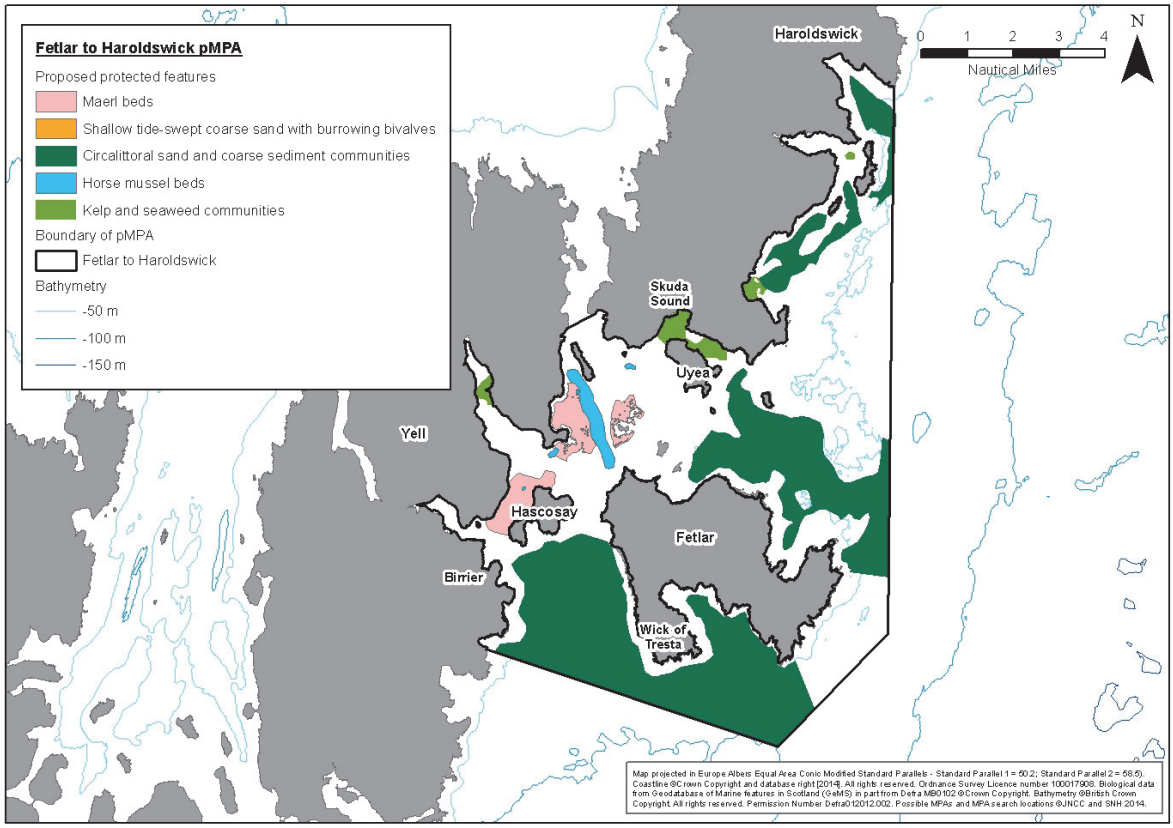

Figure 14. The distribution of all proposed protected features for the Fetlar to Haroldswick possible MPA.

3.3 Loch Sunart possible Nature Conservation MPA

The Loch Sunart possible Nature Conservation MPA was identified for the following two MPA search features, both of which are now referred to as proposed protected features - flame shell beds and northern feather star aggregations on mixed substrata. Serpulid aggregations are not an MPA search feature but have been recommended as a proposed protected feature as they are considered to add to the broader representativity of the Scottish MPA network (i.e. is a representative feature). The proposed protected features to be mapped are shown in Table 5.

Details of supporting evidence are provided in the Loch Sunart possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1032173.pdf]. The existing available data holdings can be seen in Figure 15.

Table 5: *Proposed protected features to be mapped within the Loch Sunart possible MPA.*

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes
Loch Sunart	Flame shell beds	SS.SMx.IMx.Lim
	Northern feather star aggregations on mixed substrata	*no specific biotope*
	Serpulid aggregations	SS.SBR.PoR.Ser

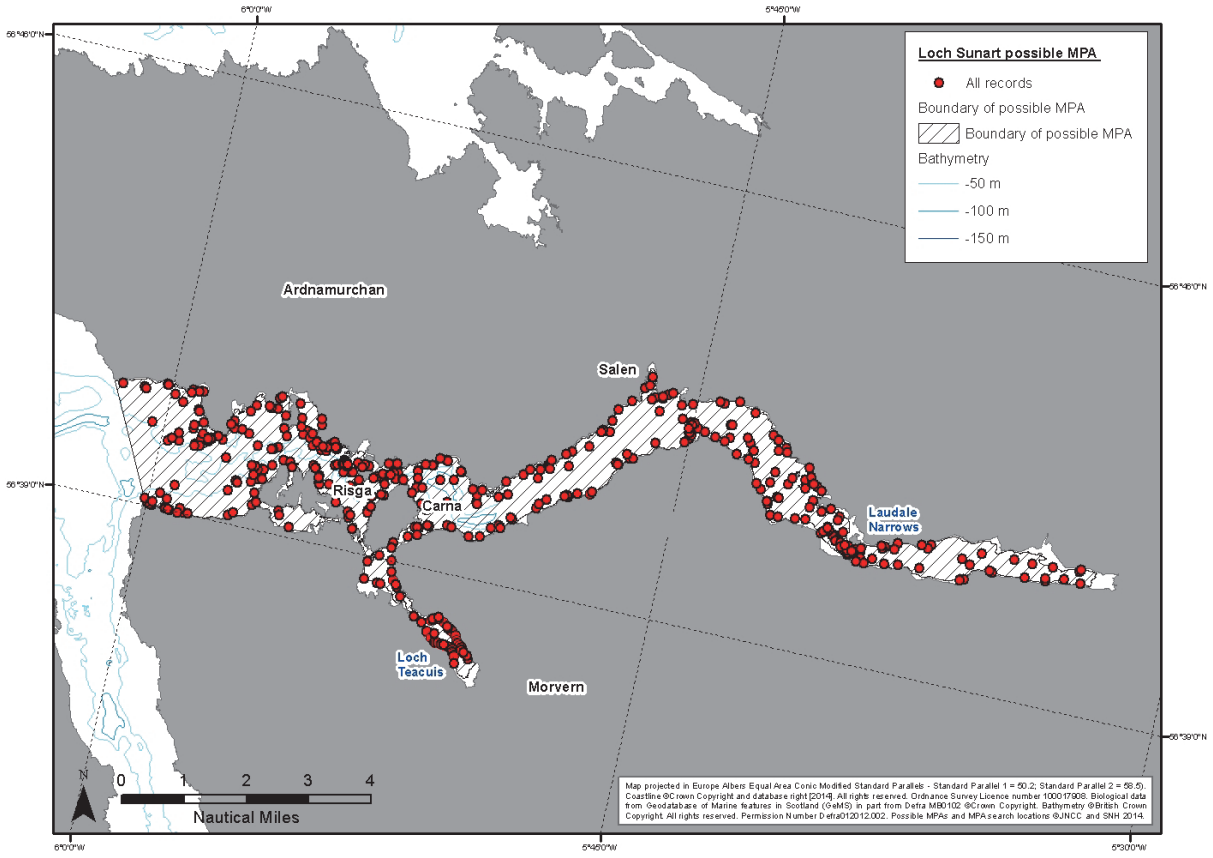

Figure 15. Existing data holdings within the Loch Sunart possible MPA

3.3.1 Data assessment and requirements for more comprehensive mapping

The bathymetry data available for the Loch Sunart possible Nature Conservation MPA (Bates *et al.,* 2004) are of high quality and were used to create depth contours and a slope layer (which was designed to have a greater emphasis on moderate slopes than the layer provided in the PMF database). The mosaicked side scan images were of moderate quality and could be used to separate hard from soft sediment. However, it was impossible to derive a spatially detailed map of hard features due to the very heterogeneous nature of the topography, and neither was it possible to discriminate with any confidence between bedrock and other strongly reflecting substrates, such as cobble and gravel.

Some polygons based on a survey conducted in 2001 were provided in the database (Bates *et al.,* 2004) but have largely been superseded by the additional data collected since that date (Mercer *et al.,* 2007).

It is possible that the collection and processing of multibeam data could give a comprehensive backscatter image that would improve on the present side scan images and help to give better definition of the substrata and topography which in turn could lead to better modelling of habitat suitability. Ideally, this work should then be followed by targeted ground truthing to refine and add confidence to feature boundaries.

Future work could use all records of flame shells to determine their habitat preferences. This information could then be used to model the predicted distribution of the feature in areas such as the Loch Sunart possible Nature Conservation MPA.

3.3.2 Proposed protected features

3.3.2.1 Flame shell beds

Flame shell beds, *Limaria hians*, (**SS.SMx.IMx.Lim**) are nominally assigned to the habitat IMx (infralittoral mixed sediment) although their lower depth range is stated as being -30 m (i.e. circalittoral). The -15 m contour was used to constrain polygons in the absence of positive records in deeper water. The biotope is associated with other gravelly/muddy gravel habitats, especially **SS.SMx.CMx.OphMx**. Where records of these biotopes lie close together, there is a possibility that the actual extent of *L. hians* could be wider than the records for **SS.SMx.IMx.Lim** might indicate. For this reason, polygons were drawn around points where **SS.SMx.CMx.OphMx** was intermixed with **SS.SMx.IMx.Lim**. *Limaria hians* also favours tide-swept conditions and if the records were located in shallow areas where the tide is likely to be accelerated, this was taken as further evidence that supports the possible occurrence of flame shell beds.

However, other more isolated records of **SS.SMx.IMx.Lim** were often mixed with non-gravelly habitats, particularly rock or sand. The Marine Recorder records often had very diverse habitats co-located and this was taken to mean that habitats were likely to be very patchy. This situation weakens the evidence for *L. hians* beds and no attempt was made to draw polygons around these records.

The combination of gravel/mixed sediment in shallow/moderately shallow water in narrows (tidally accelerated areas) are limited and most have been sampled moderately comprehensively. Therefore, it is reasonable to assume that the polygons drawn, whilst they cannot be considered to be comprehensive, are representative of the flame shell beds within the Loch Sunart possible Nature Conservation MPA.

Figure 16 shows the distribution of flame shell bed records for the whole of Loch Sunart. However, at this scale, the point records hide the polygons for this feature and the two areas where polygons have been drawn are shown in Figure 17 and Figure 18.

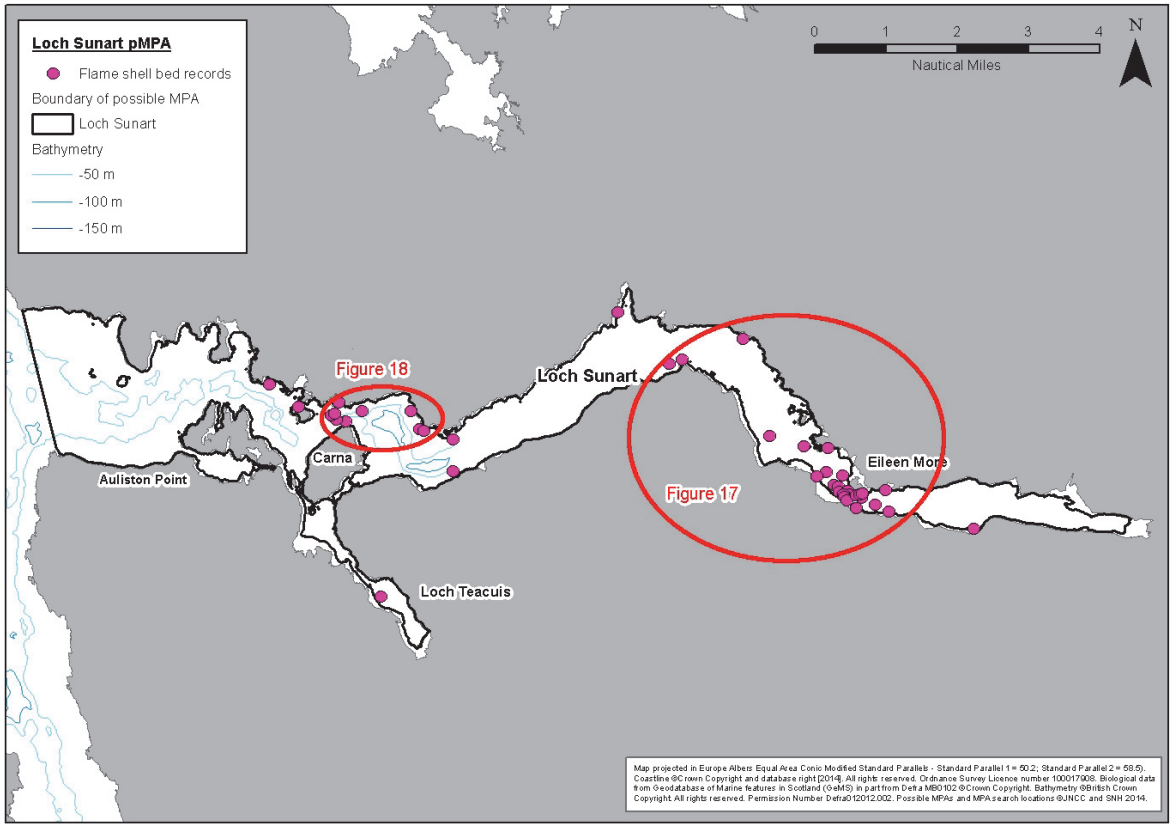

Figure 16. The point distribution of flame shell bed records within the Loch Sunart possible MPA. Polygons have not been shown at this scale as they are obscured by points.

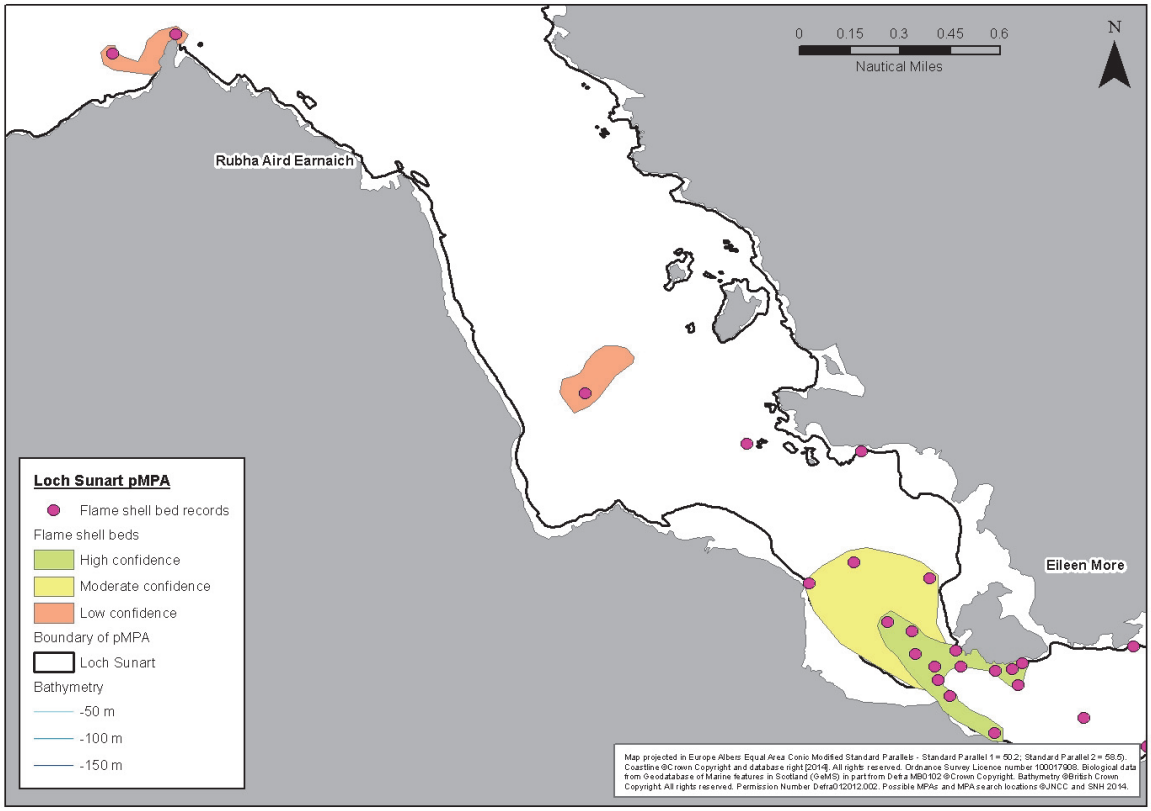

Figure 17. The distribution of flame shell beds in upper Loch Sunart, coded for confidence. N.B., Defra bathymetry does not extend into this area.

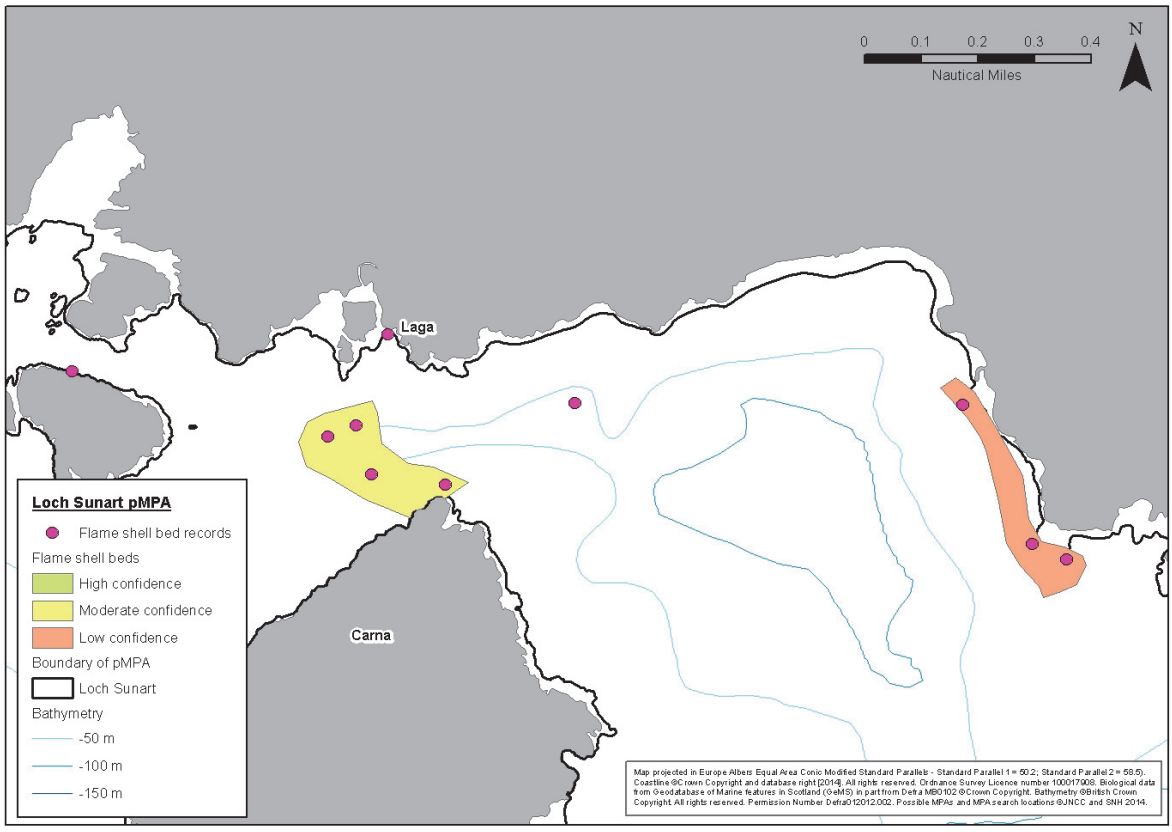

Figure 18. The distribution of flame shell beds in lower Loch Sunart, coded for confidence.

3.3.2.2 Northern feather star aggregations on mixed substrata

Existing records of northern feather star (*Leptometra celtica*) aggregations are scattered throughout the Loch Sunart possible Nature Conservation MPA, although there were groups of a few records in a few locations. The records appeared to be situated close to the boundaries of acoustically hard areas (possibly bedrock, boulders or cobble) in a wide range of depths. Such suitable locations are widely distributed within Loch Sunart and, therefore, provided little support for polygons to be drawn to encompass the points. An attempt has been made to create some polygons for the cluster of records where these are located on well-defined features. However, many records are located in extensive areas of hard ground in deep water and there is little supporting evidence to suggest the likely extent and boundaries to the distribution of aggregations on mixed substrata.

(Note: there is a concentration of records in the deep central part of lower Loch Sunart. However, the nature of the sediment is not clear from the evidence and may be mud).

In summary, the distribution and extent of the polygons and the point records cannot be regarded as truly representing the likely distribution of northern feather star aggregations. It seems probable that *L. celtica* favours muddy mixed sediments either in deep water or at the boundaries between rock and sediment at all depths. It may be possible to test this hypothesis using a more extensive database than is available for Loch Sunart or by targeted sampling.

Figure 19 shows the distribution of northern feather star aggregation records for the whole of Loch Sunart. However, the point records hide the polygons for this feature and so two further maps have been inserted to show the distribution of these polygons in Figure 20 and Figure 21.

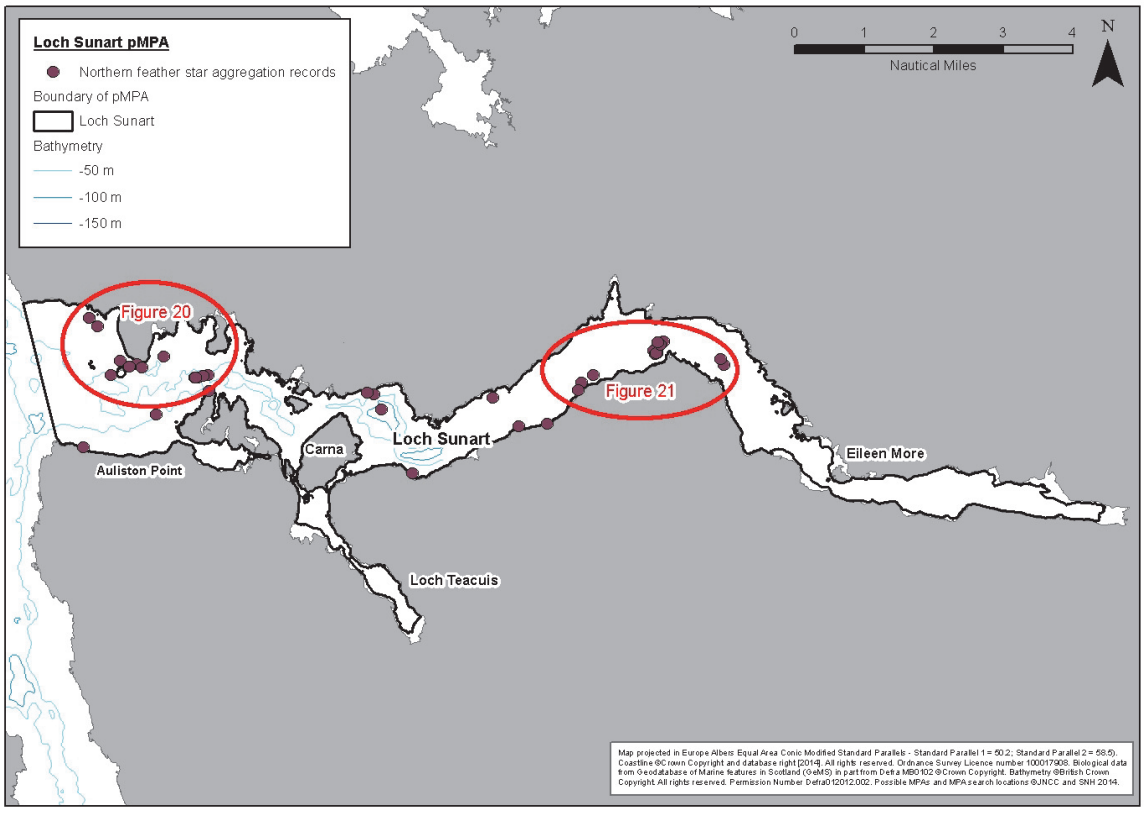

Figure 19. The point distribution of records of northern feather star aggregations within the Loch Sunart possible MPA.

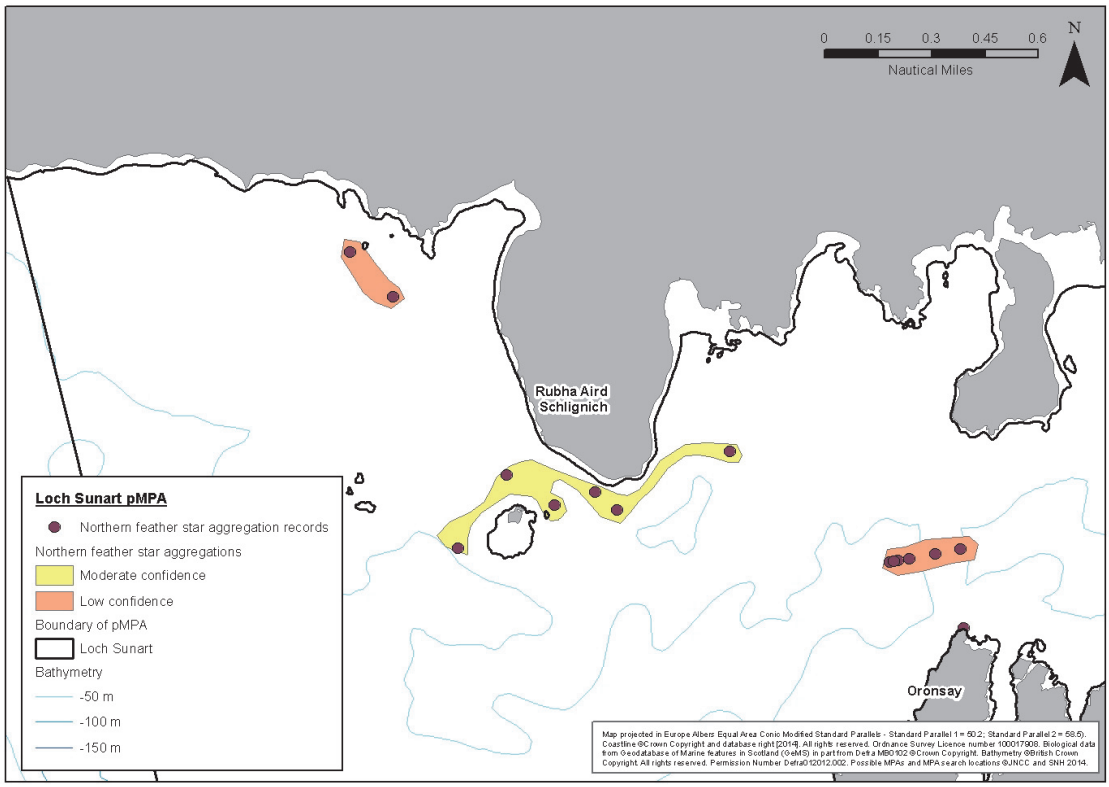

Figure 20. The distribution of northern feather stars aggregations on mixed substrata in the lower Loch Sunart, coded for confidence.

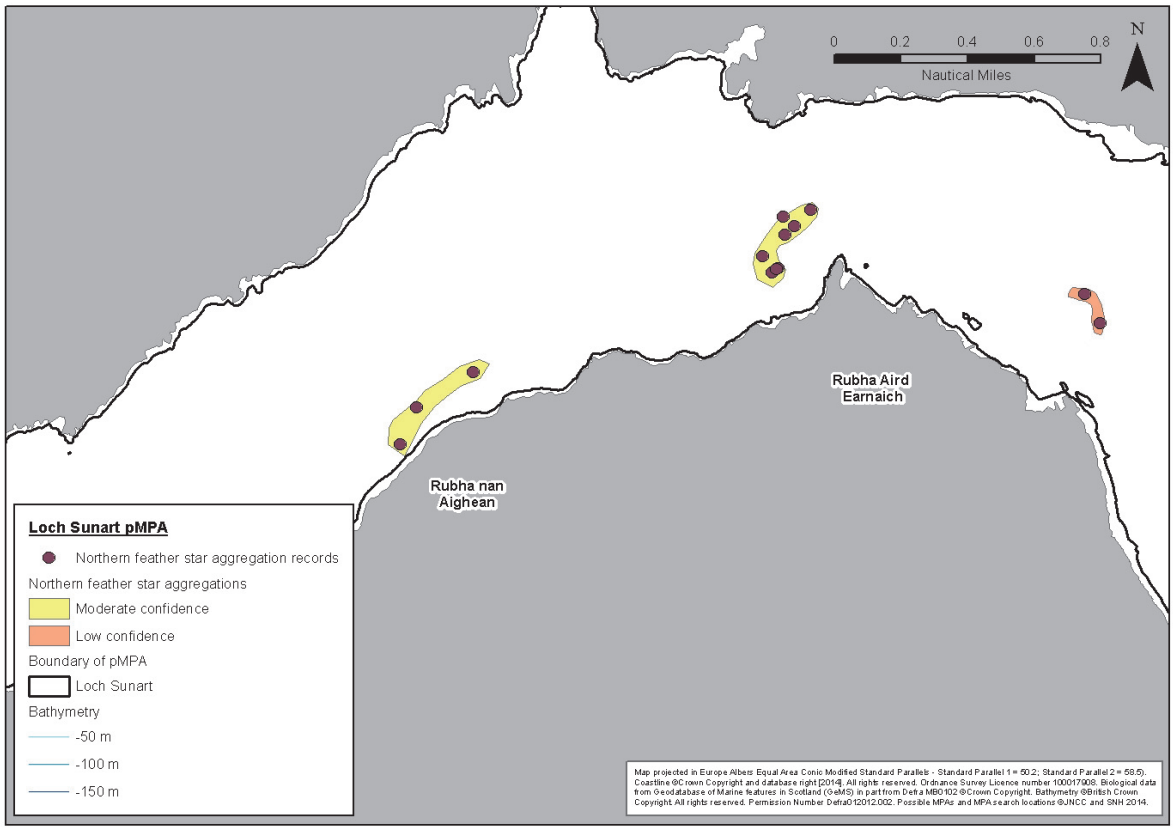

Figure 21. The distribution of northern feather stars aggregations on mixed substrata in the upper Loch Sunart, coded for confidence.

3.3.2.3 Serpulid aggregations

The serpulid aggregations (**SS.SBR.PoR.Ser**) within Loch Teacuis have been well surveyed (Dodd *et al.,* 2009) and the polygon provided from the report on this survey has been re-digitised from a printed map provided by SNH (Figure 22).

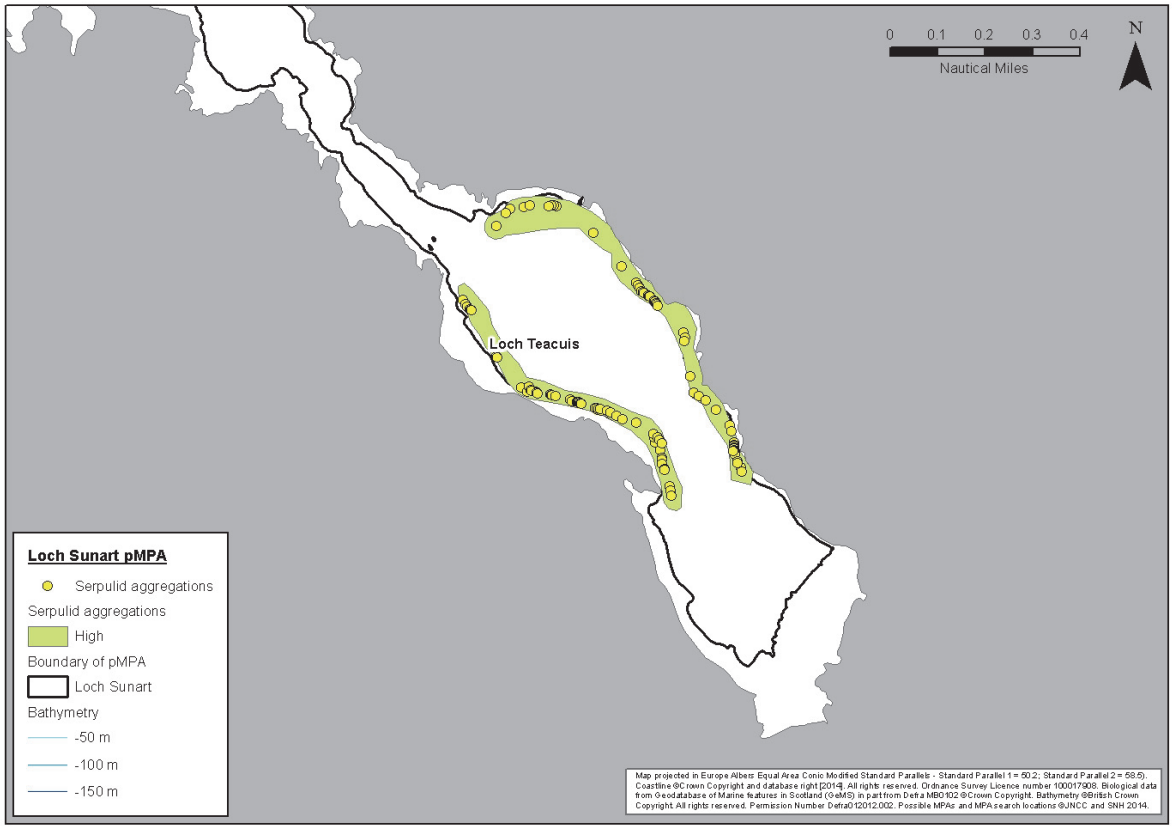

Figure 22. The distribution of serpulid aggregations in the Loch Teacuis coded for confidence.

3.3.2.4 Summary of proposed protected features for the Loch Sunart possible Nature Conservation MPA

The proposed protected feature records within the Loch Sunart possible Nature Conservation MPA are all patchily distributed with a few locations where the density of records supports a polygon drawn to encompass the higher density of these. This particularly applies to flame shell beds and northern feather star aggregations on mixed substrata. Both of these proposed protected features could be more widely distributed. The occurrence of northern feather stars (including records not classed as aggregates) is widespread throughout Loch Sunart.

Much of the area has not been assigned to a proposed protected feature. Further survey work and better definition of substrata from backscatter data combined with modelling techniques would refine the apparent restricted distribution at present.

The distribution of all the proposed protected features is summarised in Figure 23. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

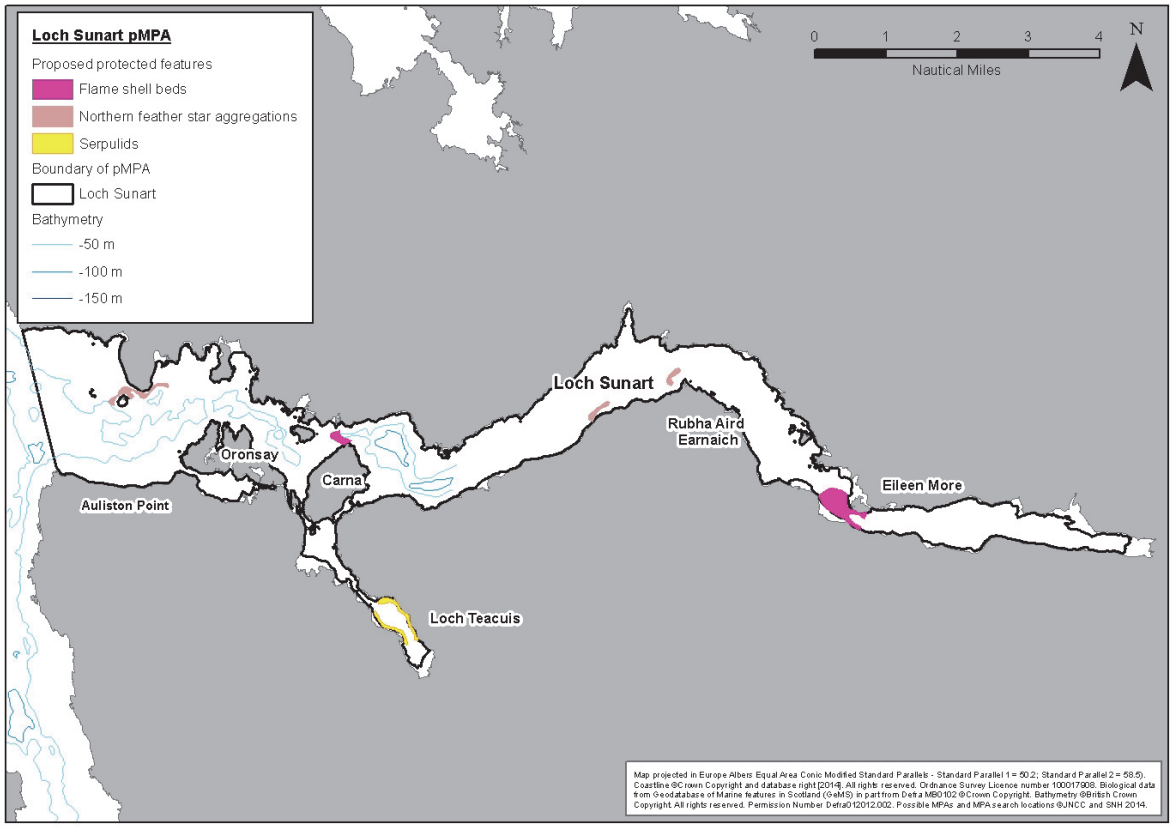

Figure 23. The distribution of all proposed protected features for the Loch Sunart possible MPA.

3.4 Loch Sween possible Nature Conservation MPA

The Loch Sween possible Nature Conservation MPA was identified for the following MPA search features, which are now referred to as proposed protected features - burrowed mud, maerl beds and native oysters (Table 6). Sublittoral mud and mixed sediment communities (SMS) is not an MPA search feature but has been recommended as a proposed protected feature as it is considered to add to the broader representativity of the Scottish MPA network (i.e. is a representative feature). The proposed protected features to be mapped are listed in Table 6. Please note although native oysters are a proposed protected feature they have not been shown here.

Details of supporting evidence are provided in the Loch Sween possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1034851.pdf] with the existing available data holdings shown in Figure 24.

Table 6: Proposed protected features and component biotopes to be mapped within the Loch Sween possible MPA

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
Loch Sween	Burrowed mud	SS.SMu.CFiMu.SpnMeg SS.SMu.CFiMu.MegMax Tall sea pen, *Funiculina quadrangularis* Fireworks anemone, *Pachycerianthus multiplicatus*
	Maerl beds	SS.SMp.Mrl
	Sublittoral mud and mixed sediment communities (SMS)	SS.SMu.ISaMu SS.SMu.IFiMu SS.SMx.IMx SS.SMx.CMx

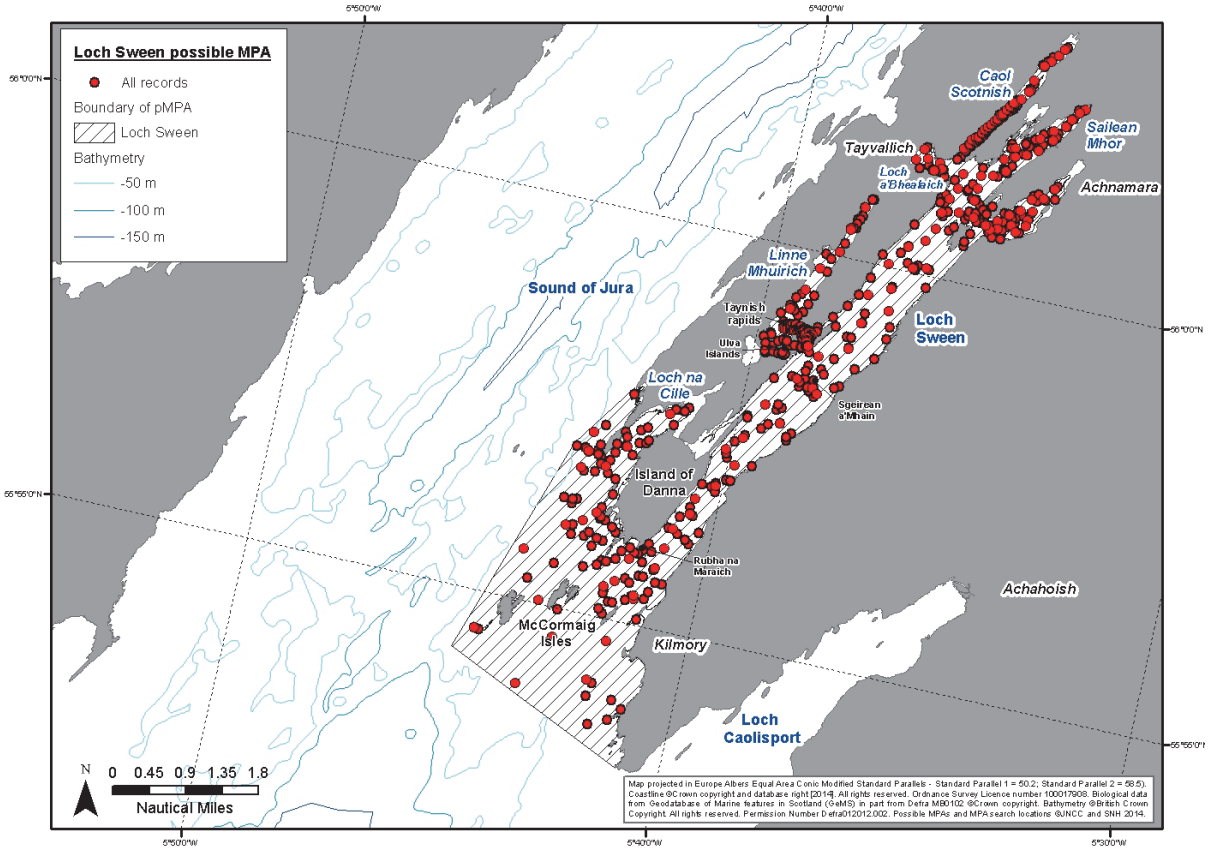

Figure 24. Existing data holdings within the Loch Sween possible MPA

3.4.1 Data assessment and requirements for more comprehensive mapping

The point sample data that have been collected over a number of years are extensive and are representative of the distribution of the protected features. A recent survey (Moore *et al*., 2013) has produced results which have also been incorporated into the polygon delineation.

Loch Sween has been intensively sampled and the numbers of records are sufficient for boundary delineation of the proposed protected features with a moderate to high level of confidence. The contours drawn from the Defra bathymetry have been used to inform the proposed protected feature boundary drawing process, however there is currently no acoustic data available for the area. There are a large number of non-proposed protected feature records and this has helped to constrain the boundaries around the proposed protected features.

Loch Sween is generally quite shallow, Caol Scotnish, Linne Mhuirnich and Loch na Cille are very shallow (mostly shallower than -10 m). The majority of Loch Sween itself is shallower than -20 m except for a depression in the northern sector.

The proposed protected features for Loch Sween occupy different parts of the sediment spectrum. Maerl beds and native oyster beds lie in mixed sediment (mostly infralittoral) whilst burrowed mud is located at the opposite end of the spectrum in circalittoral fine muds. This separates these two groups into two quite distinct habitats.

However, the sublittoral mud and mixed sediment communities (abbreviated to SMS) feature is composed of disparate habitats that has the potential to considerably expand the distribution of the combined features (Figure 25).

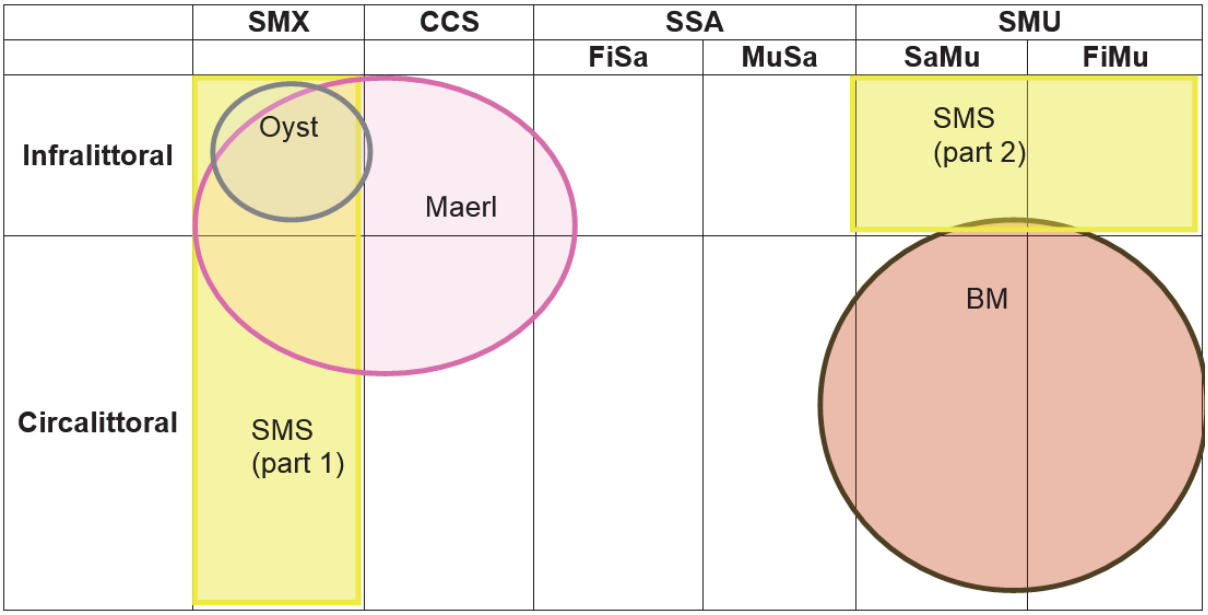

Figure 25. Schematic diagram indicating the distribution of proposed protected features on a sediment/depth plot.

The Loch Sween possible Nature Conservation MPA has been intensively sampled over the years and it is unlikely that some of the features, such as burrowed mud, will have changed. Higher resolution boundaries could be obtained if comprehensive acoustic survey coupled with stratified sampling is undertaken.

3.4.2 Proposed protected features

3.4.2.1 Burrowed mud

The density of point data for the burrowed mud proposed protected feature is high, although intermixed to some extent with other habitats. Therefore, the evidence for the polygons is

good (Figure 26). The 2013 data confirm the distribution of the feature and the point records have been incorporated into the evidence for the burrowed mud polygon. The boundaries for the polygon have been drawn using the Defra bathymetric data as collateral information. As has been noted, Loch Sween is quite shallow and most of the burrowed mud records are located between the 10 m and 20 m depth contours.

There remain some scattered points that are situated either in isolated locations away from the main body of records, or close to the coastline. It is possible that pockets of burrowed mud could occur throughout the area, even in relatively shallow water. However, these points have been excluded from polygons delineated here.

The burrowed mud habitat records may not have been well differentiated from other muddy habitat records. In shallow water, muddy habitats not assigned to burrowed mud may be better considered as sublittoral mud and mixed sediment communities (SMS) and form a component of that proposed protected feature. Other SMS records lie within areas of dense burrowed mud records and the decision has been made to give priority to the more specific burrowed mud habitat. However, where the predominant record is SMS, then a polygon for this latter feature has been considered.

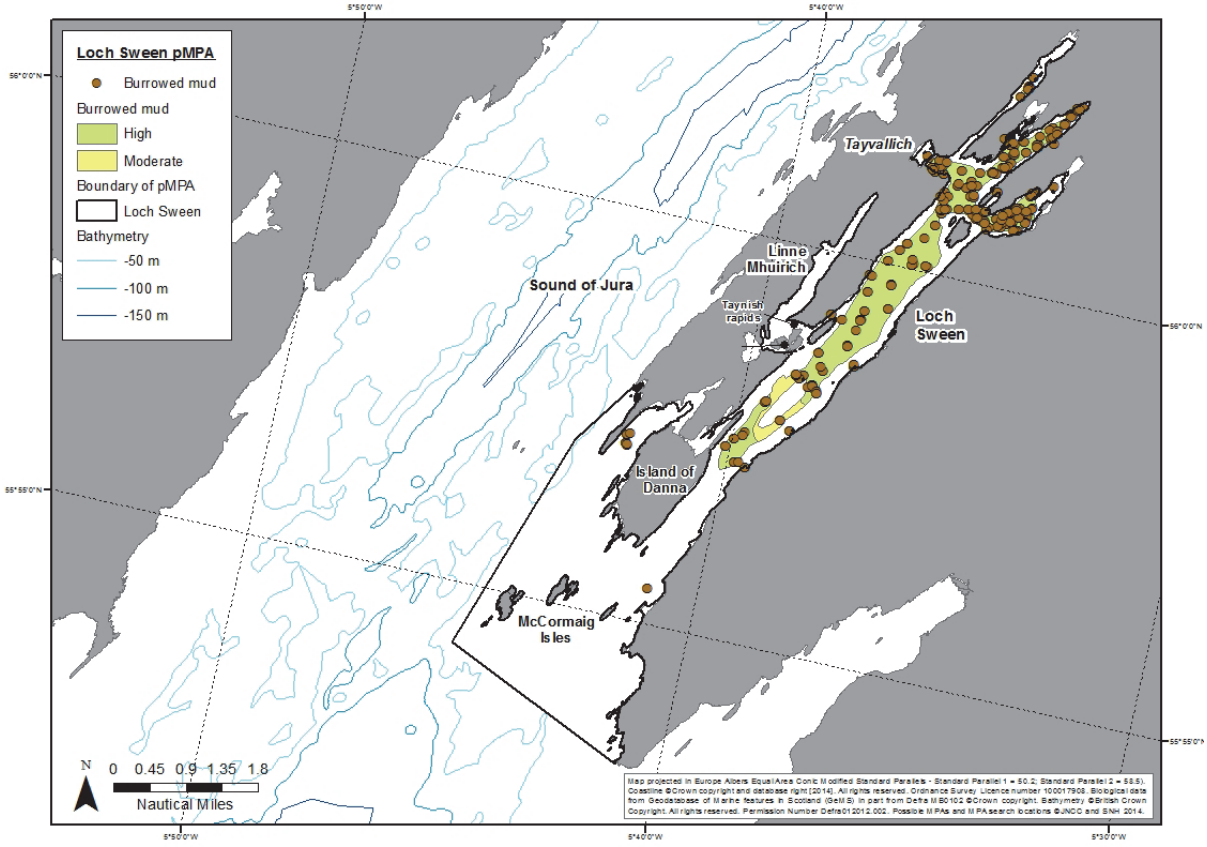

Figure 26. The distribution of burrowed mud within the Loch Sween possible MPA, coded for confidence.

3.4.2.2 Maerl beds

Maerl bed records (**SS.SMp.Mrl**) are mostly clustered in two locations in shallow water in the narrows (Figure 27). A survey, involving the mapping of the extent of the maerl beds within Linne Muhurich rapids and at Caol Scotnish, produced up to date information regarding the current distribution of the maerl beds (Moore *et al.*, 2013). Both the 2013 and pre 2013 records are shown in Figure 27, however, the point records hide the polygons for this feature

and the two areas where polygons have been drawn are shown in Figure 28 and Figure 29. These polygons have been adopted directly from the 2013 study (Moore *et al*., 2013) and so only records from 2013 are shown in these figures.

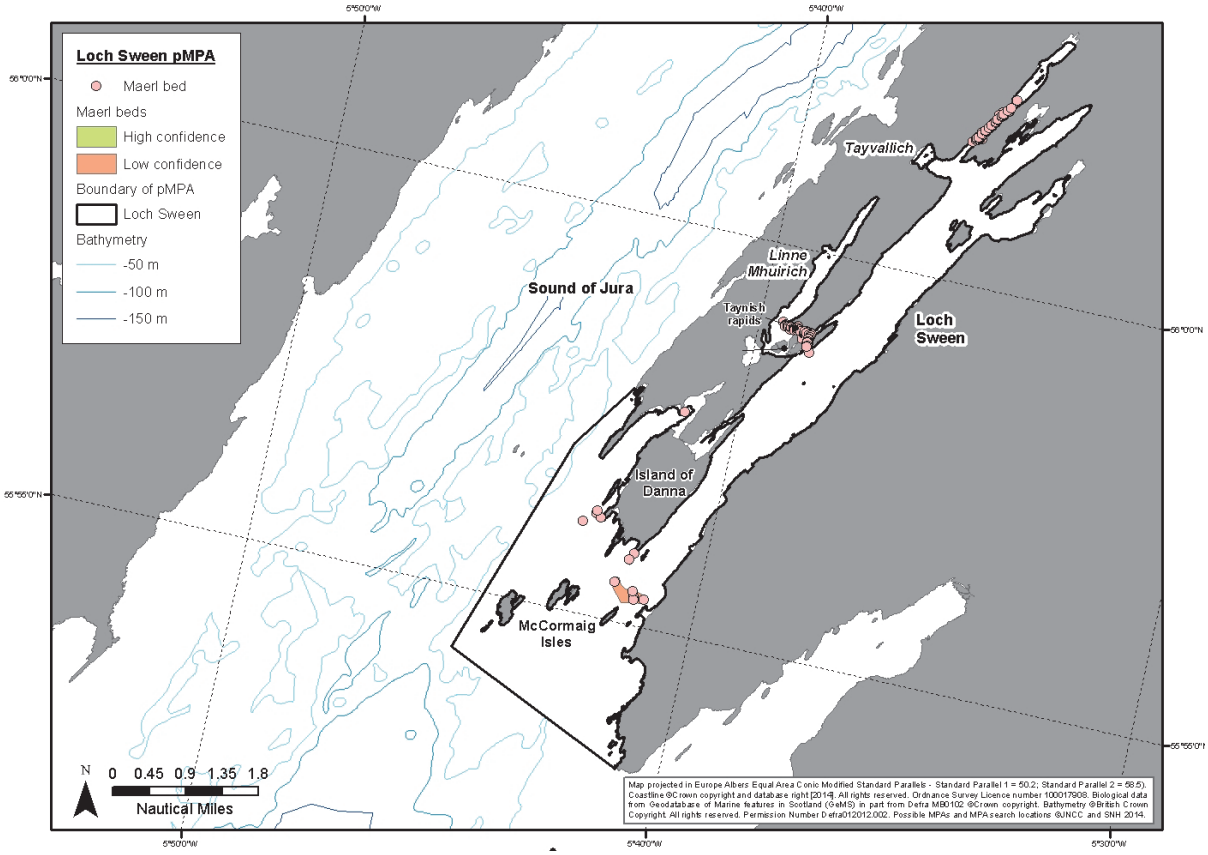

Figure 27. The point distribution of maerl bed records within the Loch Sween possible MPA.

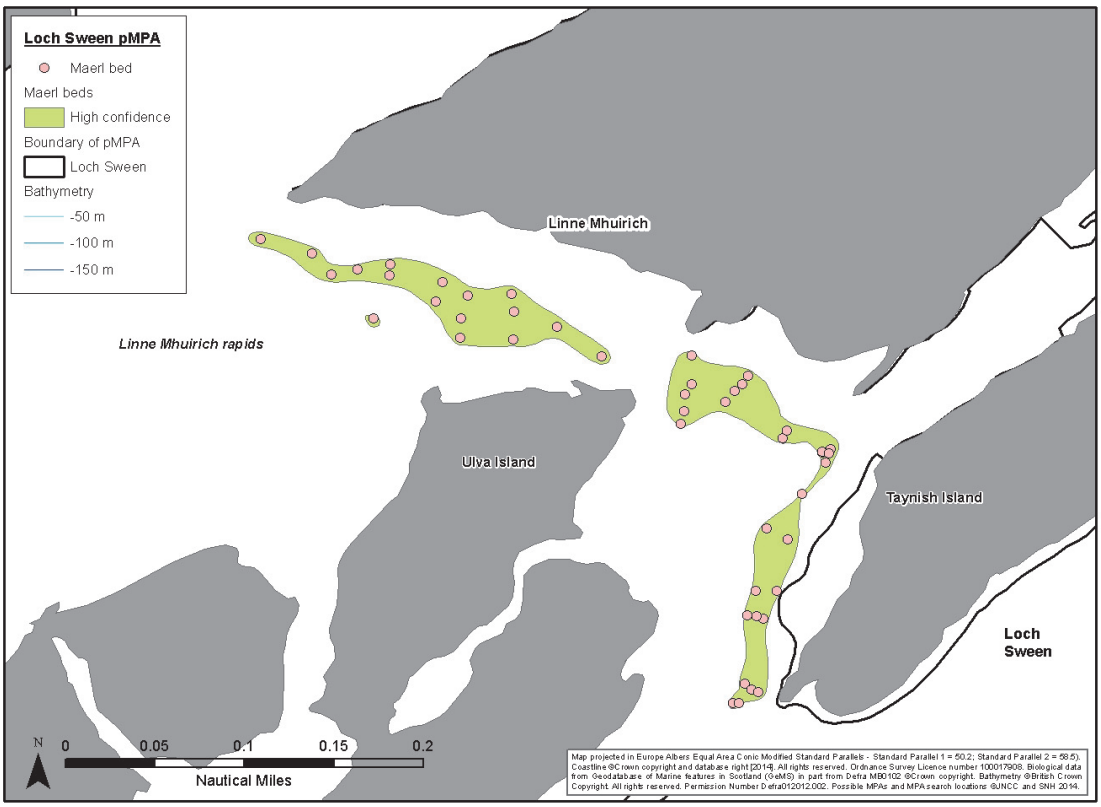

Figure 28. The distribution of maerl beds in the Linne Mhurich rapids coded for confidence.

Figure 29. The point distribution of maerl bed within Caol Scotnish, coded for confidence.

Maerl beds were also found in the narrow central section of Caol Scotnish and this was confirmed in 2013. However, the location of the records from previous surveys were probably inaccurate and linked to shore locations rather than positions on the loch. The polygon drawn from these earlier data is, therefore, slightly wider than the polygon from the 2013 data. Otherwise, the distribution is little changed for this site.

Other scattered records occur at the mouth of Loch Sween where there also appear to be narrow “fingers” of rocky outcrop. These maerl bed records are too widely scattered and interspersed with other non-maerl records to be able to draw polygons with a high degree of certainty.

3.4.2.3 Sublittoral mud and mixed sediment communities

These are defined as infralittoral sandy mud (**SS.SMu.ISaMu** and **SS.SMu.IFiMu**) and infra- and circalittoral mixed sediment (**SS.SMx.IMx/CMx**) communities (SMS). It is likely that the SMS proposed protected feature occurs in deeper water and extends into Loch Sween from the mouth of the loch. However, there are also records scattered around the littoral margins of the loch in shallow water. These habitats could be considered a continuation of the littoral sediments into the sublittoral before the sea bed dips into the muddy sediments in slightly deeper water. This situation appears to be particularly applicable to the eastern shore of Loch Sween where there is a wide sediment shore in many places (as seen on Google Earth images). Other shores appear to be rocky but are likely to give way to muddy sediments close into shore. Thus, the distribution of this proposed protected feature is likely to be more extensive than the existing data points would indicate (Figure 30). However, the actual extent along the coast is hard to map, given the lack of discrimination that the Google images allow.

Some of the records of circalittoral sandy muds lie in water between the 0 and -10 m contours which ought to qualify as infralittoral. Thus, the evidence for proposed protected feature versus non-proposed protected feature mud sediment is equivocal. Boundaries have been drawn around definite records of SMS and extension polygons enclose possible SMS records.

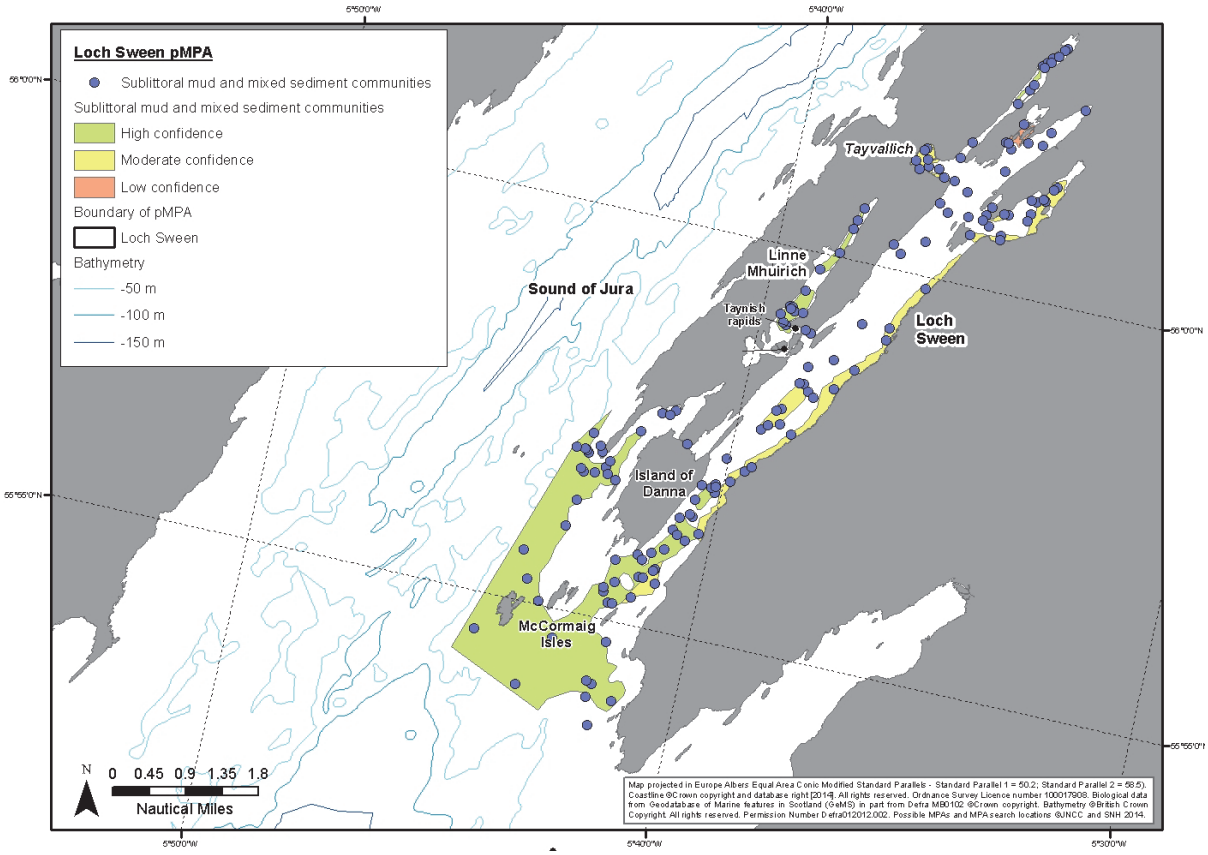

Figure 30. The distribution of sublittoral muds and mixed sediment communities within the Loch Sween possible MPA, coded for confidence.

3.4.2.4 Burrowed mud component mapping

During the course of this study a requirement was made to differentiate between the biotope **SS.SMu.CFiMu.MegMax** and other components of the burrowed mud proposed protected feature. Since there are no acoustic remote images available for the Loch Sween possible Nature Conservation MPA, it is not possible to model the distribution of the biotope **SS.SMu.CFiMu.MegMax** and other burrowed mud components. The distribution of the point data shows that the various habitats are intermixed and do not obviously correspond to any particular depth. However, there would appear to be spatial clusters within the records. These seem to have persisted over a period of time and these may be amenable to probability mapping. The technique for deriving probability images from the point data is described in detail in Section 2.7.

Note that many records were assigned to the proposed protected feature burrowed mud without any definite statement about the presence or absence of *Maxmuelleria lankesteri* and these records were not used for the positive burrowed mud without *M. lankesteri* since uncertain records would have an adverse impact on the probability images.

Since the burrowed mud feature is constrained by neighbouring habitats, it was decided that the approach would be applied to these habitats as well. The records assigned to the following five habitats:- (1) **SS.SMu.CFiMu.MegMax**; (2) burrowed mud; (3) sublittoral mud and mixed sediment communities; (4) maerl beds and; (5) mixed sediment.

Previously, a single polygon was drawn for burrowed mud according to the guidelines set out in Section 2.6. However, information from the probability modelling was incorporated into the final polygon maps. This was achieved by dividing the burrowed mud polygon into its

components and also reclassifying an area in the central region of Loch Sween as sublittoral mud and mixed sediment communities

The trimmed model output of the distribution of the components of burrowed mud is shown in Figures 31 and 32. The resulting distribution map is constrained to be true to the original point data and it is not surprising, therefore, that the fit between the records and the modelled distribution is good. However, given the lack of environmental data, the polygons appear to have been drawn around clusters quite successfully. *Maxmuelleria lankesteri* (which confirms the presence of **SS.SMu.CFiMu.MegMax**) have been predicted to occur mostly in the wider, deeper parts of Loch Sween with burrowed mud and other habitats. The distribution of *M. lankesteri* may have been underestimated for the section of Loch Sween to the south-west of the Ulva Islands. However, the records here are very intermixed and very different habitats have been recorded in close proximity. The distribution of *M. lankesteri* is probably on the cautious side.

One significant difference in the overall distribution of all burrowed mud features in the modelled version compared to the original polygon is the section of sublittoral mud and mixed sediment that is predicted to occur in the middle section of Loch Sween. The results of the model may provide enough evidence to re-assign this from burrowed mud to sublittoral mud and mixed sediment.

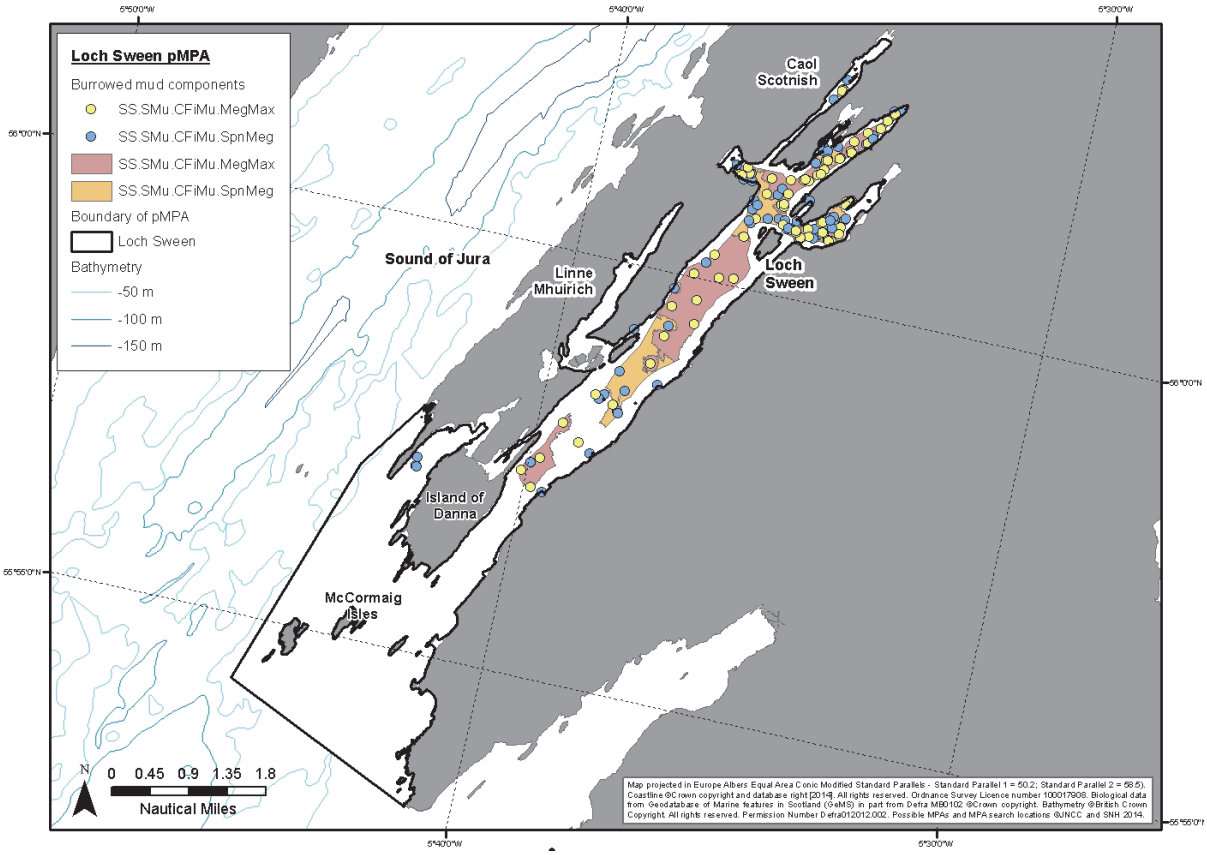

Figure 31. Modelled burrowed mud component polygons within the Loch Sween possible MPA

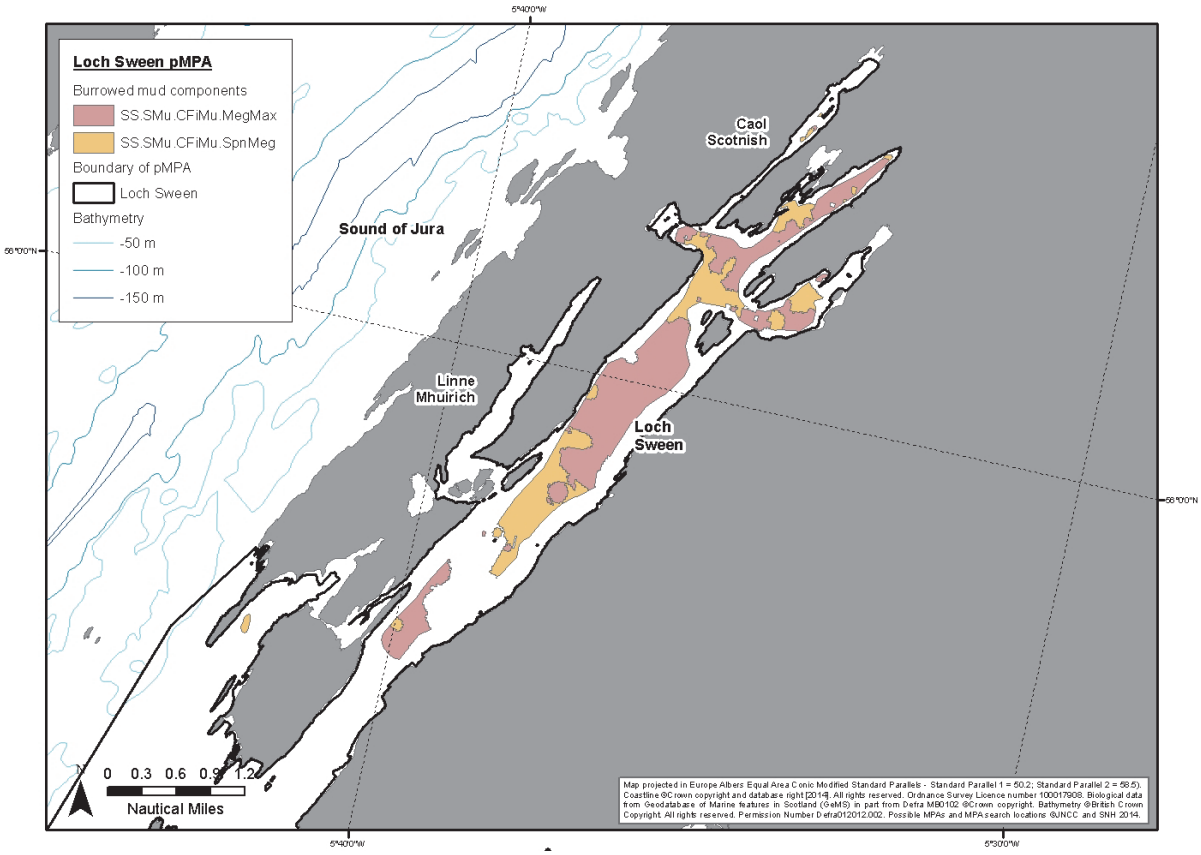

Figure 32. Modelled burrowed mud component polygons within upper Loch Sween.

3.2.2.5 Summary of proposed protected features for the Loch Sween possible MPA

Figure 33 shows the polygons drawn for those proposed protected features that were suitable for polygon boundaries in the Loch Sween possible Nature Conservation MPA. Most of the site was assigned to either burrowed mud or sublittoral mud and mixed sediment communities. This is not surprising since these habitats are broadly defined in terms of possible biotopes and sediment habitat categories. The unassigned areas at the entrance to Loch Sween were likely to be rock or sublittoral sands.

The distribution of burrowed mud appears to have been fairly consistent over the years for which samples have been taken (1982 – 2013). However, the distribution of the maerl beds has changed. This is likely due to a greater accuracy of the position-taking during the more recent survey, involving GPS tracking systems to map the maerl bed boundaries to a greater resolution.

The distribution of all the proposed protected features is summarised in Figure 33. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

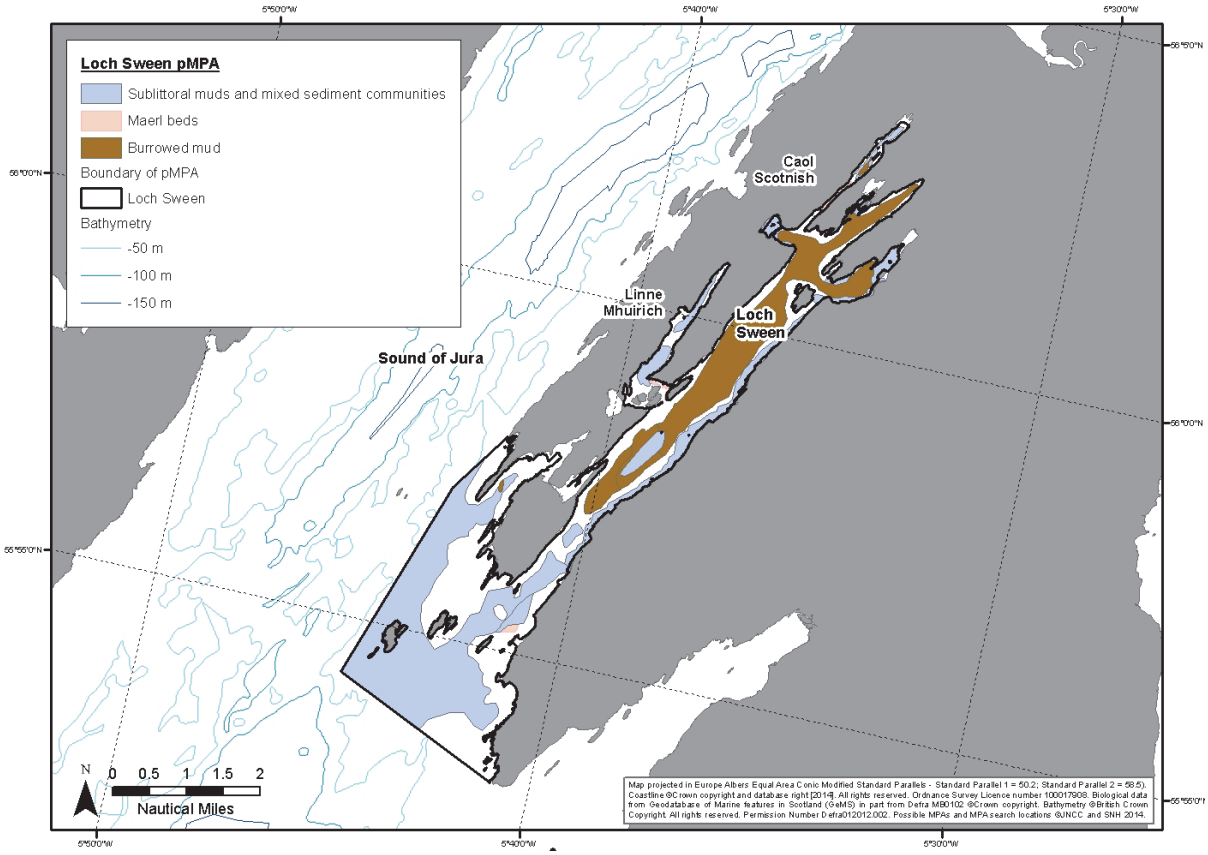

Figure 33. The distribution of all proposed protected features within the Loch Sween possible MPA.

3.5 Lochs Duich, Long and Alsh possible Nature Conservation MPA

The Lochs Duich, Long and Alsh possible Nature Conservation MPA was identified for two MPA search features, now referred to as proposed protected features; flame shell beds and burrowed mud. The proposed protected features to be mapped are listed in Table 7.

Details of supporting evidence are provided in the Lochs Duich, Long and Alsh possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1033202.pdf] with the existing available data holdings shown in Figure 34.

Table 7: Proposed protected features mapped within the Lochs Duich, Long and Alsh possible MPA.

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
Lochs Duich, Long and Alsh	Burrowed mud	SS.SMu.CFiMu.SpnMeg SS.SMu.CFiMu.MegMax Tall sea pen, *Funiculina quadrangularis* Fireworks anemone, *Pachycerianthus multiplicatus*
	Flame shell beds	SS.SMx.IMx.Lim

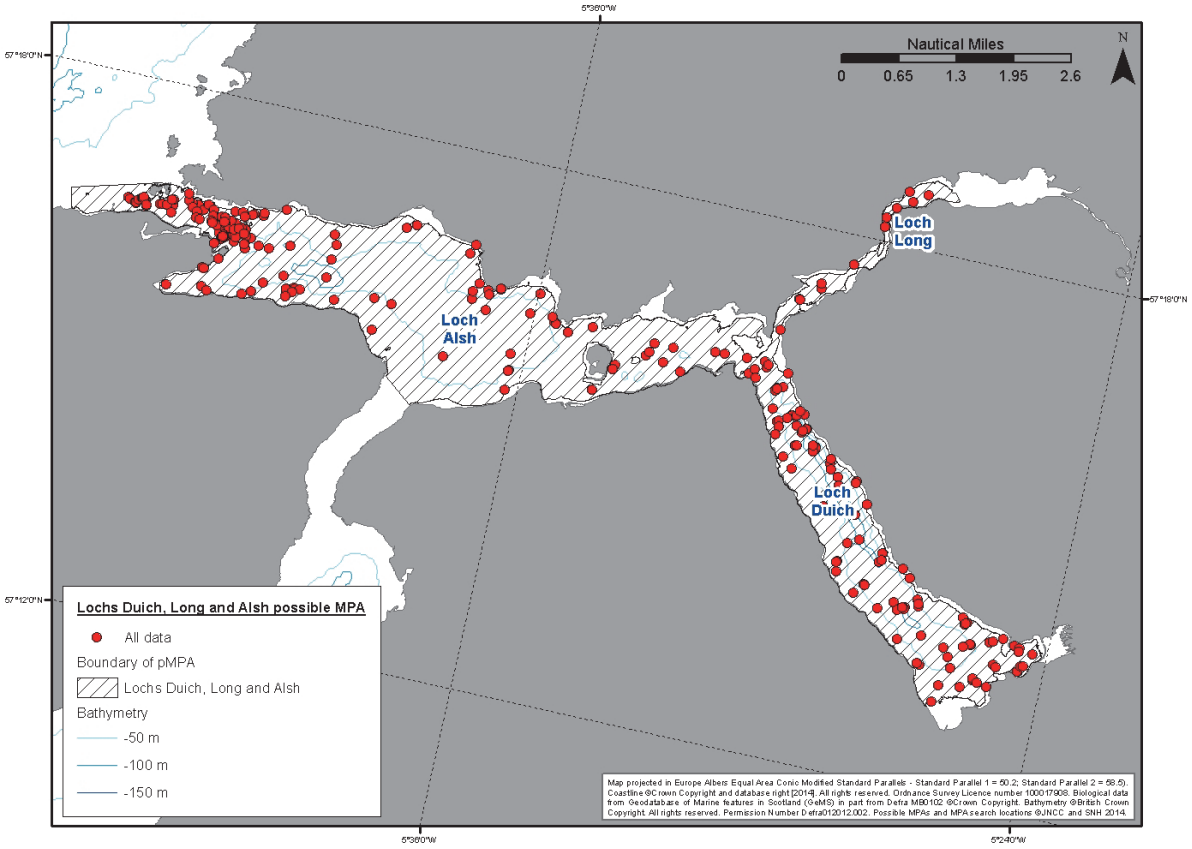

Figure 34. Existing data holdings within the Lochs Duich, Long and Alsh possible MPA.

3.5.1 Data assessment and requirements for more comprehensive mapping

The density of point records for burrowed mud is high within Loch Duich but scattered in Lochs Long and Alsh. The flame shell beds at Kyle of Lochalsh have been intensively surveyed and the polygon provided is based on strong evidence (Moore and Harries, 2012).

Acoustic multibeam data collected by BGS, on behalf of Marine Scotland, in March 2013 includes comprehensive bathymetry and backscatter data of excellent quality. The grey-scale backscatter tiff images have been re-classed into “soft” and “hard” returns (the “hard” class actually ranges from moderately hard to hard backscatter values). No exact correspondence between the grey scale values and sea floor physical habitat can be given. However, ‘very soft’ may represent soft mud and ‘moderately hard’ may represent rocky and mixed substrata The three separate images for the three lochs were re-classed using different break values so that the end results match each other (Figure 35).

The bathymetry was re-classed into depth zones (0-15 m; 15-30 m; 30-60 m; 60+ m) and the image was also filtered to show variability and the most variable topography assigned to probable rocky outcrops (rugged and very rugged topography Figure 36). These layers were used to constrain the protected feature polygon boundaries for burrowed mud by excluding areas of rugged topography.

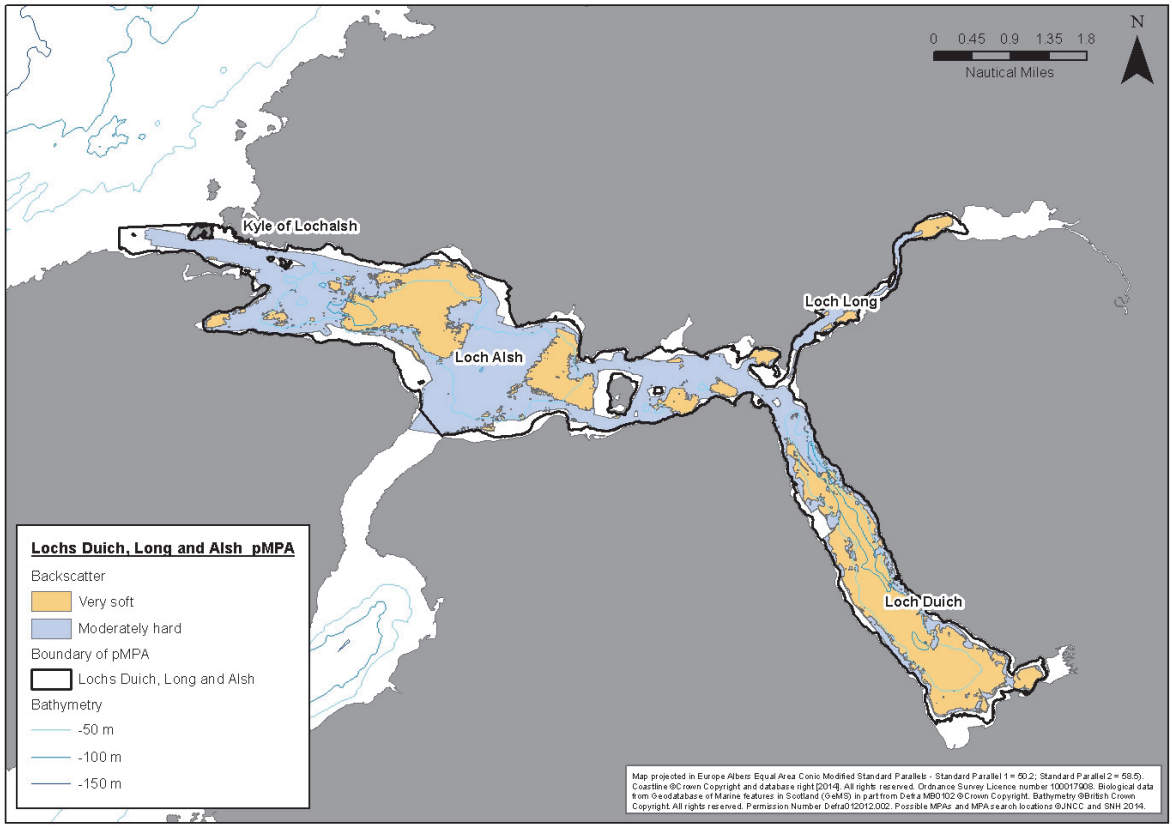

Figure 35. BGS/ MS backscatter images re-classed into soft and hard ground.

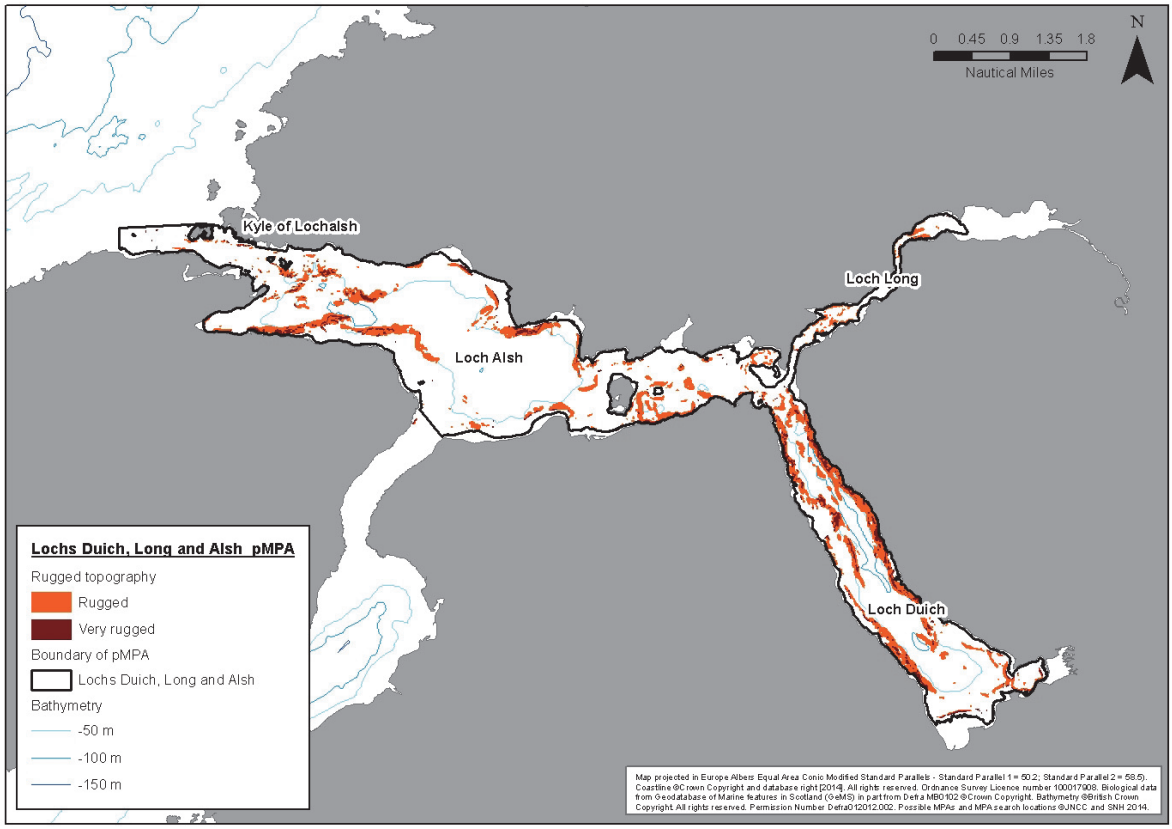

Figure 36. BGS/ MS bathymetry filtered to show rugged and very rugged topography.

The excellent acoustic data set gives scope for the use of classification techniques for comprehensive biotope mapping of these three lochs. The deeper regions of Loch Alsh and Loch Long require much more biological sampling effort for mapping to be effective.

3.5.2 Proposed protected features

3.5.2.1 Burrowed mud

As already highlighted the density of the current burrowed mud records is high within Loch Duich but sparse within Lochs Alsh and Long. Thus, the nature of the moderate to deep water habitats in Loch Duich can be confidently presumed to be of burrowed mud (most often with *Pachycerianthus multiplicatus* and *Funiculina quadrangularis* (Figure 37) (see Section 3.5.2.3 for further detail).

However, there is some doubt regarding the positional accuracy of some of the records as some lie inshore of the shallow, fringing rocky outcrops (as indicated by topography and supported by Google Earth images). Some of the records in the north eastern sector of Loch Duich have also been discounted as there appeared to be conflict between the versions of the records. This area also has high backscatter values, which accords with the shelly, gravelly records located there.

The Loch Duich polygon has been drawn using the rocky fringe and the soft/hard boundaries to constrain the polygon. Loch Long has two records and a polygon has been drawn with moderate confidence around the record in the deep water at Allt-nan-Sugh, supported by depth and low backscatter values.

Loch Alsh has been sparsely surveyed in the deeper central region where burrowed mud is most likely to occur. There are scattered records mainly around the periphery of the loch, some of which have been assigned to burrowed mud. Two polygons have been drawn based on very sparse records and constrained to be within areas of low backscatter values. These polygons are drawn with low confidence, although it is likely that further sampling would confirm the presence of burrowed mud roughly in the areas delineated.

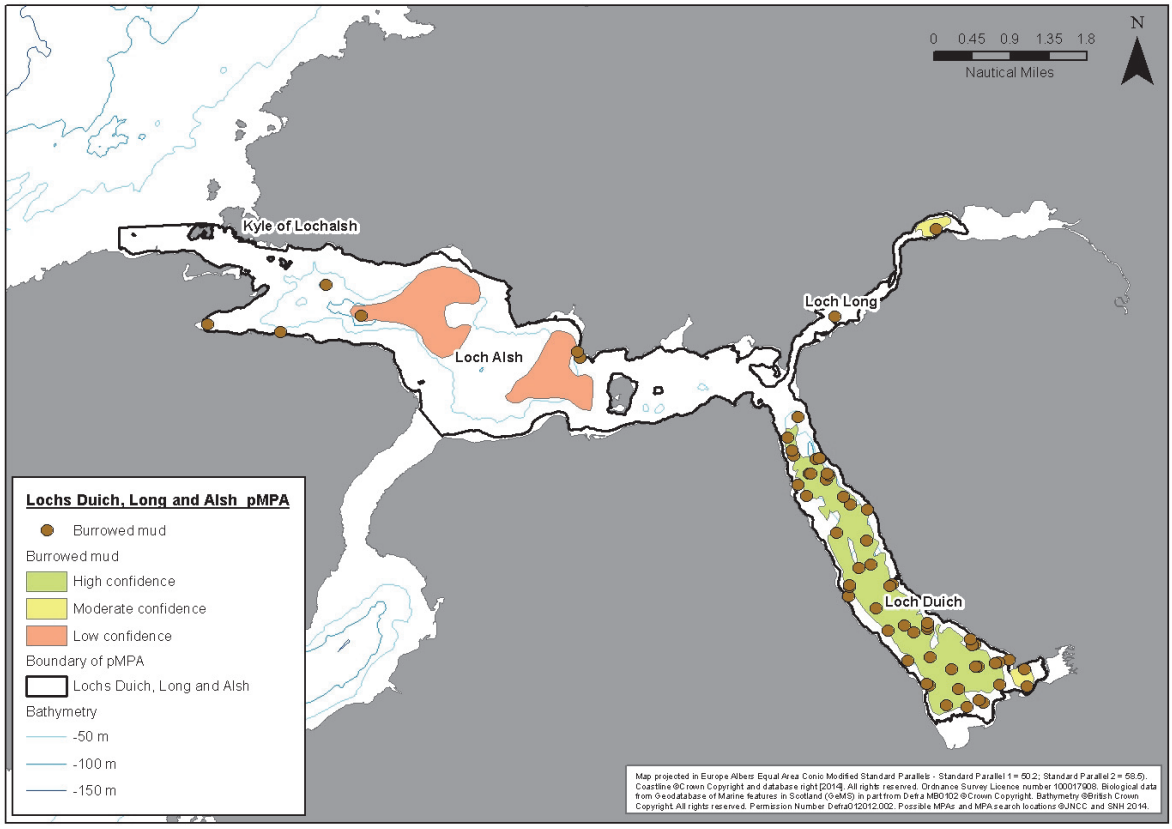

Figure 37. The distribution of burrowed mud within the Lochs Duich, Long and Alsh possible MPA, coded for confidence.

3.5.2.2 Flame shell beds

Flame shell aggregations have been the subject of a dedicated survey and their distribution has been mapped (Moore and Harries, 2012). The polygon for this feature has been adopted directly from this recent survey (Figure 38). It should be noted, however, that the full western extent of the flame shell bed was not reached in 2012. Note that Moore and Harries (2012) did not incorporate older records of flame shells into the polygon they constructed and these points have similarly not been used to modify their polygon in this study.

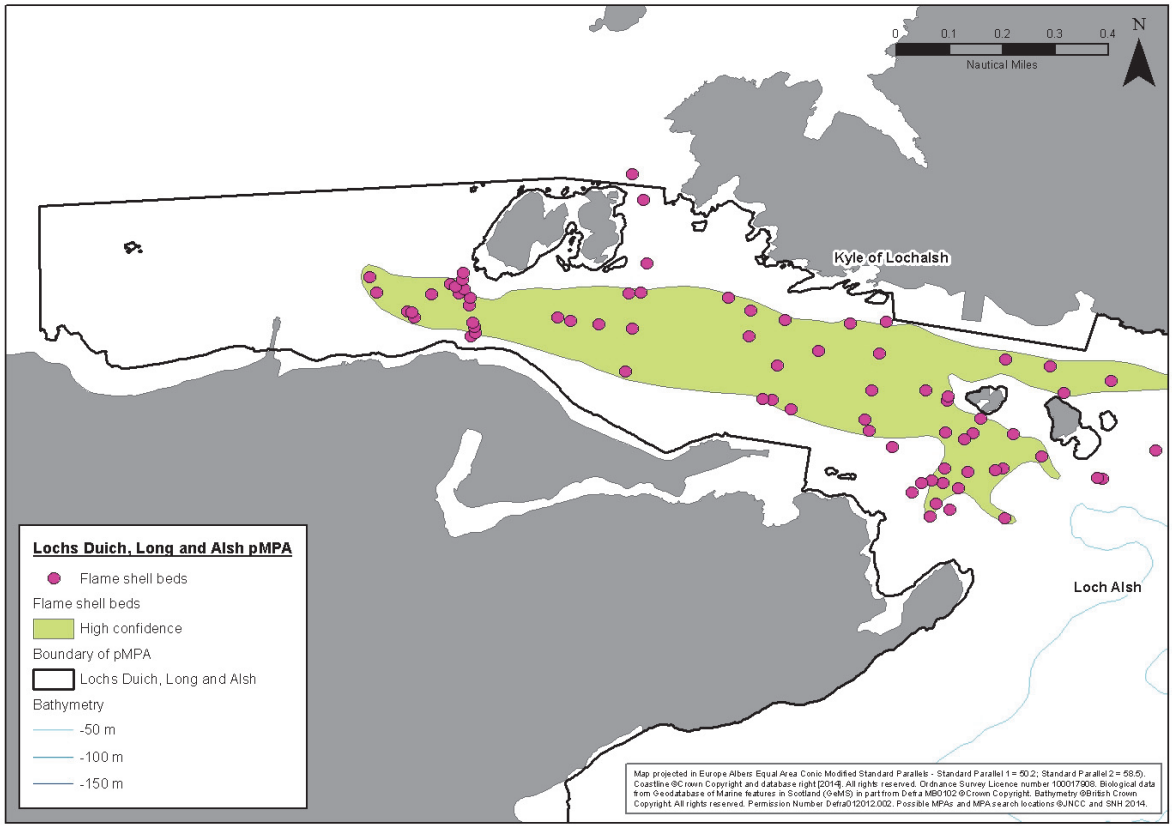

Figure 38. The distribution of flame shell beds at Kyle of Loch Alsh, coded for confidence.

3.5.2.3 Burrowed mud components

A supervised classification modelling approach has been taken to delineate polygons to show the distribution of the fireworks anemone, *Pachycerianthus multiplicatus,* within Lochs Duich, Long and Alsh possible MPA. This is largely because *P. multiplicatus* appears to be widely distributed, but at different levels of abundance on different types of habitat. This makes the "by-eye", rule-based approach difficult since the various conditions that potentially support this species and its habitat are quite wide. A "fuzzy" probabilistic approach, available through supervised classification, may give a more nuanced view of the likely distribution of the species.

The focus of the analysis was on the distribution of *P. multiplicatus* and four classes were identified for ground truthing:-

- *P. multiplicatus* recorded as Frequent or Abundant (SACFOR scale) and where biotope **SS.SMu.CFiMu.SpnMeg** was assigned to the record
- Records in similar biotopes, but with abundance of Occasional, Rare or Present.
- *P. multiplicatus* at low abundance (Occasional or Rare) where the indications were that the habitat was mixed.
- *P. multiplicatus* at all abundance levels where the biotope was **SS.SMu.IFiMu.Vir**

In addition four classes representing neighbouring habitats were also used for ground truthing:- burrowed mud (without *P. multiplicatus*), mud (not burrowed), muddy sand and rock. These additional ground truth classes provided context for the model (Figure 39). Note that care has been taken to exclude data where there is uncertainty about the presence or

absence of *Pachycerianthus multiplicatus* as poor ground truth data can undermine the results of the classification process.

Available burrowed mud records range from 1980 to 2012 with most records from 1988 or 2004. These records have been checked and are “certain”. They also include SACFOR abundance records and notes attached with details of biota for some but not all of the records. Records with no *P. multiplicatus* have been used as null records.

Four acoustic images were used for the classification process:- (1) bathymetry; (2) backscatter; (3) variance in depth (standard deviation of a moving window filter measuring roughness); and (4) hillshade (another view of topographic roughness). The images were processed so that they were co-registered and had exactly the same geographic extent and resolution (5 m). The original values of the variables were standardised by stretching to nominal values between 0 – 255.

The resulting raster distribution map of the ground truth classes was then converted into a vector format and exported to the ArcGIS project for mapping. The polygons resulting from the classification process are very detailed and often small and isolated, despite the filtering applied to the raster images. No attempt has been made to generalise these polygons as this would only reduce the information content of the polygons. However, the polygons for each habitat class have been combined to reduce the complexity and extent of the attribute tables. Because of the great difference in the number of ground truth records within the possible MPA, the polygons have been divided into two sets covering Loch Duich (where the polygons have been assigned high confidence) and Lochs Long and Alsh (low confidence due to sparse ground truth data).

The modelling results correspond to the pattern of distribution of the point data. A map of the *P. multiplicatus* classes has been presented without the other neighbouring classes for greater simplicity (Figure 39).

The higher abundance of *P. multiplicatus* occurs in the deeper and more sheltered regions of Loch Duich whilst the lower abundances are found in the burrowed mud towards the sides of the lochs. Low abundances are also recorded on mixed substrata around the margins of the lochs where bedrock slopes give way to sand, muddy sand and cobble.

The model has also been applied to Loch Alsh and Loch Long and the model suggests that there might be small areas where *P. multiplicatus* could be found in abundance (frequent to abundant), although the predicted habitat in the deeper regions of Loch Alsh is for burrowed mud only. Sparse records of *P. multiplicatus* could be found almost anywhere in mixed sediment and muddy sand around the margins of the lochs.

Note that the map resulting from supervised classification does not coincide precisely with the map drawn using the rule-based approach. This should be expected as the classification procedure is only as good as the data input into the process: If there are sparse ground truth data (as there are in many areas of this site, such as Loch Long), then the classification will be less successful than areas where there are many high quality data points. In such cases, polygons drawn using a rule-based approach. However, the study provides an example of the type of results that could be expected from supervised classification if improved upon using a well-designed sampling program.

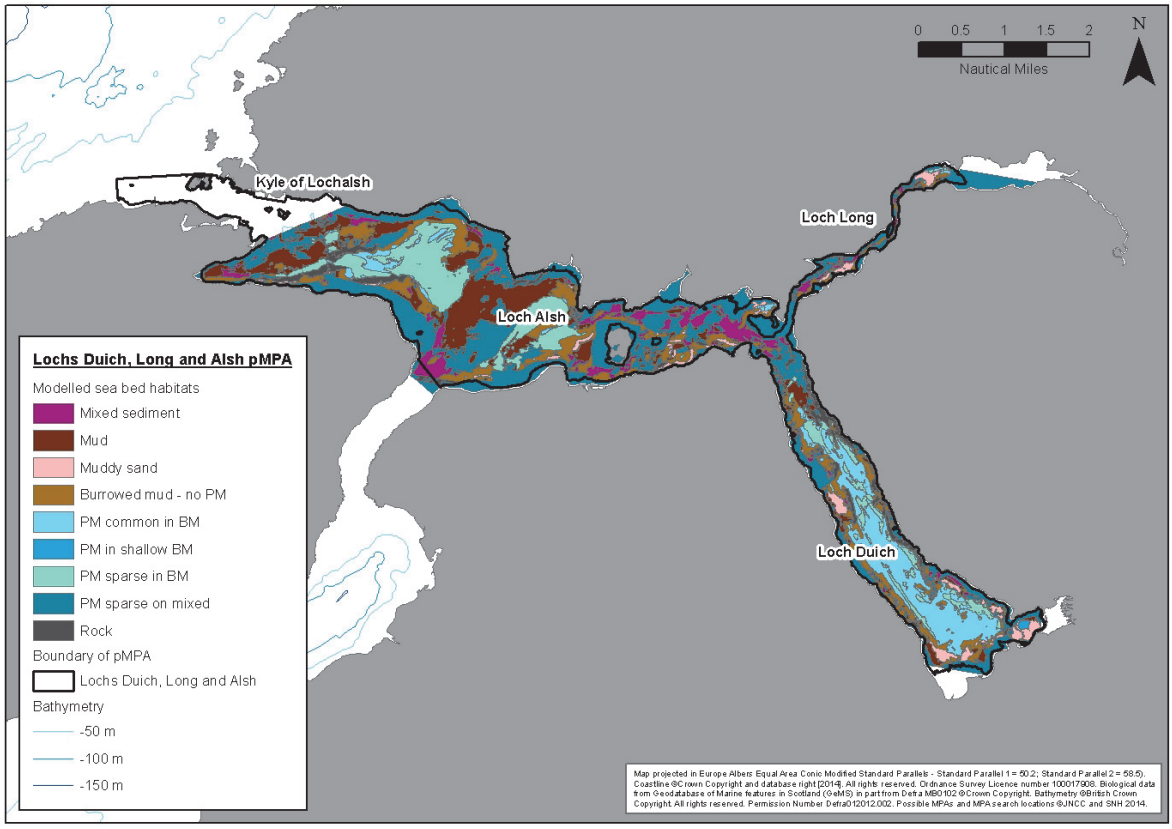

Figure 39. Modelled distribution of muddy habitats within Lochs Duich, Long and Alsh possible MPA (PM = Pachycerianthus multiplicatus*)*

3.5.2.4 Summary of Proposed protected features for the Lochs Duich, Long and Alsh possible MPA Lochs Duich, Long and Alsh possible MPA

Loch Duich has been well sampled. The majority of the sea floor, away from the rocky margins, consists of the proposed protected feature burrowed mud. Conversely to this the deeper water of Lochs Alsh and Long have been sparsely sampled and so the distribution of burrowed mud has been interpreted from the acoustic data. Consequently the burrowed mud polygons within these two lochs are of low confidence (see Section 3.5.2.3 for burrowed mud component mapping). The distribution may extend beyond the tentative boundaries drawn. However, much of the sea floor, especially at the confluence of the three lochs, is shallow , consisting of mixed sediment (Figure 40).

The flame shell bed at Kyle of Loch Alsh has been well surveyed, the most recent of which took place in summer 2012 (Moore and Harries, 2012).

The distribution of all the proposed protected features is summarised in Figure 40. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

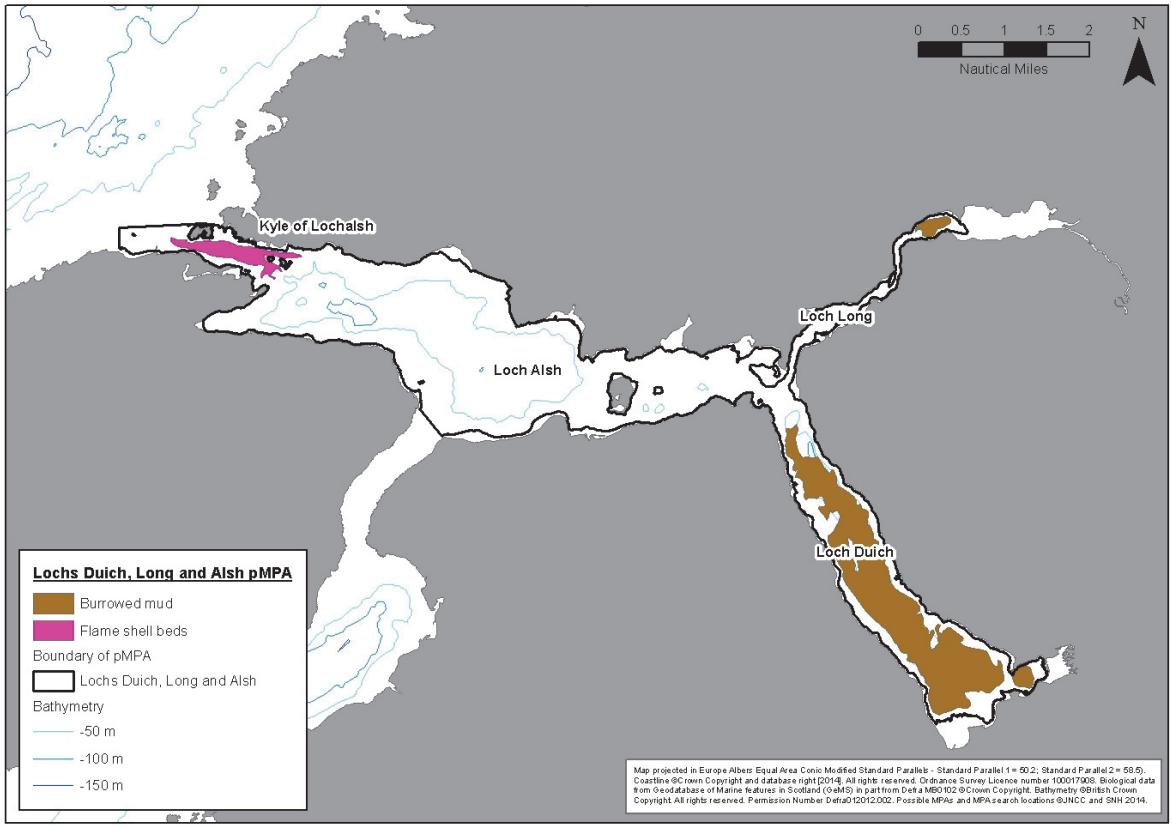

Figure 40. The distribution of all proposed protected features within the Lochs Duich, Long and Alsh possible MPA.

3.6 North-west sea lochs & Summer Isles possible Nature Conservation MPA

The North-west sea lochs and Summer Isles possible Nature Conservation MPA was identified for the following MPA search features, which are now referred to as proposed protected features; burrowed mud, flame shell beds, kelp and seaweed communities on sublittoral sediment, maerl beds, maerl or coarse shell gravel with burrowing sea cucumbers, and northern feather star aggregations on mixed substrata. Marine Geomorphology of the Scottish Shelf Seabed, Quaternary of Scotland, Submarine Mass Movement and Seabed Fluid and Gas Seep geodiversity features are also present and have been recommended for inclusion. Circalittoral muddy sand communities (CMS) are not a MPA search feature but have been recommended as proposed protected features as they are considered to add to the broader representativity of the Scottish MPA network (i.e. representative features). The proposed protected features to be mapped are listed in Table 8.

Details of supporting evidence are provided in the North-west sea lochs and Summer Isles possible MPA data confidence assessment [see- http://www.snh.gov.uk/docs/A1034854.pdf] with the existing available data holdings in Figure 41.

Table 8: Proposed protected features to be mapped within the North-west sea lochs and Summer Isle possible MPA.

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
North-west sea lochs and Summer Isles	Burrowed mud	SS.SMu.CFiMu.SpnMeg SS.SMu.CFiMu.MegMax Tall sea pen, *Funiculina quadrangularis* Fireworks anemone, *Pachycerianthus multiplicatus*
	Circalittoral muddy sand communities	SS.SSa.CMuSa
	Flame shell beds	SS.SMx.IMx.Lim
	Kelp and seaweed communities on sublittoral sediment	SS.SMp.KSwSS
	Maerl beds	SS.SMp.Mrl
	Maerl or coarse shell gravel with burrowing sea cucumbers	SS.SCS.CCS.Nmix
	Northern feather star aggregations on mixed substrata	*no specific biotope*

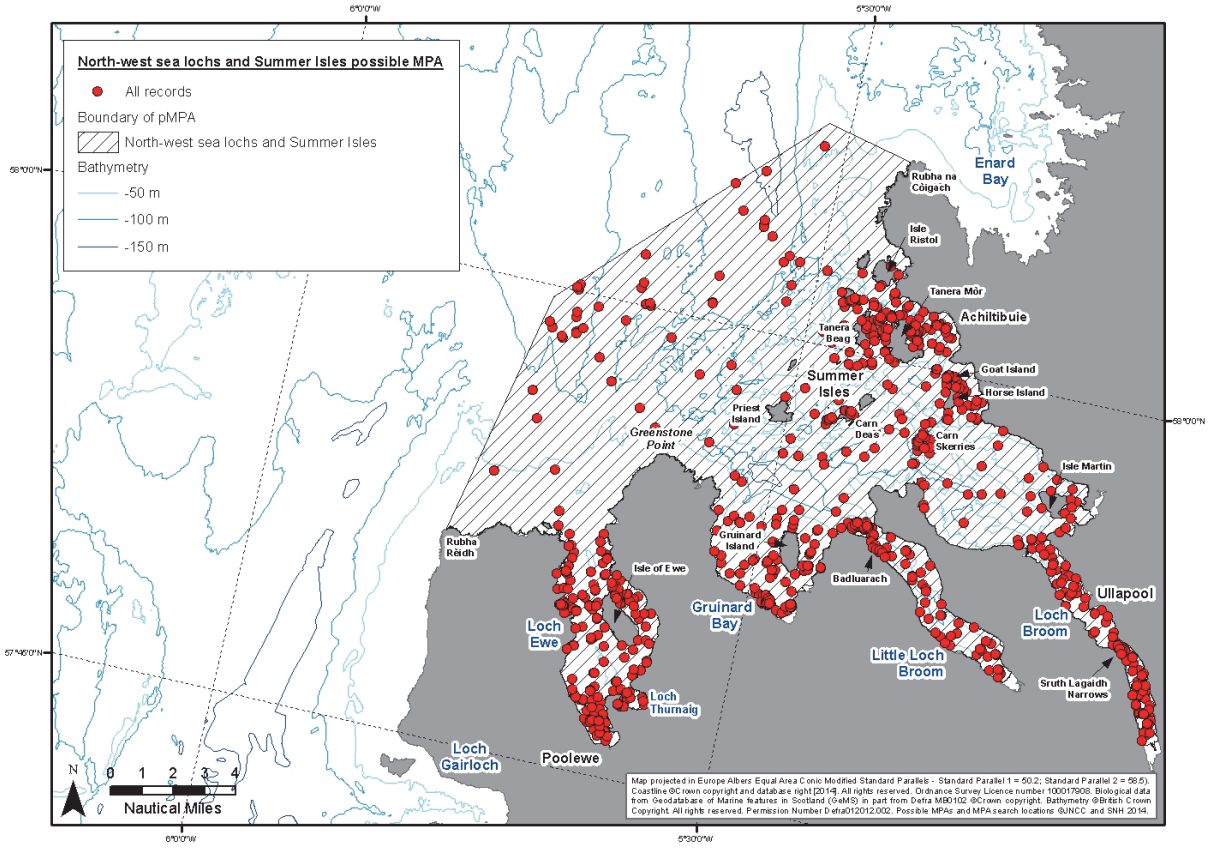

Figure 41. Existing data holdings within North-west sea lochs and Summer Isles possible MPA.

3.6.1 Data assessment and requirements for more comprehensive mapping

The North-west sea lochs and Summer Isles possible Nature conservation MPA is large and has a complex, indented coastline and varied physiography. There are eight proposed protected features present within the possible MPA and the point data are scattered for many of these features. The inlets appear to be reasonably well surveyed, however, the areas adjacent to the headlands have sparse records.

The acoustic data are of variable quality and the coverage is incomplete. However, digital elevation models derived from the Defra bathymetry have provided a low resolution background layer over which the available multibeam images have been draped and this combination has been used to guide boundaries.

The backscatter images available for this possible MPA are only partially useful, showing areas of hard and soft ground. However, it is difficult to correlate the distribution of many of the records to acoustic ground type except in homogeneous areas. This is probably because of the positional accuracy of many of the records combined with the heterogeneity over much of the area. The coverage is also incomplete, especially in shallow inshore areas around the Summer Isles themselves. This has made it particularly difficult to map the distribution of some features, such as maerl beds, whose distribution is scattered around these complex geographic features.

The proposed protected features, burrowed mud and circalittoral muddy sand communities (CMS), have the potential to overlap, as shown in the schematic in Figure 42.

The geographic distribution of the proposed protected feature records seems to indicate that there is a geographic overlap with the CMS bordering the burrowed mud in much of the area (see section 3.6.2.8).

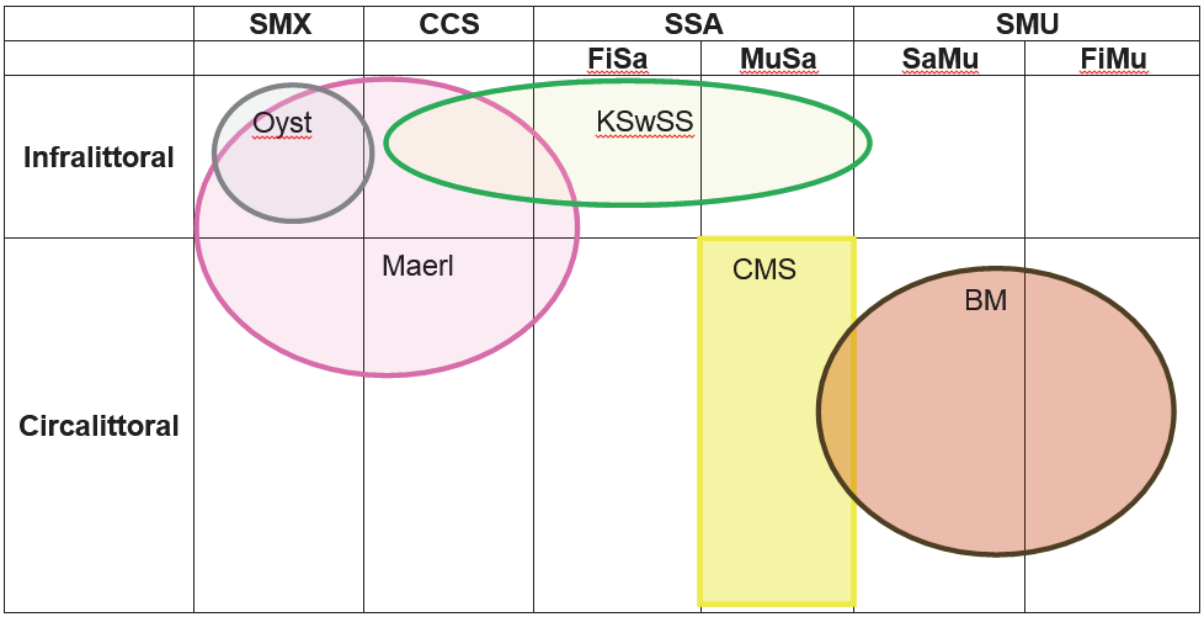

Figure 42. Schematic diagram indicating the distribution of possible protected features on a sediment/depth plot.

Mapping with the data at present has provided an unequal coverage of polygons and widely varying levels of confidence across the possible MPA. For example, the sediment areas

around the headlands between the lochs lack adequate sampling. The acoustic data will be used to structure a sampling campaign to fill gaps in the existing ground truthing coverage. This will help improve our accuracy and understanding of the protected features present.

3.6.2 Proposed protected marine features

3.6.2.1 Burrowed mud

The distribution of burrowed mud appears to occur in three different physiographic areas: (1) the deeper, central regions of the sheltered lochs, (2) the approaches to the sea lochs and (3) deeper water offshore (Figure 43).

The habitats recorded in the deeper regions of the sheltered sea lochs are predominantly burrowed mud, and polygons can be drawn around these features, guided by slope (DEM and concentration of depth contours), with high confidence. Note that depth alone is not a good guide as burrowed mud records occur in relatively shallow water in the inner lochs (e.g. -15 m in the inner Loch Broom and Little Loch Broom) and much deeper in the outer regions of these lochs (- 40 m is typical).

The approaches to the sea lochs are much more varied and, although there are numerous records for burrowed mud, these are often intermixed with other habitats and therefore have been assigned a moderate or low level of confidence. The boundaries to these burrowed mud areas have been guided by indications of homogeneous, level sea floor from depth contours and the DEM.

Records for burrowed mud located deeper and further from shore are more homogeneous. However, the records are scattered and grade into coarser sediment at the margins of their distribution. For this reason, the boundaries are uncertain and the polygon has been assigned moderate confidence.

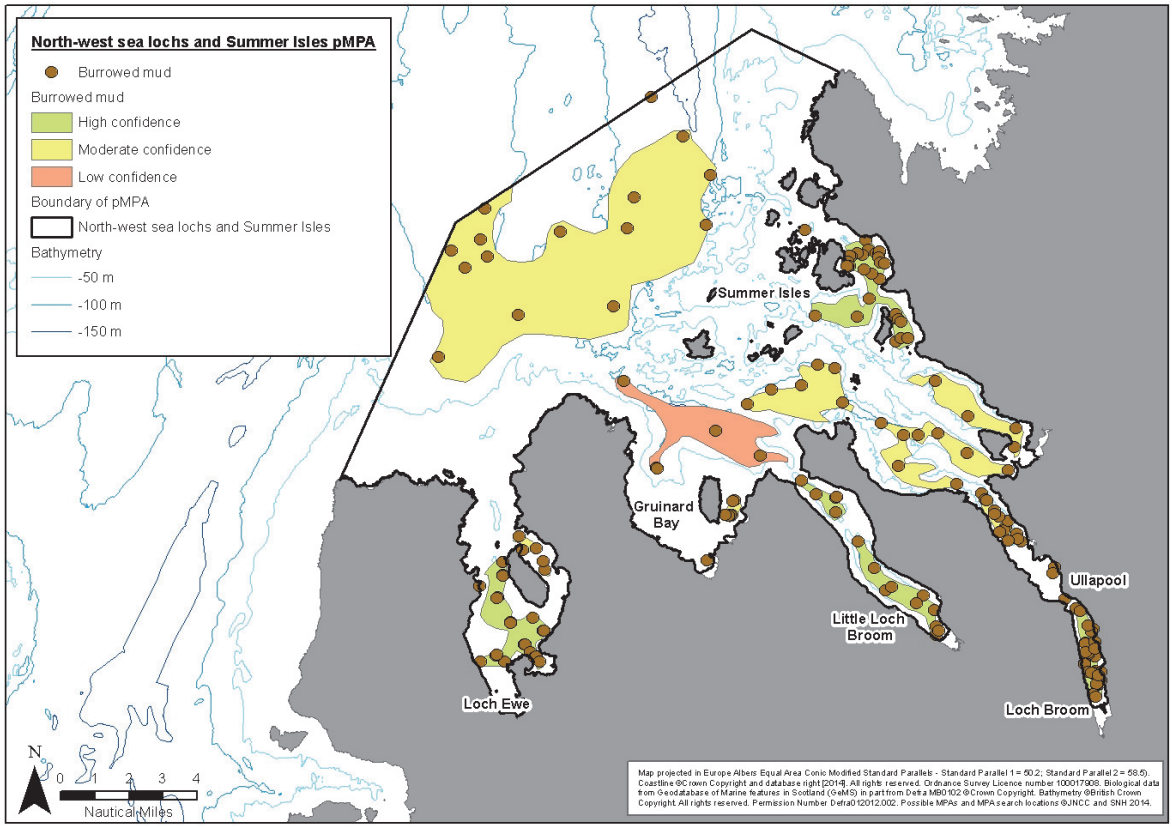

Figure 43. The distribution of burrowed mud for the North-west sea lochs and Summer Isles possible MPA, coded for confidence.

3.6.2.2 Circalittoral muddy sand communities (CMS)

The CMS proposed protected feature occurs around the margins of the burrowed mud feature. In the sea lochs this means slightly shallower water fringing the coastline. Depth and a small buffer have been used to constrain the possible distribution of CMS in the lochs and the polygons have been constructed with high confidence.

Further offshore the records are more scattered and the potential distribution of the CMS feature is large. Accordingly, a moderate level of confidence has been assigned to these polygons (Figure 44).

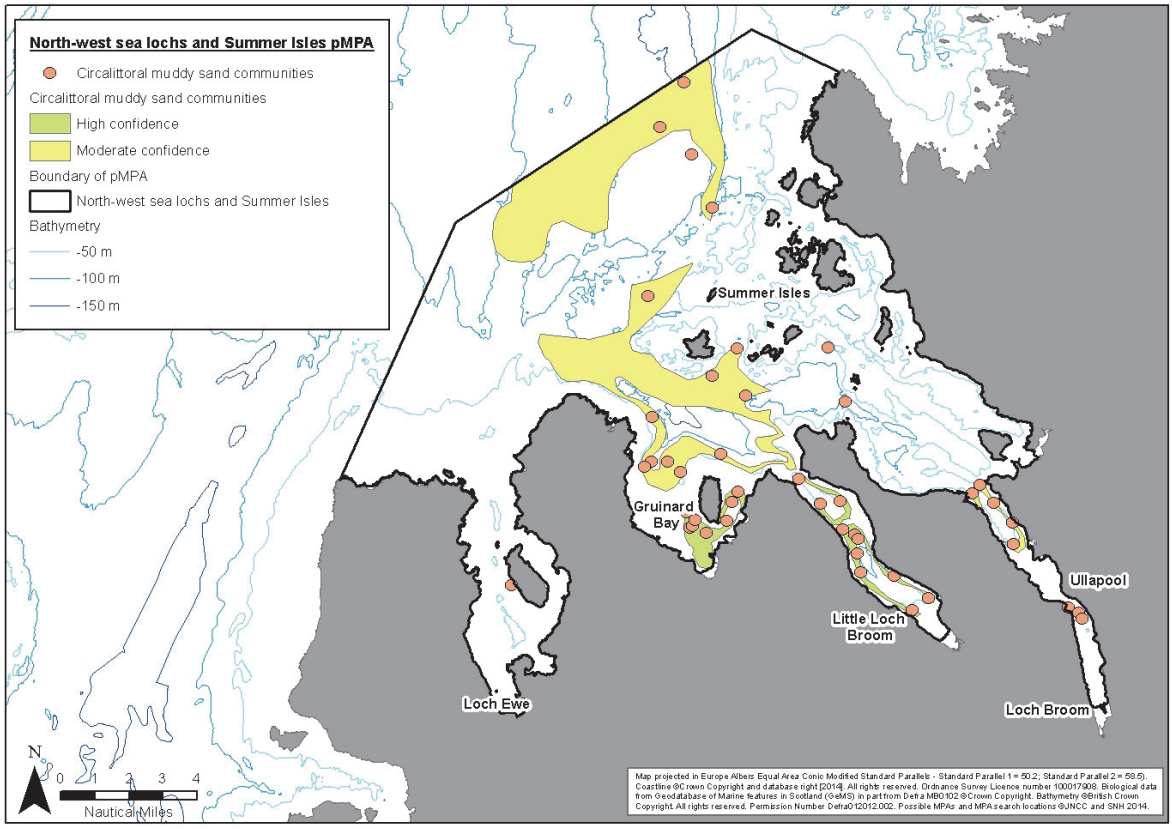

Figure 44. The distribution of circalittoral muddy sand communities for the North-west sea lochs & Summer Isles possible MPA, coded for confidence.

3.6.2.3 Kelp and seaweed communities on sublittoral sediment

Records of kelp and seaweed communities (**SS.SMp.KSwSS**) are widely distributed (Figure 45). However, given that this community is often located in a narrow strip on moderately steep-sided lochs between the lower shore and the circalittoral zone, the point records themselves are a poor indication of the true extent of the feature. It is likely that the true pattern of distribution is a thin (almost linear) strip found extensively on infralittoral sediment habitats in sheltered to moderately sheltered conditions. This potentially favourable habitat is probably very widespread and scattered point samples cannot adequately cover all of these habitats.

However, the acoustic data have insufficient coverage in this zone and it was not possible to plot the distribution of this feature with the aid of the aerial photographs supplied due to poor light penetration and surface reflectance.

An attempt has been made to draw polygons following the coastlines of Loch Broom and Little Loch Broom aided by the images in Google Earth which showed the sediment shores. Other small polygons have been drawn around the Summer Isles although these suffer from the same constraints as the maerl polygons in that the point samples are very intermixed spatially and the topography is very complex at a fine spatial scale.

Larger polygons have been drawn in Gruinard Bay and Loch Ewe where there are more extensive areas of infralittoral sediment. These have been well sampled, although the **SS.SMp.KSwSS** feature is intermixed with sandy and muddy sediments, maerl and sea grass. The boundaries to these polygons have been constrained by these other records and by the topography of the sea bed.

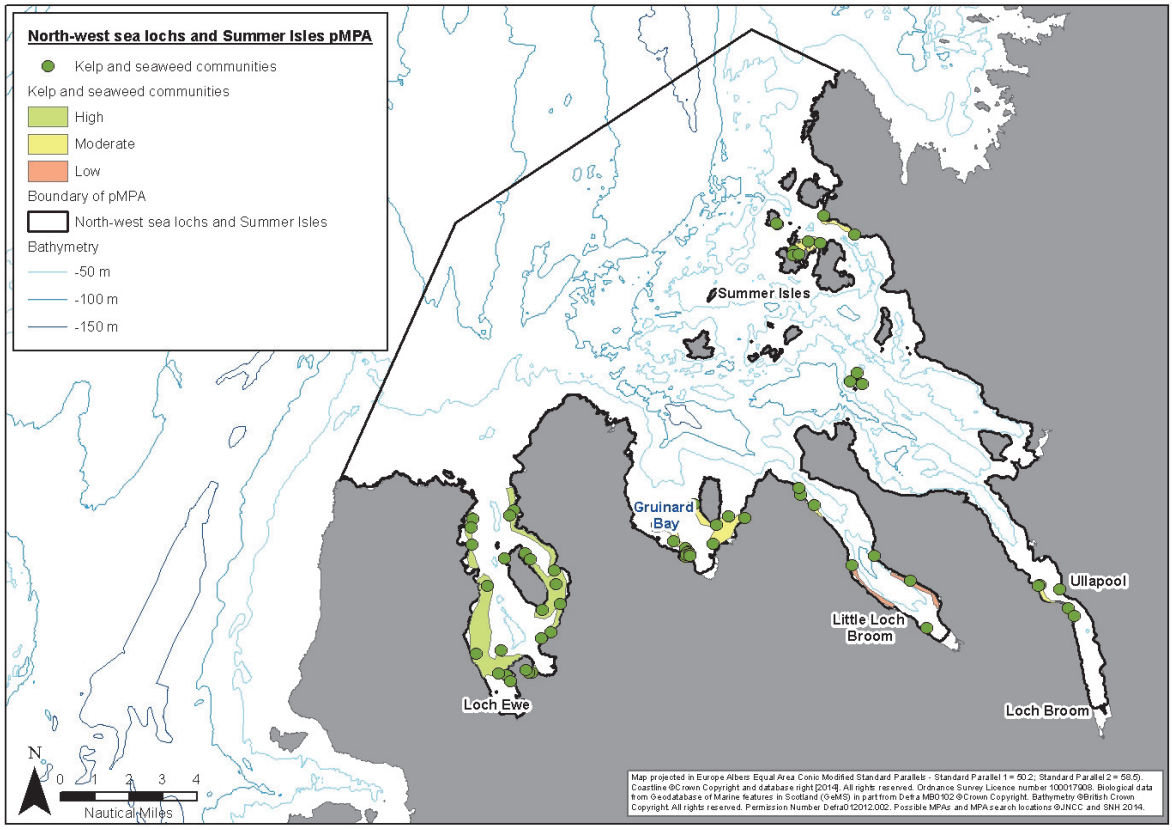

Figure 45. The distribution of kelp and seaweed communities on sublittoral sediment within the North-west sea lochs & Summer Isles possible MPA, coded for confidence.

3.6.2.4 Flame shell beds

There is a concentration of flame shell bed records within the narrows at Corry Point, Loch Broom for which a small polygon can be drawn. These records are located in a mixed sediment habitat, often with brittlestars. The polygon for this proposed protected feature has been drawn to enclose the data points and exclude neighbouring mixed sediment and brittlestar records.

Apart from these records, there are two other records in the possible MPA which are both located in maerl beds (Figure 46 and Figure 47).

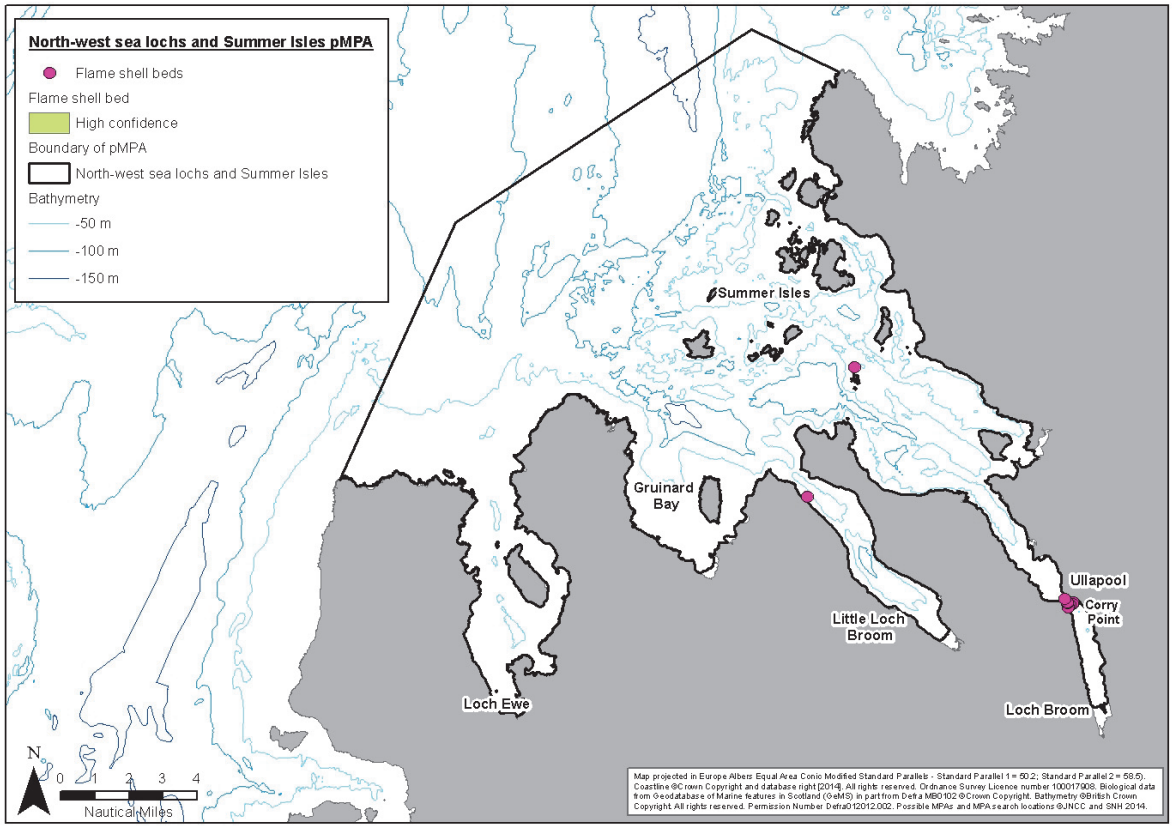

Figure 46. The point distribution of flame shell bed records within the North-west sea lochs and Summer Isles possible MPA, coded for confidence.

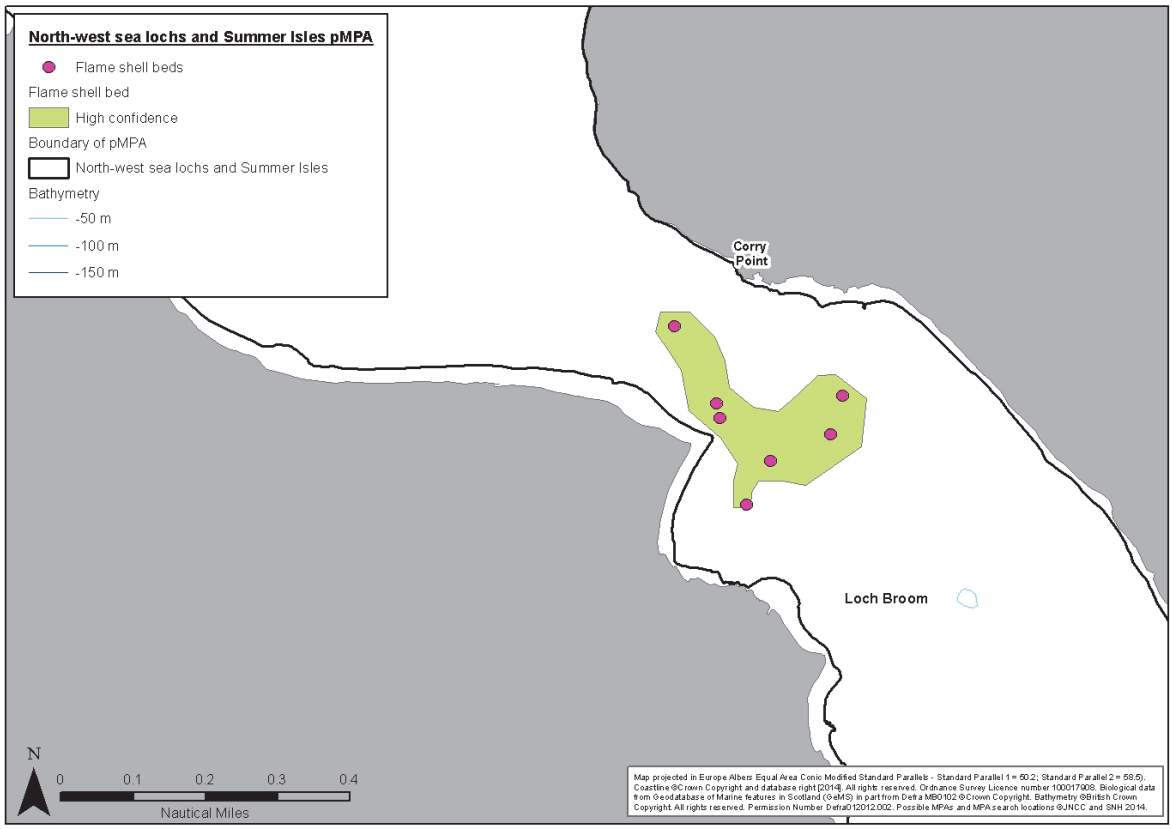

Figure 47. The distribution of flame shell beds in Loch Broom.

3.6.2.5 Maerl beds

The majority of the maerl bed records are located in a few small locations, with some scattered records throughout the possible Nature Conservation MPA (Figure 48). This may be due to a small number of focused surveys having been conducted and may not represent the true distribution or extent of maerl beds in the area.

Drawing polygons around maerl bed records is problematic for a number of reasons: Firstly, although the records are quite numerous, they are often mixed spatially with non-maerl records, particularly kelp and seaweed communities, sand, and mixed substrate habitats. Secondly, the bathymetric and acoustic data are not of a fine enough resolution to support numerous small polygons around many of the complex geographic features that maerl seems to favour.

Polygons have been drawn around the maerl bed records and constrained by non-maerl records. Depth and topography were not particularly useful since most records are from shallow areas situated some distance from steep slopes. The majority of the records are shallower than -25 m (derived from the Defra bathymetry) and this contour has been used to constrain polygons where no other data provided constraints (e.g. the **SS.SMp.KSwSS** polygons). The aerial photographs did not provide any definitive information to support boundaries.

All of the polygons, therefore, are supported by point records without much extrapolation based on collateral information. Thus, whilst the polygons probably reflect the distribution of maerl close to the point records to a moderate level of confidence, they are unlikely to represent the full extent of this habitat.

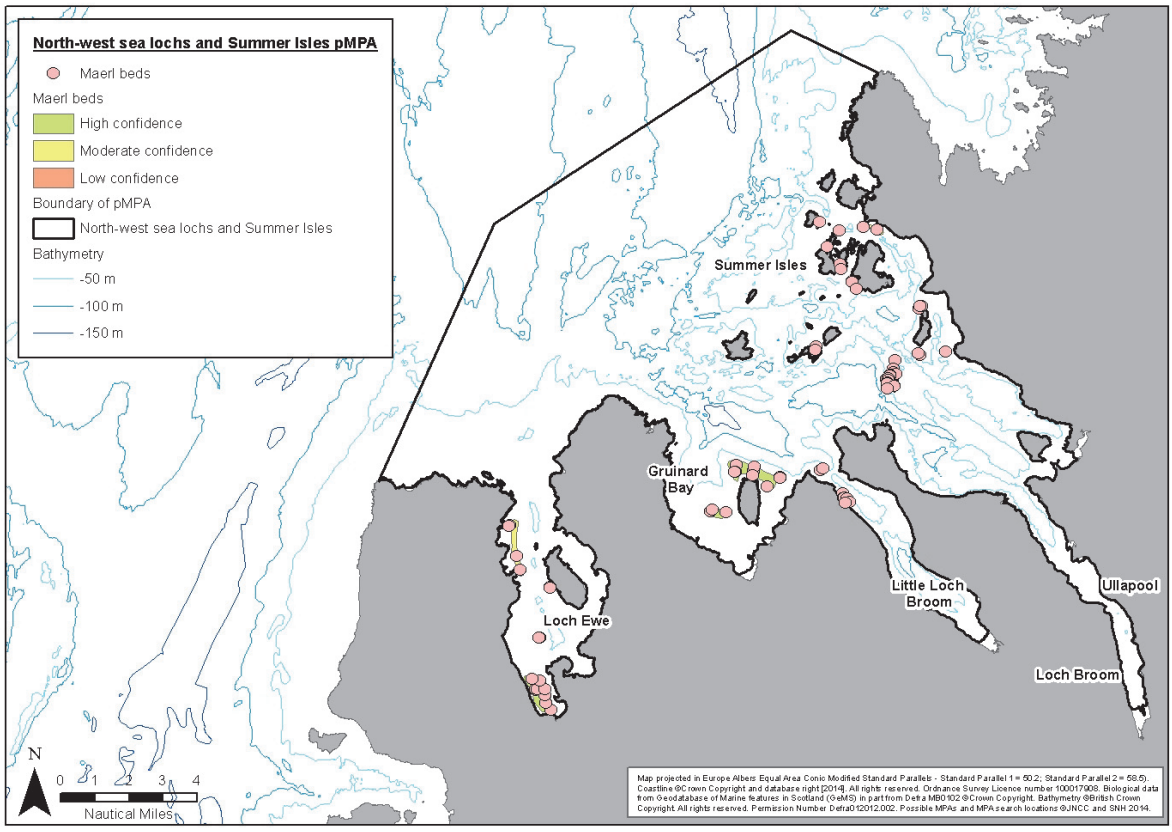

Figure 48. The distribution of maerl beds for the North-west sea lochs and Summer Isles possible MPA, coded for confidence.

3.6.2.6 Maerl or coarse shell gravel with burrowing sea cucumbers

There are only three records of the biotope **SS.SCS.CCS.Nmix**, all of which lie close to maerl beds. There are numerous records of the related maerl with *Neopentadactyla mixta* (**SS.SMp.Mrl.Pcal.Nmix**) that have been included in the maerl records and used to help map the distribution of maerl beds (Figure 49). Only polygons for maerl beds (including **SS.SMp.Mrl.Pcal.Nmix**) have been drawn and the point records of **SS.SCS.CCS.Nmix** are probably best shown as points overlaying the maerl bed polygons.

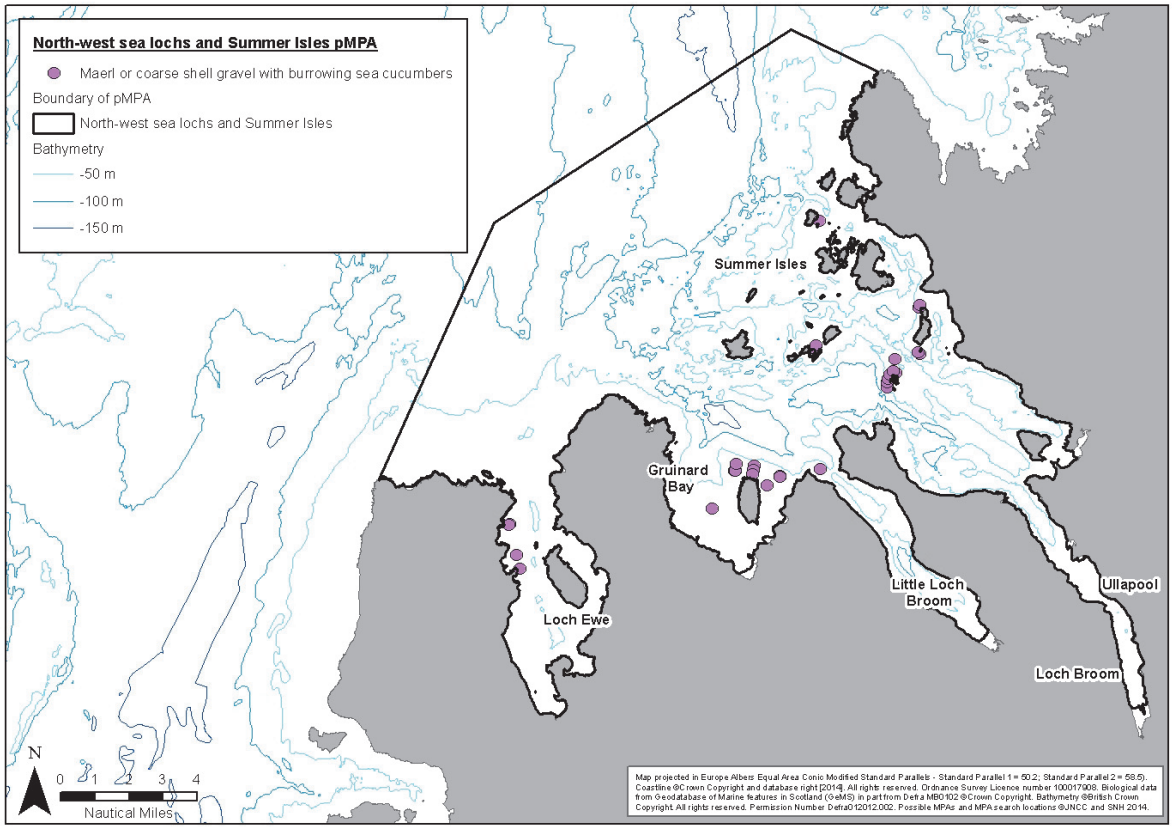

Figure 49. The point distribution of maerl or coarse shell gravel with burrowing sea cucumbers within the North-west sea lochs and Summer Isles possible MPA.

3.6.2.7 Northern feather star aggregations on mixed substrata

Records of northern feather star aggregations on mixed substrata (*Leptometra celtica*) have been considered potential aggregations if they have been assigned between frequent (F) and abundant (A) on the SACFOR scale in the attribute table. The records within this possible MPA are scattered (Figure 50), although there appears to be some focus of survey effort on mixed substrata in the narrows of Loch Broom and Little Loch Broom, especially at the entrance to Little Loch Broom (Figure 51). However, the situation is confused even at the latter location with a mix of abundant and rare SACFOR scores.

In general, the location of abundant northern feather star records appears to be correlated with the backscatter values. However, the records are scattered over large areas of potential habitat as suggested by the backscatter image and it would be dubious to extrapolate the distribution of the feature on the basis of backscatter without many more definitive records. It is doubtful, therefore, if drawing a polygon around the records supported by the backscatter values would add more than the point records themselves.

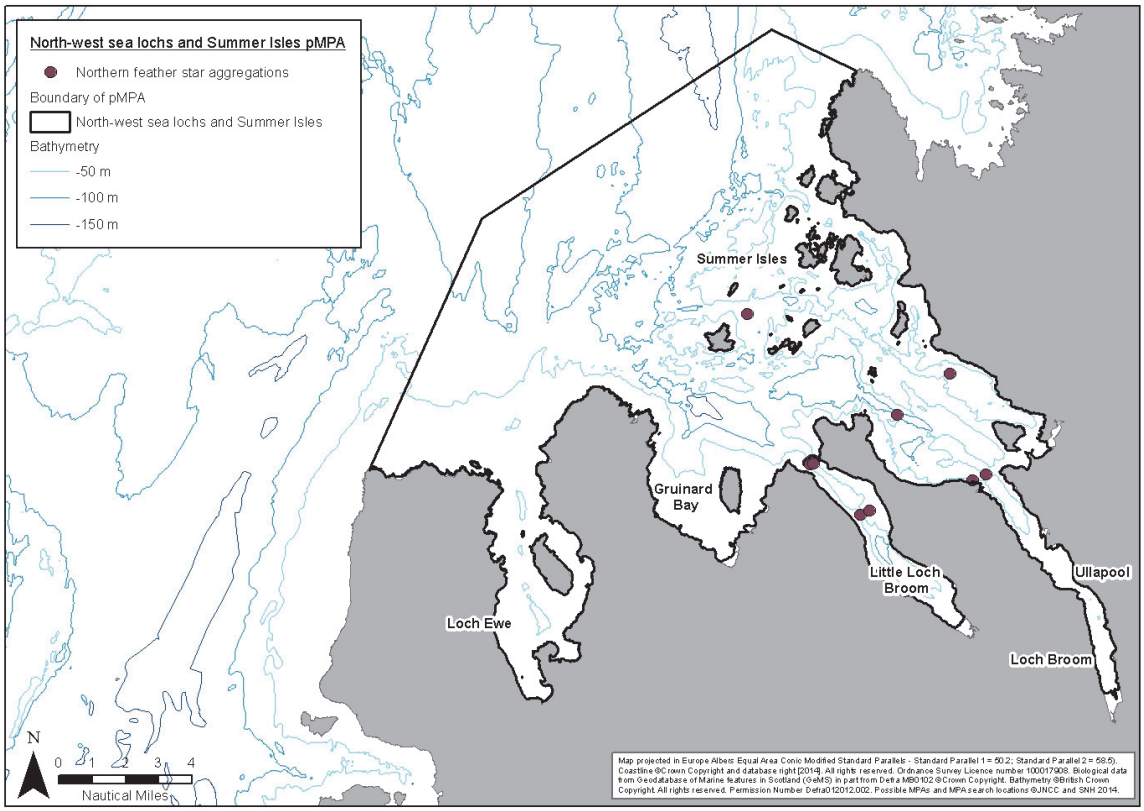

Figure 50. The point distribution of northern feather star aggregations on mixed substrata within the North-west sea loch and Summer Isles possible MPA.

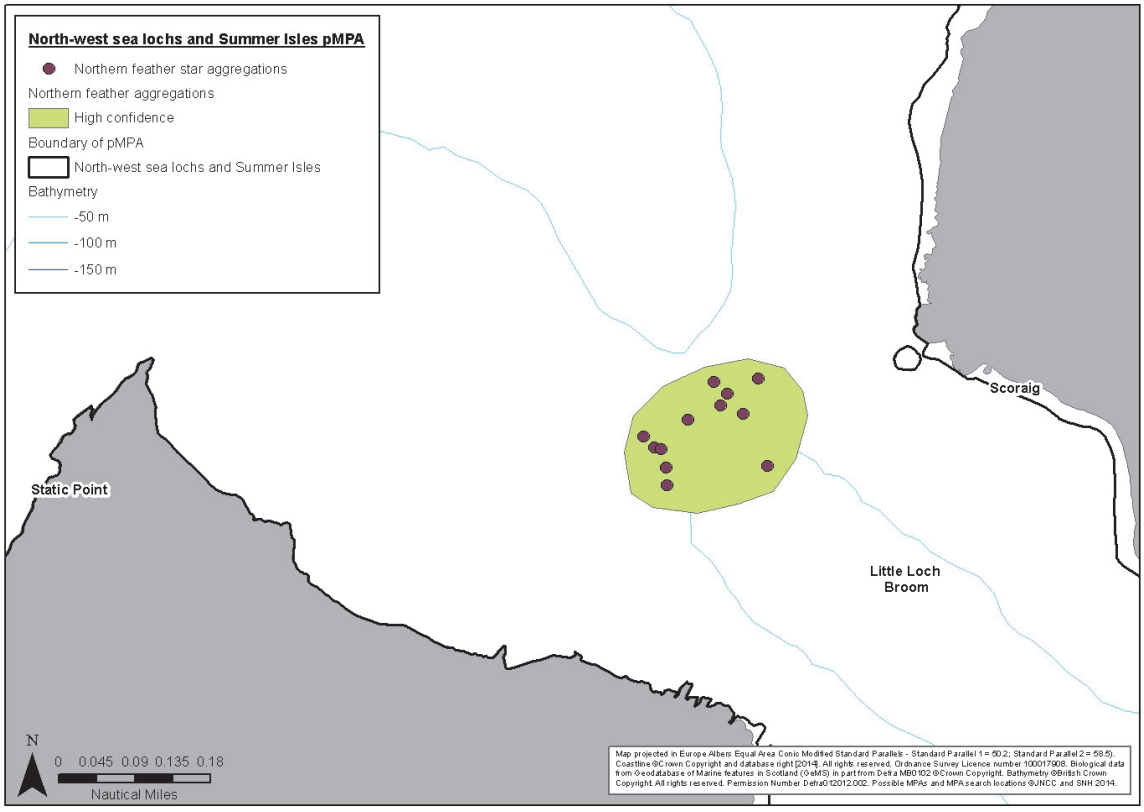

Figure 51. The concentration of northern feather star aggregations on mixed substrata at the entrance to Little Loch Broom

3.6.2.8 Burrowed mud component mapping

The majority of all records of the tall sea pen *Funiculina quadrangularis* lay within an existing polygon for the generic burrowed mud proposed protected feature and, without an intensive modelling programme for all habitats, it is unlikely that the boundaries of these polygon should change.

Instead, the approach adopted was to re-assign polygons to a burrowed mud, *Funiculina quadrangularis* proposed protected feature where this is the dominant feature and the "component" attribute table altered to read **SS.SMu.CFiMu.SpnMeg.Fun** only. The attributes for burrowed mud polygons where no (or very limited) *F. quadrangularis* was indicated were amended to **SS.SMu.CFiMu.SpnMeg** only. Mixed polygons were either subdivided into two or more polygons (where there appeared to be geographic separation of the components) or left as burrowed mud with the components in the attribute table remaining as both biotopes.

The distribution of *F. quadrangularis* (and the biotope **SS.SMu.CFiMu.SpnMeg.Fun**), as distinct from the higher level biotope **SS.SMu.CFiMu.SpnMeg**, appears to be related to areas with low water movement (Figure 52). There are numerous records in the deeper offshore region of this possible Nature Conservation MPA (with even stronger representation further west in the Minch) and also the more sheltered inner regions of Loch Broom and Little Loch Broom. Between these two regions the muddy sediment supports burrowed mud without *F. quadrangularis*. Presumably this is subject to greater wave action.

However, there is a great deal of overlap in the distribution. For example, there is a cluster of records of *F. quadrangularis* in the lee of the Summer Isles. The records of the components of the generic burrowed mud proposed protected feature are scattered and also clustered where there has been a concentration of sampling effort.

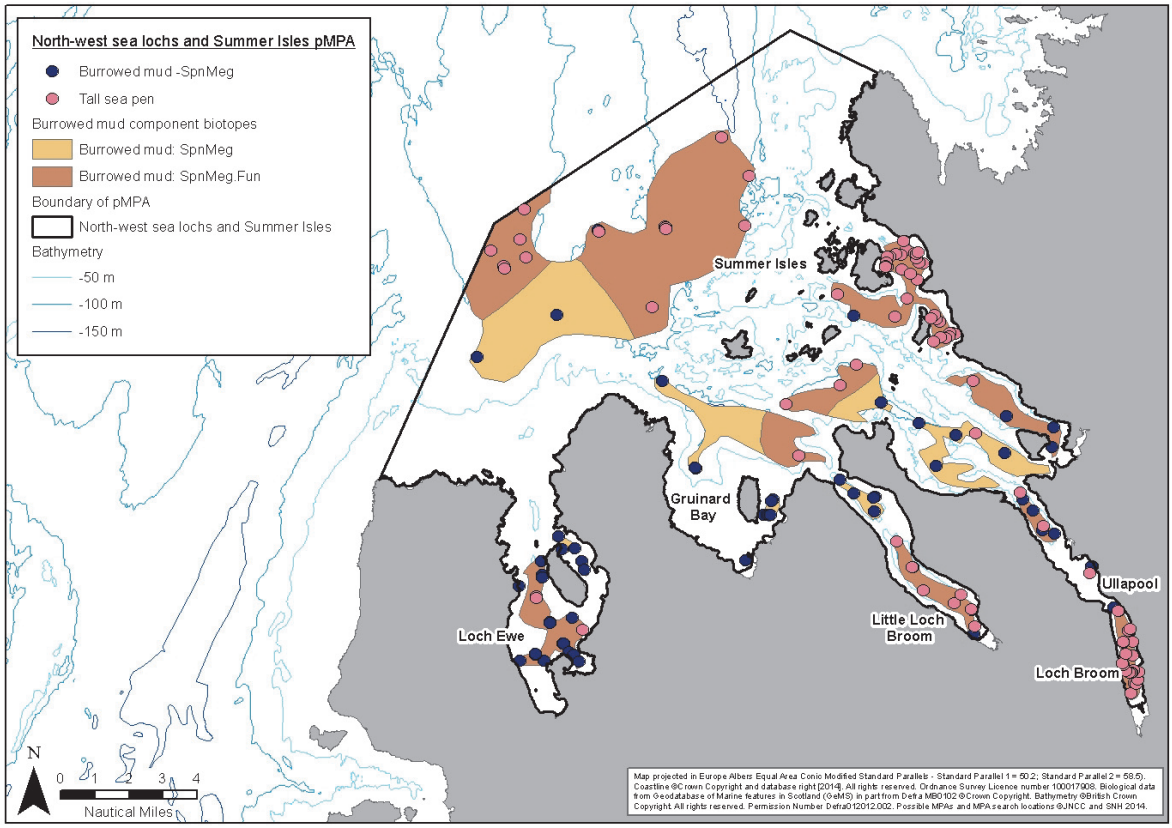

Figure 52. Burrowed mud component polygons within the North-west sea lochs and Summer Isles possible MPA.

3.6.2.9 Summary of proposed protected features for the North-west sea lochs and Summer Isles possible MPA.

The physical geography of this site is complex and ranges from deep offshore sediments, exposed near-shore rock and coarse sediment to very sheltered sea lochs with narrows with shallow and tidally accelerated water flow. The conditions needed to sustain some of the proposed protected features must be very local and specific leading to many small isolated patches of features. This makes it difficult to estimate the distribution of many features in a comprehensive way, despite the number of records for the area (Figure 41).

On the other hand, some features that are more broadly defined (e.g. burrowed mud, circalittoral muddy sands) occur widely and in very different situations. It is likely that these features have a distinct composition in these different environmental conditions, which is not apparent from the current polygon maps.

The distribution of all the proposed protected features is summarised in Figure 53. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

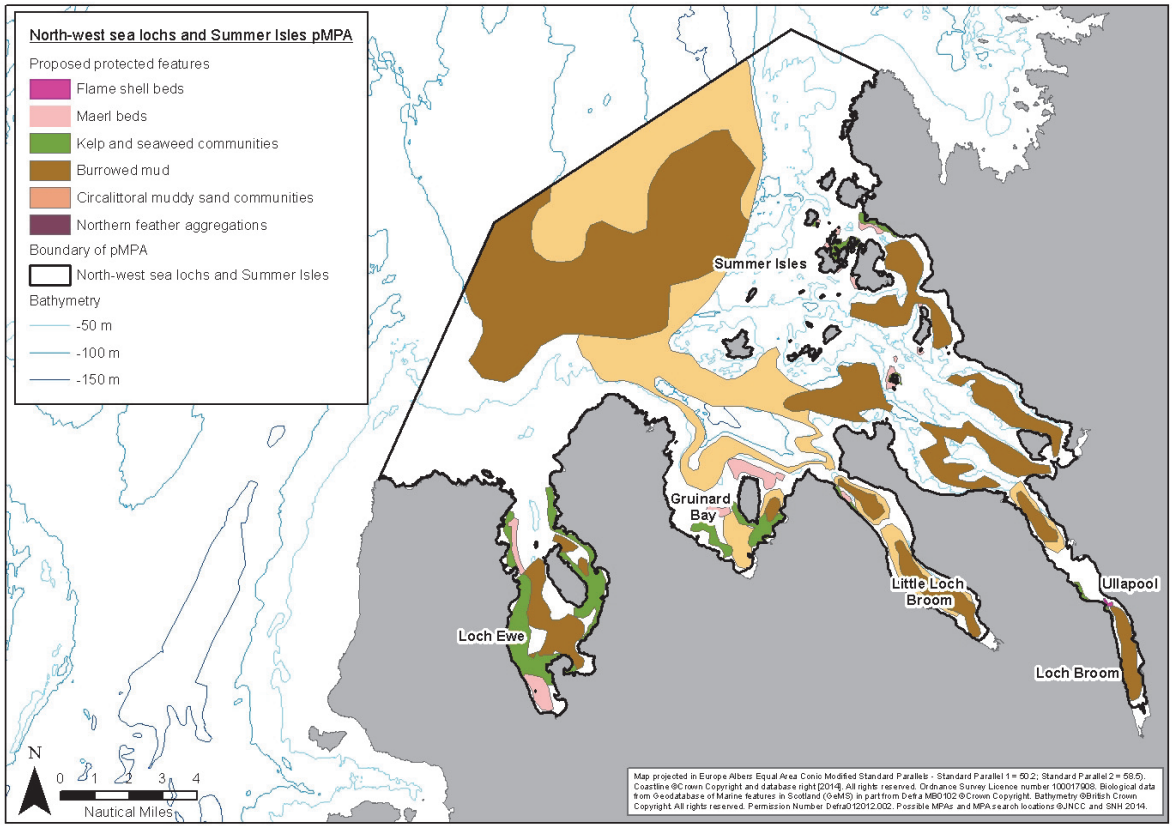

Figure 53. The distribution of proposed protected features within the North-west sea lochs and Summer Isles possible MPA.

3.7 Small Isles possible Nature Conservation MPA

The Small Isles possible Nature Conservation MPA was identified for seven MPA search features, which are now referred to as proposed protected features; the black guillemot; burrowed mud; fan mussel aggregations; horse mussel beds; northern feather star aggregations on mixed substrata; northern sea fan and sponge communities and shelf deeps, and one geodiversity feature (Quaternary of Scotland). Circalittoral sand and mud communities and white cluster anemones are not MPA search features but have been recommended as proposed protected features as they are considered to add to the broader representativity of the Scottish MPA network (i.e. representative features). The proposed protected features to be mapped within this project are listed in Table 9.

Details of supporting evidence are provided in the Small Isles possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1034852.pdf] with the existing data holdings shown in Figure 54.

Table 9: Proposed protected features to be mapped within the Small Isles possible MPA.

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
Small Isles	Burrowed mud	SS.SMu.CFiMu.SpnMeg SS.SMu.CFiMu.MegMax Tall sea pen, *Funiculina quadrangularis* Fireworks anemone, *Pachycerianthus multiplicatus*
	Circalittoral sand and mud communities (CSM)	SS.SSa.OSa SS.SMu.CSaMu.AfilMysAnit
	Fan mussel aggregations	*no specific biotope*
	Horse mussel beds	SS.SBR.SMus.ModT SS.SBR.SMus.ModMx SS.SBR.SMus.ModHAs SS.SBR.SMus.ModCvar
	Northern sea fan and sponge communities	CR.MCR.EcCr.CarSwi CR.HCR.XFa.SwiLgAs CR.HCR.DpSp Northern sea fan, *Swiftia pallida*
	Northern feather star aggregations on mixed substrata	*no specific biotope*
	Shelf deeps	*no specific biotope*

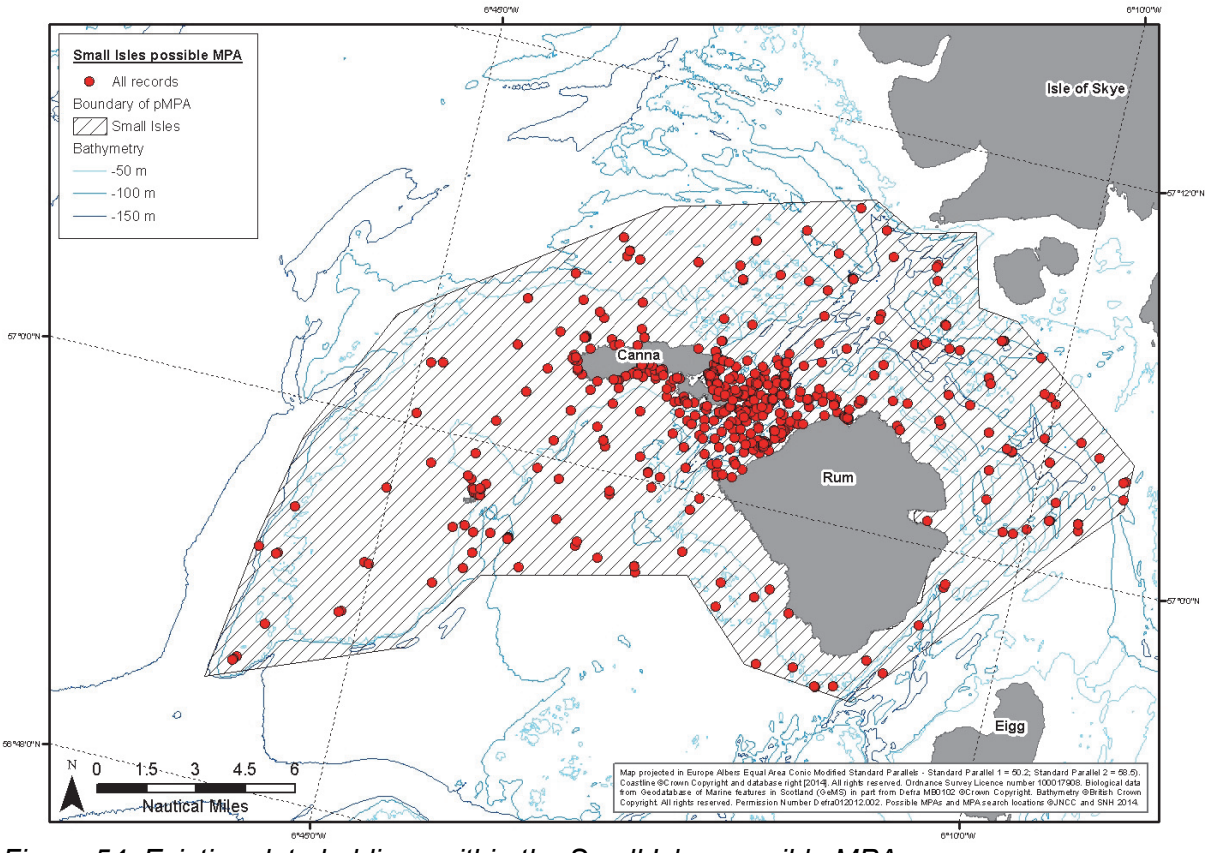

Figure 54. Existing data holdings within the Small Isles possible MPA.

3.7.1 Data assessment and requirements for more comprehensive mapping

The area has been well covered by multibeam, with the exception of the east of Rum. A composite digital elevation model (DEM) with a resolution of 25m was constructed from the three primary datasets (UKHO HI1299 & HI1297 and MS/BGS/SNH 2011), filled in where data are missing using the Defra bathymetry data. The bathymetry and hill-shaded DEM were used to guide interpretation. Also, the composite DEM was used to extract features through filtering (an image of a spatial average was subtracted from the DEM to highlight fine scale highs and lows in topography) and this derived feature image of topography proved useful in the interpretation of the acoustic data.

The backscatter images were, unfortunately, too confused and inconsistent to be of much guidance. The substrate polygons produced by BGS were detailed and the distribution of rock correlated well with the feature image.

The Sound of Canna has been intensively sampled over recent years, most recently by Howson *et al.* (2012), but the density of sampling is sparse overall within the possible MPA. The records of the various habitats and species are spatially intermixed.

There is considerable overlap between the features and the sediment types present (Table 10). Burrowed mud, circalittoral sandy muds, horse mussel beds and northern feather star aggregations all appear to be situated in areas designated as being mud, sandy-mud and muddy-sand. Northern sea fan and sponge communities (presumably requiring hard substrata) are nominally located across a wide range of sediment types, not just rock. This apparent confusion may be due in part to the heterogeneous nature of much of the sea floor with numerous small rocky outcrops emerging from the sediment.

Table 10: The association of records for the proposed protected features with the corresponding Folk classes.

Feature/Folks	M	sM	mS	gmS	msG	(g)S	gS	Rock
Fan mussel	67	3	2					3
Burrowed mud	13	28	21	3	3	1		3
Circalittoral sand and mud communities	17	6	6	1				2
Horse mussel	9			1				
Northern feather star	4	2	9	2	1			5
Northern sea fan	1	4	5	3	5	3	1	9

In summary, although the records are dense within the Sound of Canna, it has not been simple to draw polygons to encompass the points of any one of the features to the exclusion of others. It could be argued that, although the sea floor in the Sound of Canna is heterogeneous, the concentration of proposed protected features could combine to add to the confidence of the boundaries. For this reason, the polygons for many of the proposed protected features here have been assigned a high level of confidence.

The Sound of Canna has been intensively sampled. However, there is sparse information over much of the rest of the possible MPA. This is particularly the case for the areas of patchy rocky outcrops and surrounding sediment which is poorly described at present. These areas have the potential of combining proposed protected features in a mosaic of patches that might be found extensively.

3.7.2 Proposed protected features

3.7.2.1 Burrowed mud

The records for burrowed mud are widely scattered throughout the Small Isles possible MPA (Figures 55). Burrowed mud is more closely associated with deep, level areas of the sea floor than other habitat types. However, the feature has also been recorded from heterogeneous ground (presumably pockets of mud amongst other habitats) and in moderately shallow water, especially in Canna Harbour.

The burrowed mud polygon has been constructed by drawing a broad polygon encompassing the more homogeneous sediment areas with few or no rocky outcrops. A decision was made to exclude records from the rocky outcrop areas as the records are too sparse to be able to say with certainty if the muddy sediments are pockets amongst the rocky outcrops, or the rocky outcrops are scattered throughout a predominantly muddy habitat.

The polygon was then constrained further. First, the polygons from the BGS polygons for rocky outcrops and mixed sediments (sediments with a gravel component) and sand were subtracted. Second, the narrows in the Sound of Canna would appear not to have burrowed mud and the areas assigned to fan mussel aggregations and horse mussel beds were subtracted. Third, some of the CSM polygons were subtracted (others overlap with the burrowed mud).

Assigning a confidence score to this polygon is difficult: The Sound of Canna (where the records are most dense) is very heterogeneous but with a high density of records. The boundaries have, nevertheless, been assigned a high level of confidence on account of the density of records. Areas outside the Sound of Canna have less dense records, but the sea floor would appear to be much more homogeneous and the confidence for the distribution of burrowed mud is moderately good. Overall, the polygon could be regarded as of moderately good confidence.

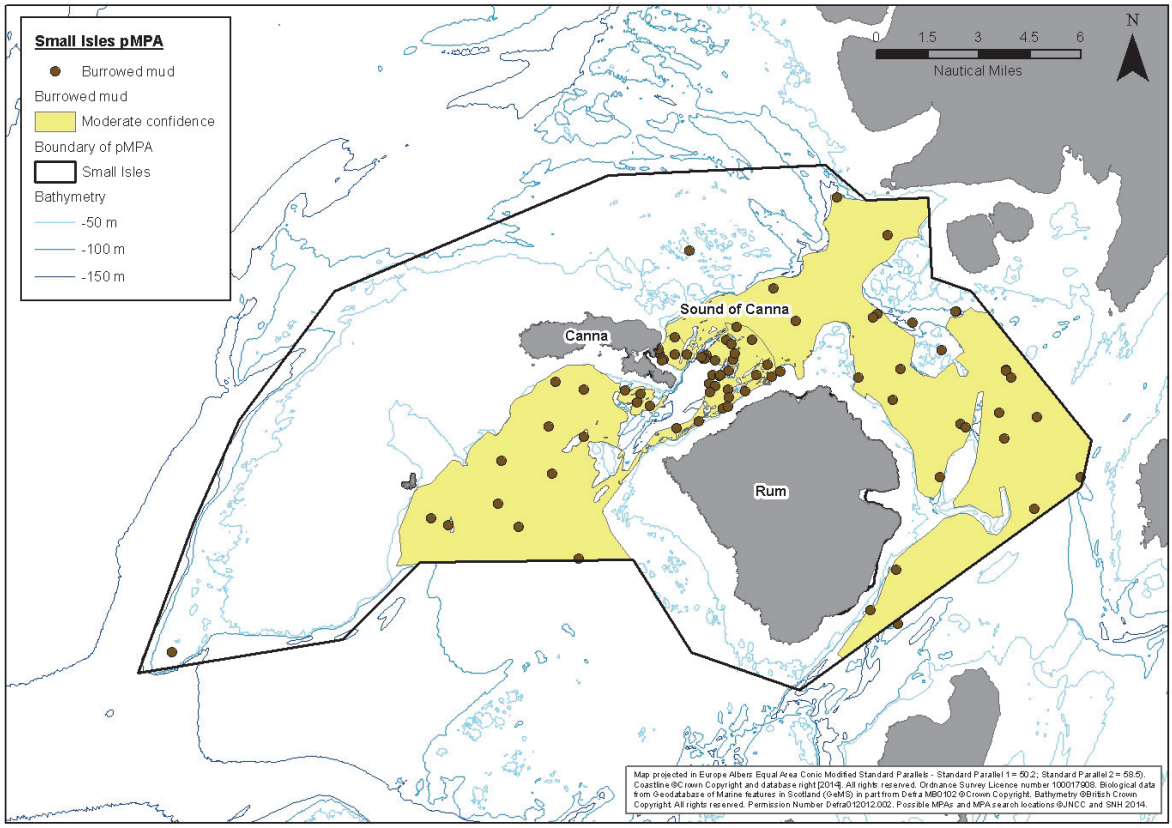

Figure 55. The distribution of burrowed mud within the Small Isles possible MPA.

3.7.2.2 Circalittoral sand and mud communities

Circalittoral sand and mud communities (CSM) are a broad category with potential overlap with the burrowed mud proposed protected feature. Since it is uncertain if the records for burrowed mud could not also have been assigned to a CSM sediment habitat, the true extent of the CMS cannot be assessed on the strength of the existing point records.

There may be locations where CSM is found to the exclusion of the more muddy habitats within the possible MPA. There are indications that some areas are characterised by a high hydrodynamic regime. The DEM suggests longitudinal sand waves in deep channels, particularly in the Sound of Canna and south of Skye. Some of these areas have been assigned exclusively to CSM, rather than as an overlap between CSM and burrowed mud (Figure 56).

Overlap between CSM and burrowed mud would appear to be the situation in the shallower areas towards the edges of the sounds and here the polygons have been left so that they overlap.

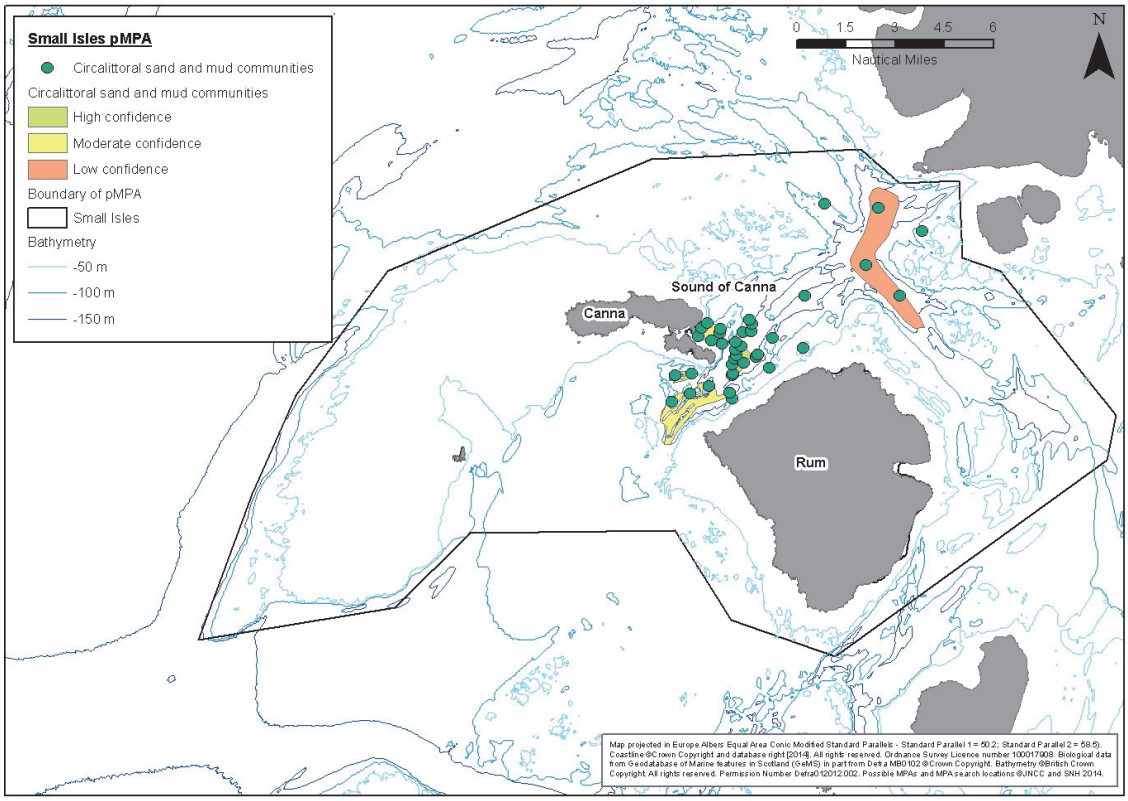

Figure 56. The distribution of circalittoral muddy sand communities within the Small Isles possible MPA, coded for confidence.

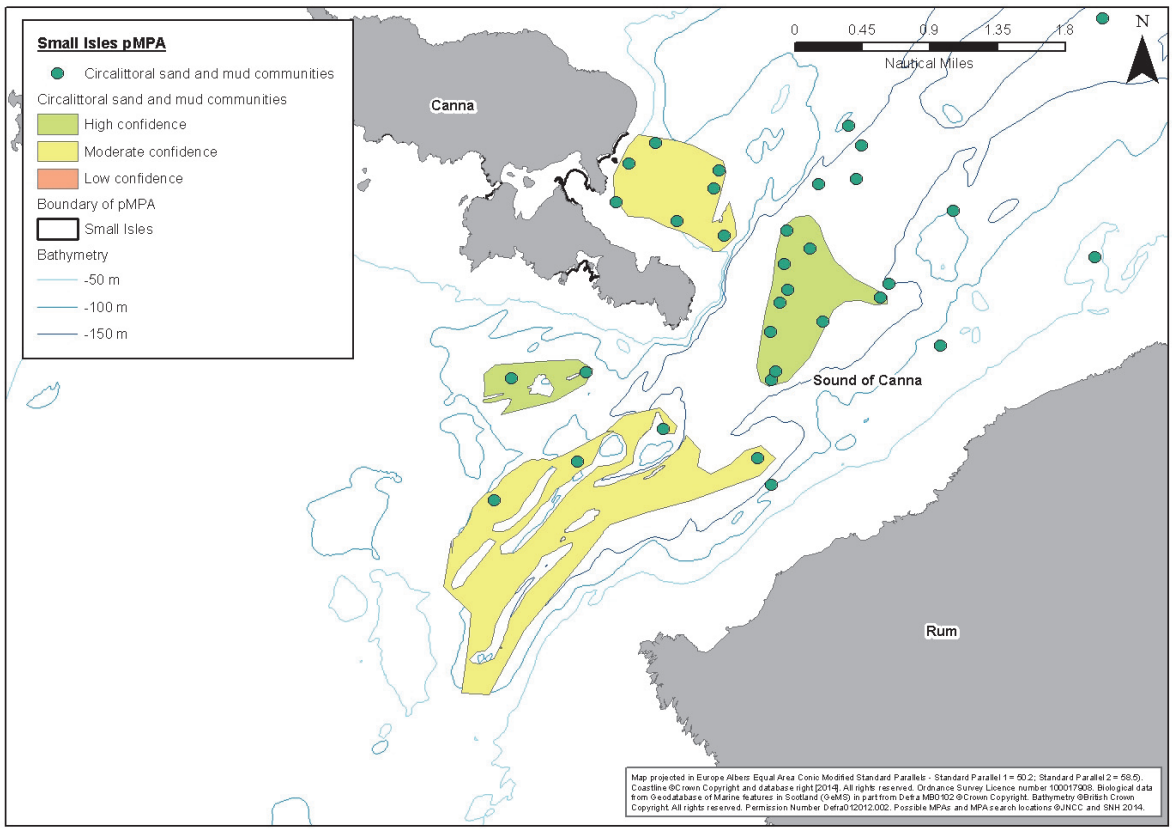

Figure 57. The distribution of circalittoral muddy sand communities, an enlargement of the Sound of Canna, coded for confidence.

3.7.2.3 Fan mussel aggregations

Records of the fan mussel*, Atrina fragilis*, are confined to the Sound of Canna, mostly at the north-eastern end of the sound (Figure 58). There is considerable overlap between the location of the fan mussel records and those of the burrowed mud and the CSM proposed protected features. The records have been enclosed in a polygon that overlaps with CSM, burrowed mud and to some extent the horse mussel beds.

Fan mussels are found in a range of sediments from gravel, muddy gravel, sand and sandy mud and could easily overlap with the other feature habitats.

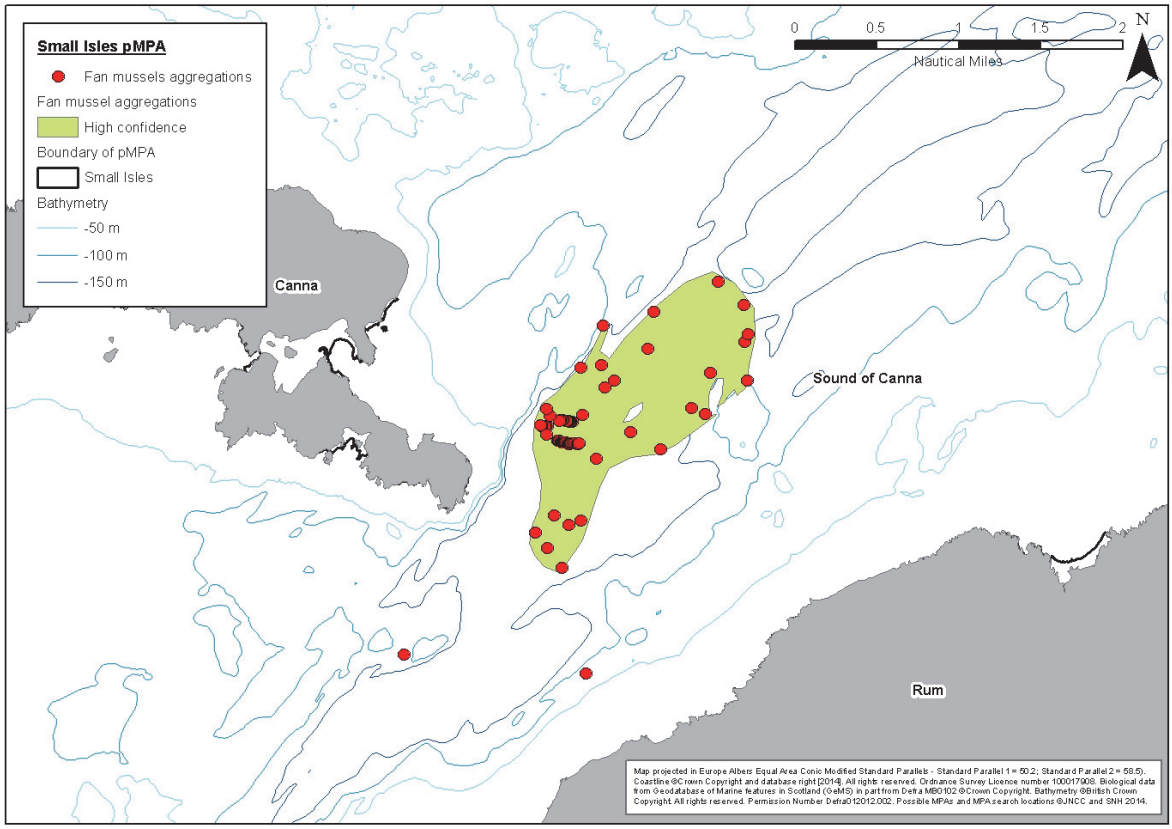

Figure 58. The distribution of fan mussel aggregations within the Sound of Canna possible MPA, coded for confidence.

3.7.2.4 Horse mussel beds

The records of horse mussel beds are confined to the Sound of Canna, to the south of the fan mussel aggregations and there is overlap with other features. The records have been enclosed in a polygon that overlaps with CSM and fan mussel aggregations. There is one outlier which has not been included within a polygon (Figure 59).

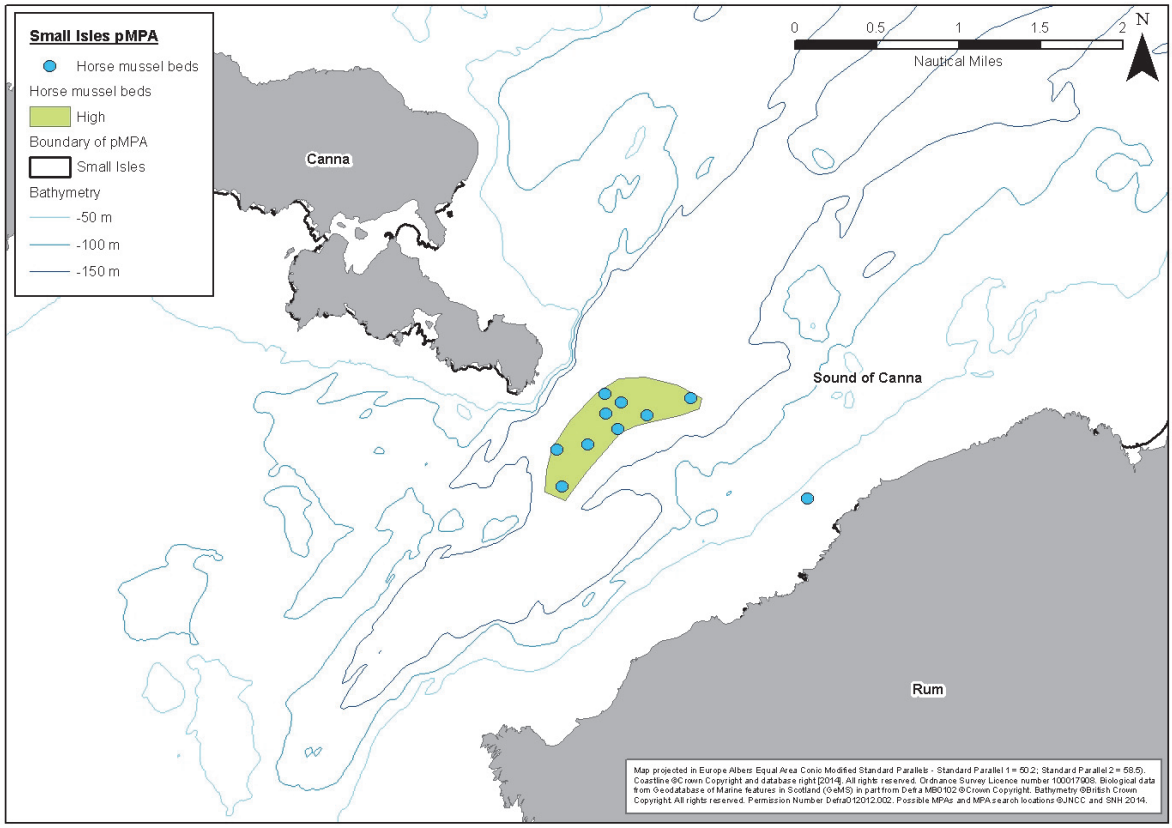

Figure 59. The distribution of horse mussel beds within the Sound of Canna possible MPA, coded for confidence.

3.7.2.5 Northern sea fan and sponge communities

This proposed protected feature, northern sea fan and sponge communities could be expected to occur widely on rocky outcrops, boulders and coarse mixed sediments within the possible MPA below the kelp zone. The records for this feature are scattered throughout the possible MPA wherever these substrata are indicated (Figure 60). The concentration of the records in the Sound of Canna reflects the focus of survey in this area and does not reflect the true distribution of this community.

The distribution of rocky outcrops has been provided in some detail by the polygons drawn by BGS. A visual inspection of the topographic map derived from the DEM has also been useful in plotting areas that are likely to have a substantial representation of rocky outcrops and surrounding ‘stony’ ground.

The polygons drawn within the Sound of Canna for this proposed protected feature are necessarily small and numerous due to the isolated nature of the rocky outcrops amongst other features (Figure 61). Not all of these polygons are supported by records, unsurprisingly since this would have required a dedicated survey to be comprehensive. However, since the polygons share the same physical characteristics and are in very close proximity to sample records, it is reasonable to assume they will support the same broadly defined communities. Those polygons supported by records are assigned a high level of confidence; those without a supporting record have been assigned moderate confidence.

Outcrops of rock and more extensive areas of rock would appear to be very widespread within the possible MPA. From the DEM and the very sparse records, it is probable that

many of these areas are a hetergeneous mix of rock and sediment. An attempt has been made to draw polygons around areas that might be considered to consist of significant proportions of rock. Although rock can be predicted with some certainty from the DEM, the presence of the northern sea fan and sponge community is at best a reasonable extrapolation, qualifying as a low level of confidence. Rock shallower than -25 m has been considered likely to support algae.

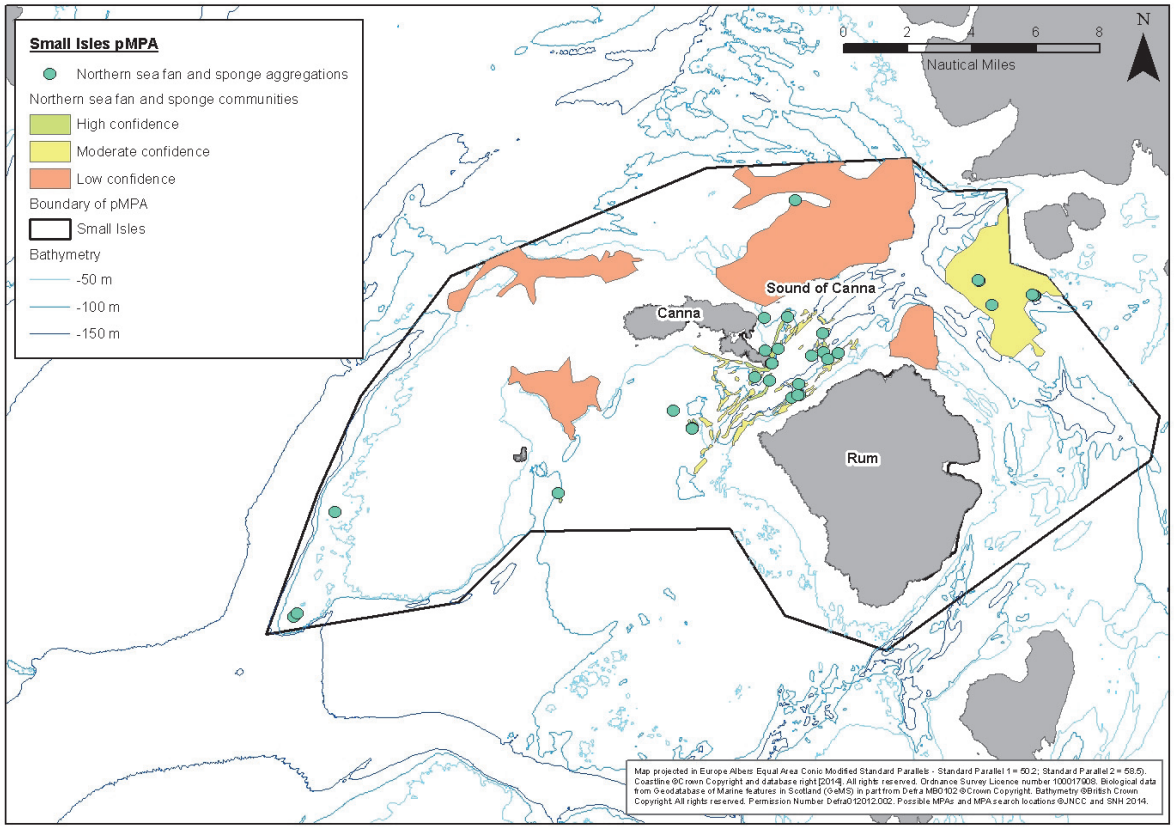

Figure 60. The distribution of northern sea fan and sponge communities within the Small Isles possible MPA, coded for confidence.

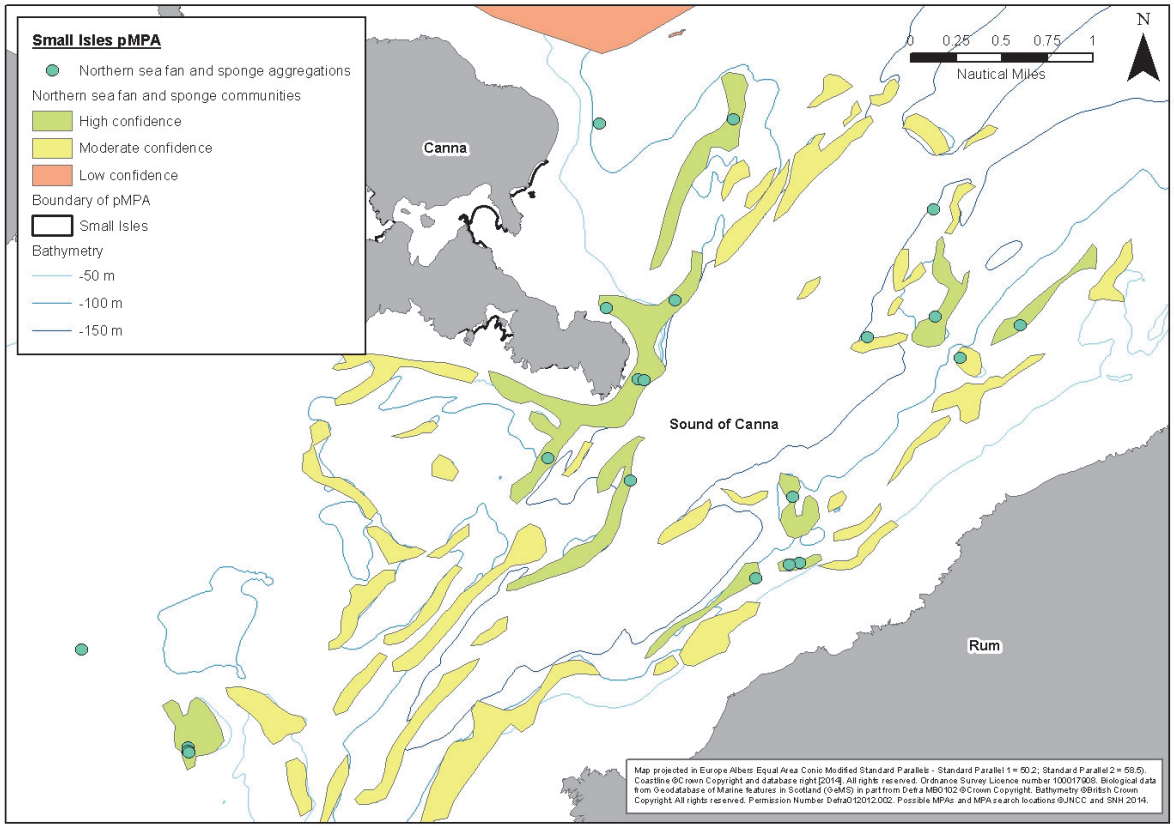

Figure 61. The distribution of northern sea fan and sponge communities within the Sound of Canna, coded for confidence.

3.7.2.6 Northern feather star aggregations on mixed substrata

Northern feather star aggregation records lie in the Sound of Canna where their location overlaps with the distributions of burrowed mud, CSM and northern sea fan communities (Figure 62). There are scattered records elsewhere and this species is probably widely distributed. It is unlikely that drawing a polygon to encompass the distribution of the records would reflect the true distribution of this feature and so it is recommended that the records are shown as points.

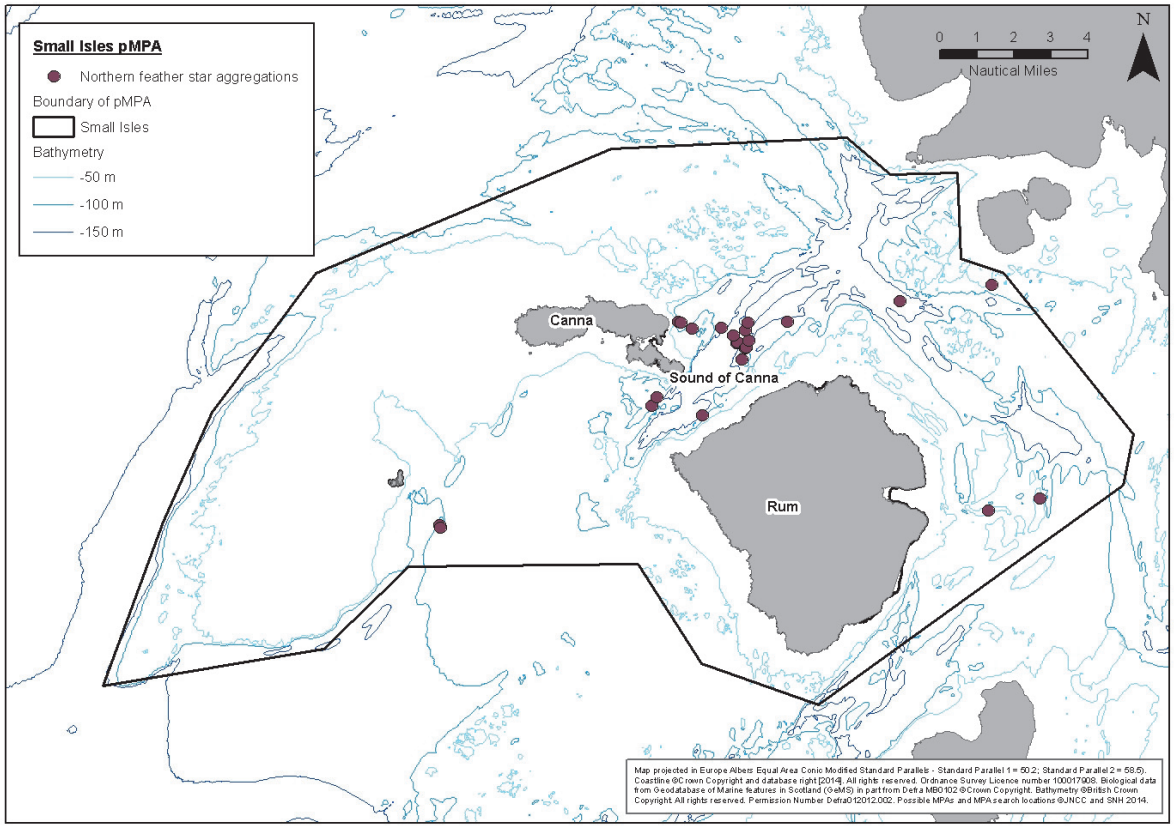

Figure 62. The point distribution of northern feather star aggregations on mixed substrata within the Small Isles possible MPA.

3.7.2.7 Burrowed mud component mapping

The burrowed mud records within the Small Isles possible MPA consist of three component biotopes: **SS.SMu.CFiMu.SpnMeg**, **SS.SMu.CFiMu.SpnMeg.Fun** and **SS.SMu.CFiMu.MegMax** (Figures 63 and 64). The records for these biotopes are intermixed on a broad scale, but are often clustered at a finer scale which may reflect distinct regions within the burrowed mud. However, the area in the Sound of Canna is very heterogeneous and, with the exception of distinct outcrops of harder ground, burrowed mud overlaps with other proposed protected features (particularly fan mussel aggregations and horse mussel beds). This level of heterogeneity means that distinguishing the components of burrowed mud within the Sound of Canna by classification of the acoustic (although a general model of all habitats may be useful at a broad scale). An alternative approach based on probability distribution determined from the point records, but constrained by the previously derived burrowed mud polygons, has been adopted. The method for deriving the probability distributions has been explained in Section 2.7.

Probability distribution images were derived for the three component burrowed mud biotopes. These images were used to derive a composite distribution map for all three based on the maximum probability. The image was converted into a vector format and imported into the GIS and the boundaries between the components used to sub-divide the burrowed mud polygons.

The polygons have been edited so that the “Feature” attribute of burrowed mud has a suffix indicating which of the three components dominated. The “Component” attribute has been edited to reflect the new composition of the polygons. The confidences have also been amended where appropriate, although none have been downgraded to “Low” since they all

belong to a broader burrowed mud polygon with “High” or “Moderate” confidence. This is a compromise position for the guidelines designed for the main features to accommodate the sub-division into components.

The probability distribution reflects the clustering of the component biotopes and gives an assurance that the process of sub-division has been successful. The burrowed mud in the Sound of Canna consists mainly of **SS.SMu.CFiMu.MegMax** (with some small pockets of **SS.SMu.CFiMu.SpnMeg.Fun**) with predominantly **SS.SMu.CFiMu.SpnMeg.Fun** to the north-east and **SS.SMu.CFiMu.SpnMeg** to the south-west.

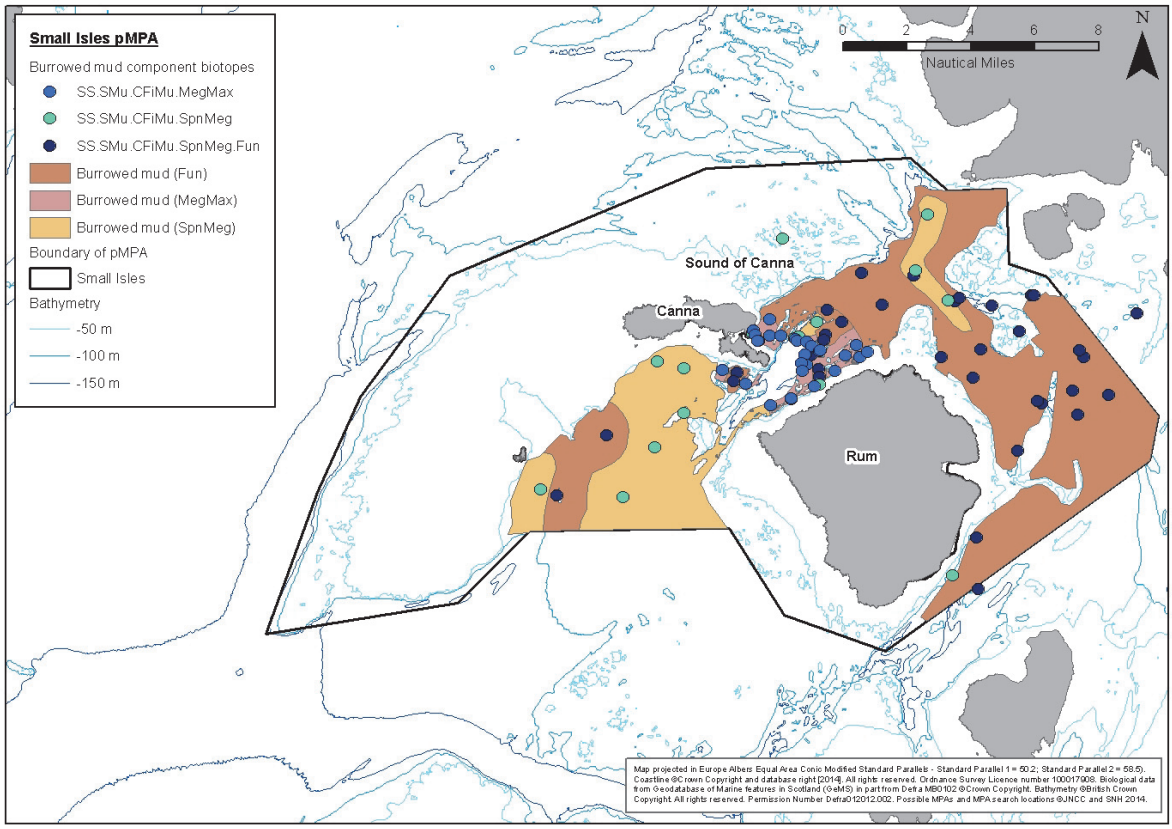

Figure 63. Burrowed mud component polygons within the Small Isles possible MPA

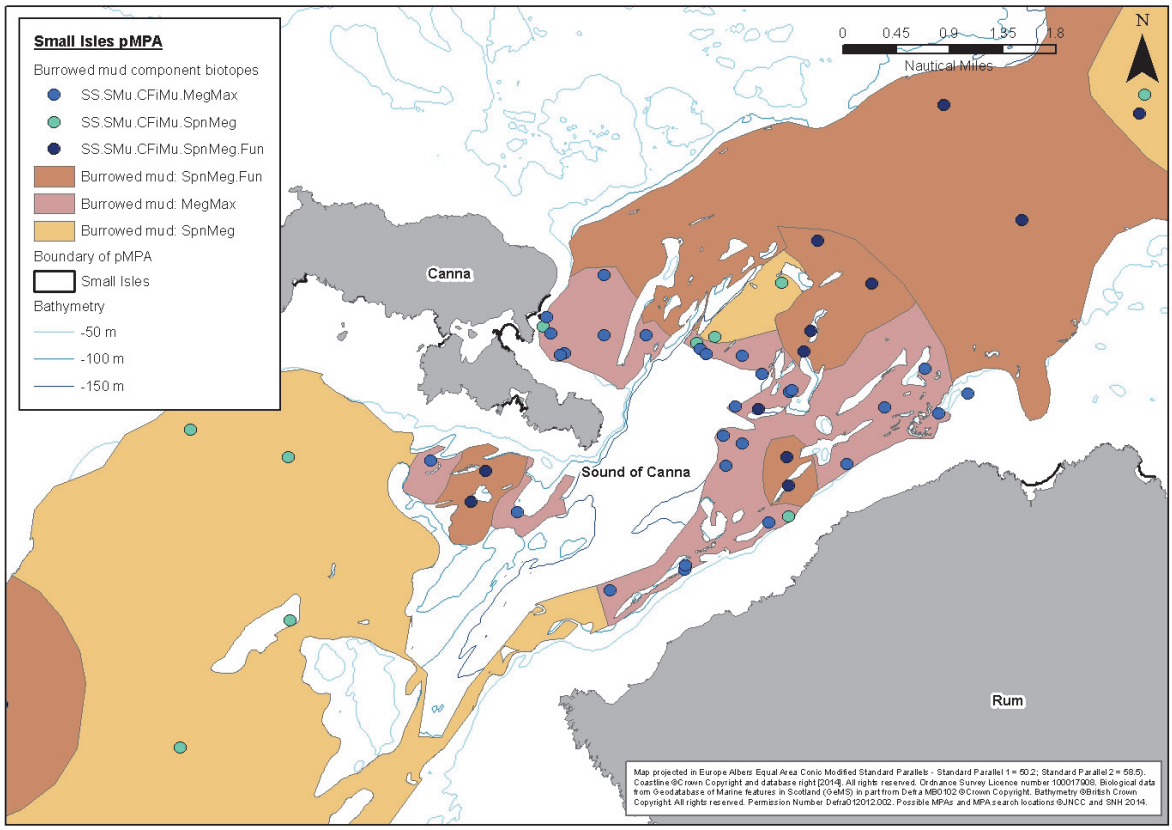

Figure 64. Burrowed mud component polygons within the Sound of Canna.

3.7.2.8 Summary of Proposed protected features for the Small Isles possible MPA

The Small Isles possible Nature Conservation MPA is very large and much is sparsely sampled. Burrowed mud is the most widely spread feature throughout the Small Isles possible MPA, found in proximity and potentially overlapping with circalittoral sand and mud communities (CSM). However, many of the features are concentrated in the Sound of Canna (Figures 65 and 66) that has been comprehensively sampled and any uncertainty about boundaries is likely to emanate more from overlap between the habitats than sampling effort, which includes the fan mussel aggregations and horse mussel beds as well as burrowed mud and CSM. Northern sea fan and sponge communities are nominally located across a wide range of sediment types and hard substrata, particularly in the Sound of Canna and in the northeast of the possible MPA. Northern feather star aggregation records are also concentrated in the Sound of Canna, but are scattered elsewhere throughout the area and may be more widely distributed.

The distribution of all the proposed protected features is summarised in Figures 65 and 66. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

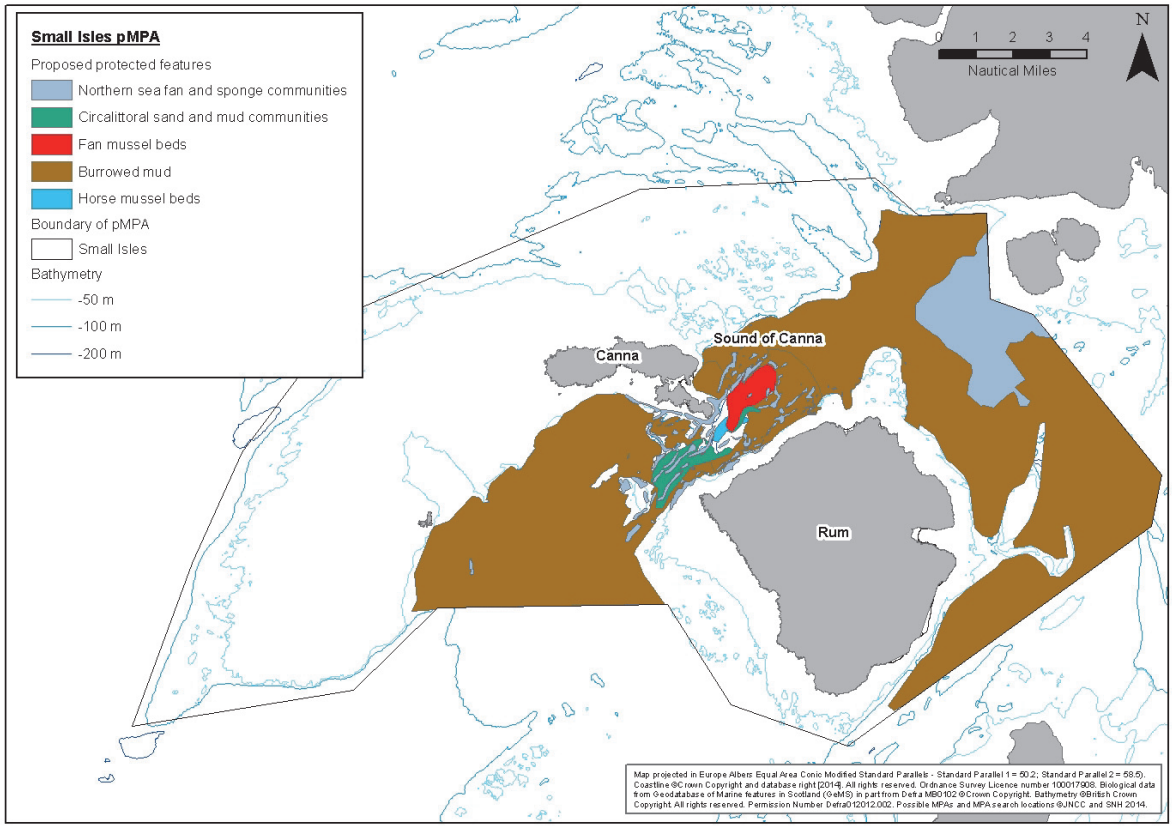

Figure 65. The distribution of all proposed protected features for the Small Isles possible MPA

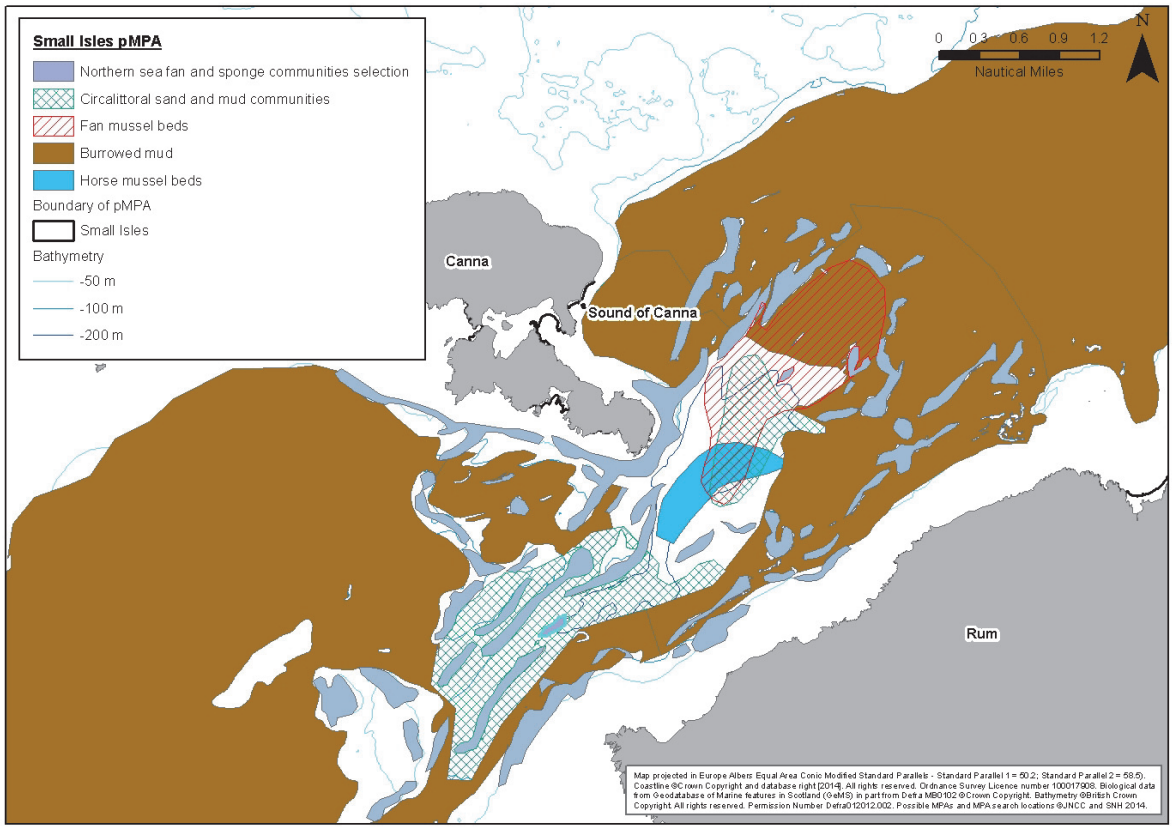

Figure 66. The distribution of all proposed protected features for the Sound of Canna.

3.8 South Arran possible Nature Conservation MPA

The South Arran possible Nature Conservation MPA was identified for the following MPA search features, which are now referred to as proposed protected features: burrowed mud, herring spawning grounds, kelp and seaweed communities on sublittoral sediment, maerl beds, maerl or coarse shell gravel with burrowing sea cucumbers, ocean quahog, seagrass beds, and shallow tide-swept coarse sands with burrowing bivalves. Those features to be mapped within this project are listed in Table 11.

Details of supporting evidence are provided in the South Arran possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1034850.pdf] with the existing data holdings in Figure 67.

Table 11: Proposed protected features to be mapped within the South Arran possible MPA.

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
South Arran	Burrowed mud	SS.SMu.CFiMu.SpnMeg SS.SMu.CFiMu.MegMax Tall sea pen, *Funiculina quadrangularis* Fireworks anemone, *Pachycerianthus multiplicatus*
	Kelp and seaweed communities	SS.SMp.KSwSS
	Maerl beds	SS.SMp.Mrl
	Maerl or coarse shell gravel with burrowing sea cucumbers	SS.SCS.CCS.Nmix
	Ocean quahog (species)	*no specific biotope*
	Seagrass beds	LS.LMp.LSgr.Znol SS.SMp.SSgr.Zmar SS.SMp.SSgr.Rup
	Shallow tide-swept coarse sands with burrowing bivalves	SS.SCS.ICS.MoeVen

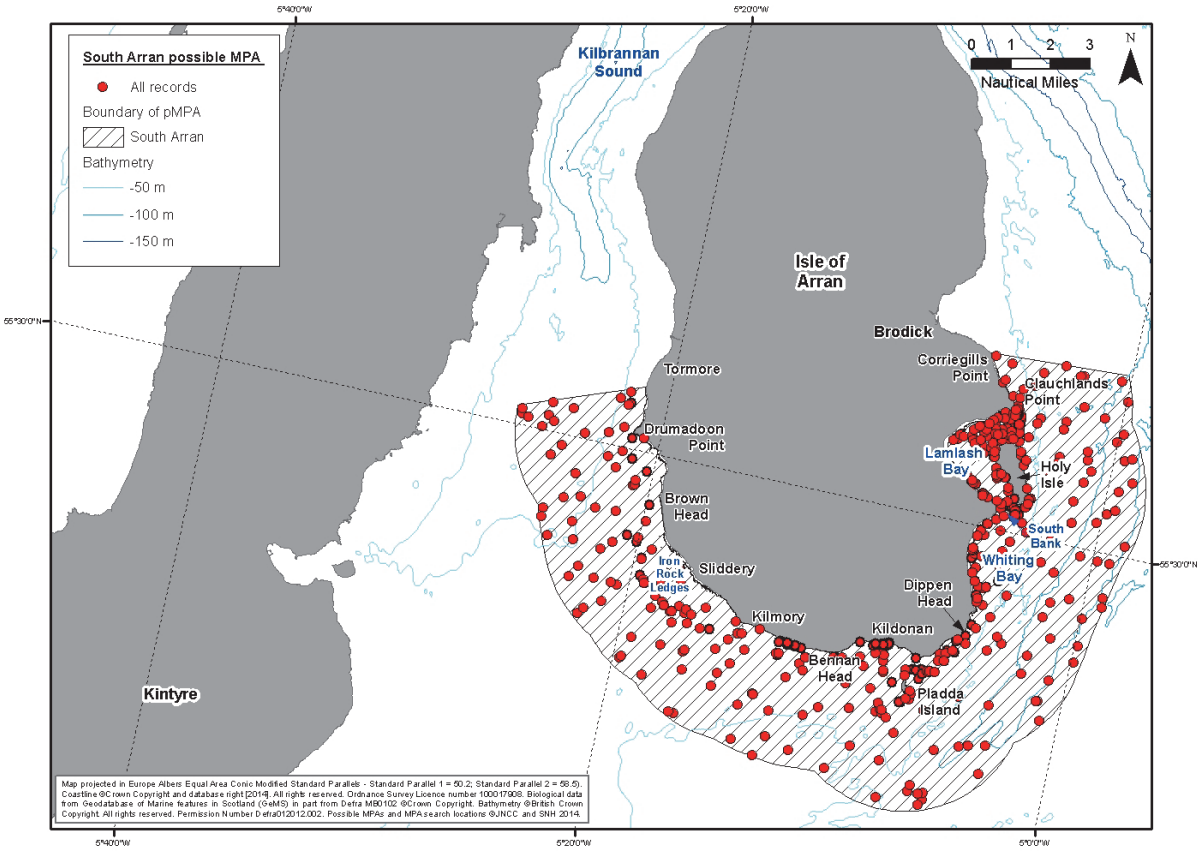

Figure 67. Existing data holdings within the South Arran possible MPA

3.8.1 Data assessment and requirements for more comprehensive mapping

No acoustic data are currently available for the South Arran possible Nature Conservation MPA. However a DEM, constructed from the Defra bathymetry, was used as guidance for constraining polygons.

The density of sample points in the possible South Arran MPA is generally high and relatively even throughout the site. Some of the offshore areas are relatively homogeneous. Other areas, such as close inshore and in Lamlash Bay, are more heterogeneous, and although intensively sampled, the occurrence of some of the proposed protected features are very localised. Many of the inshore samples of the proposed protected features were from the COAST/Seasearch dataset. Drawing polygons around points is very uncertain in these circumstances particularly due to the lack of any high resolution, collateral acoustic data or aerial images.

The general distribution of sediments within the possible MPA is clear from the distribution of points: The mud and burrowed mud lies in deep water offshore (generally deeper than the -30 m contour). Sandy habitats overlap with some mud records from deep water. However, sand is found close to the shore, particularly on the eastern side of Arran and in Lamlash Bay. Gravel and mixed substrata are found in moderately shallow water throughout the possible Nature Conservation MPA.

Clearly, the proposed protected features are closely associated with these habitat types and the general trends give added confidence to some of the distribution patterns attributed to these features. It should be borne in mind that although some of the records are ambiguous as far as the presence of proposed protected features are concerned, the fact that habitats that support the features may be located close to positive records may give added

confidence to extrapolation when drawing polygons. For example, many of the mud records are from geological samples and no mention is made, one way or another, if the sediments were also burrowed. Although not a positive confirmation of this feature, it may be a mistake to draw boundaries that exclude these points in an area where burrowed mud is frequently found and so these points have been used to help draw boundaries.

An acoustic survey of the South Arran possible MPA would be useful for mapping features with any degree of confidence, particularly inshore and within Lamlash Bay. The east side of the possible MPA around Lamlash Bay has had the greatest survey intensity, but still lacks definition for the full range of proposed protected features that occur there.

As already stated the sampling effort is very uneven across the area as a whole. The area is large and targeted sampling (after an acoustic survey) would be a cost-effective way of making the best use of survey effort.

Further survey work may also be needed in the inshore areas to prospect for localised protected features (e.g. seagrass beds and possibly kelp and seaweed) to build up confidence in the apparent localised occurrences. The distribution of many inshore features is likely to be very patchy since much of the open coast is fringed by rocky outcrops that extend from the shore into the shallow sublittoral environment.

3.8.2 Proposed protected features

3.8.2.1 Burrowed mud

The records for this proposed protected feature occur in the offshore area and are intermixed with sediment records of mud (Figure 68). Sandy habitats overlap with the distribution of both mud and burrowed mud and the polygon for the burrowed mud distribution has been drawn to include the burrowed mud and mud (as explained above) whilst excluding as many of the sand records as possible.

The distribution is a continuous area on the deeper outer section of the possible MPA boundary. The area is well supported by data and has been assigned a high level of confidence. Some records in the east are muddy sediments rather than burrowed mud specifically, although there is a predominance of burrowed mud records to justify the high confidence.

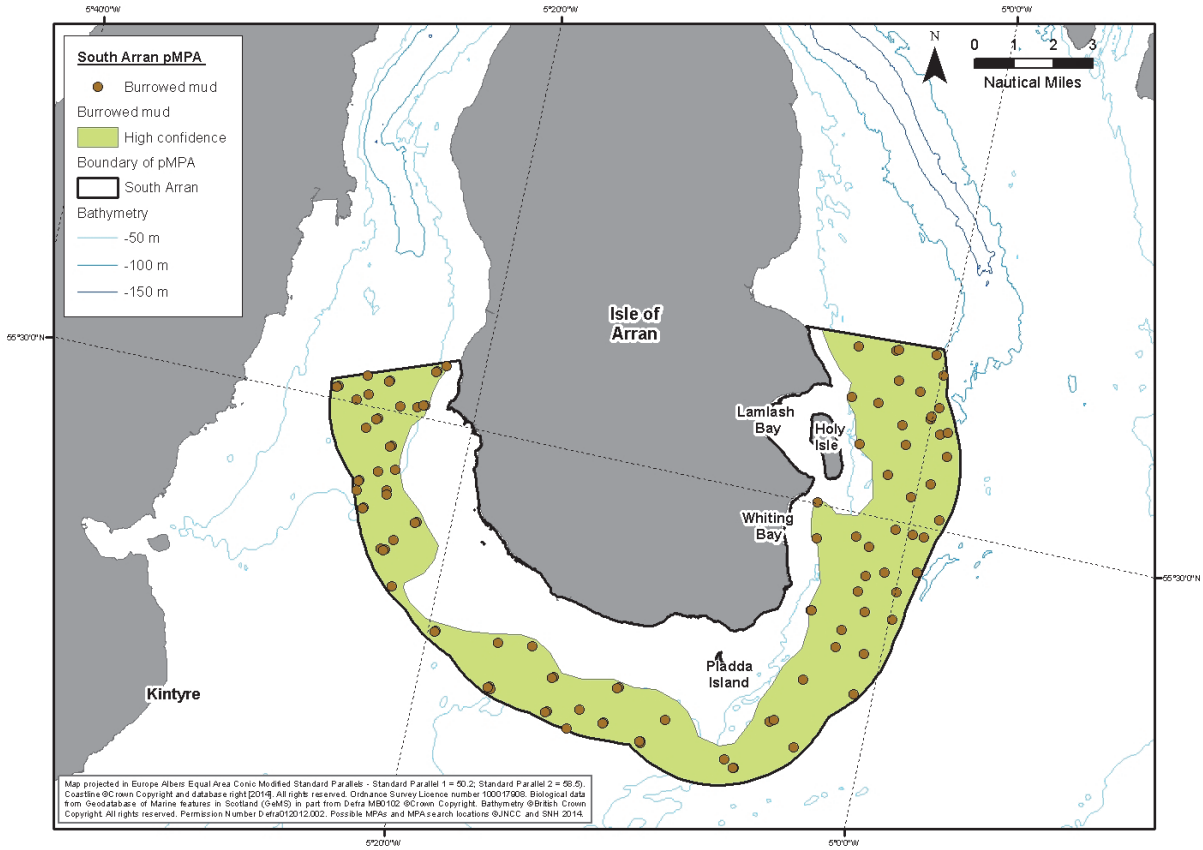

Figure 68. The distribution of burrowed mud for the South Arran possible MPA, coded for confidence.

3.8.2.2 Kelp and seaweed communities on sublittoral sediment

Kelp on sediment (**SS.SMp.KSwSS**) is recorded locally on the eastern side of South Arran. (Figures 69 and 70). However, there are many records of kelp (but not positively identified as to species) on mixed sediment and sand/boulder mixtures. These records have not been included in the feature datasets provided although, with a more complete description, they might have qualified. This feature may be more widely distributed than the existing records suggest. This is quite likely given the extent of suitable habitat. Thus, the small polygons drawn for this feature may be a considerable understatement of the extent of this feature. Further confusion arises because the feature overlaps with maerl beds within Lamlash Bay.

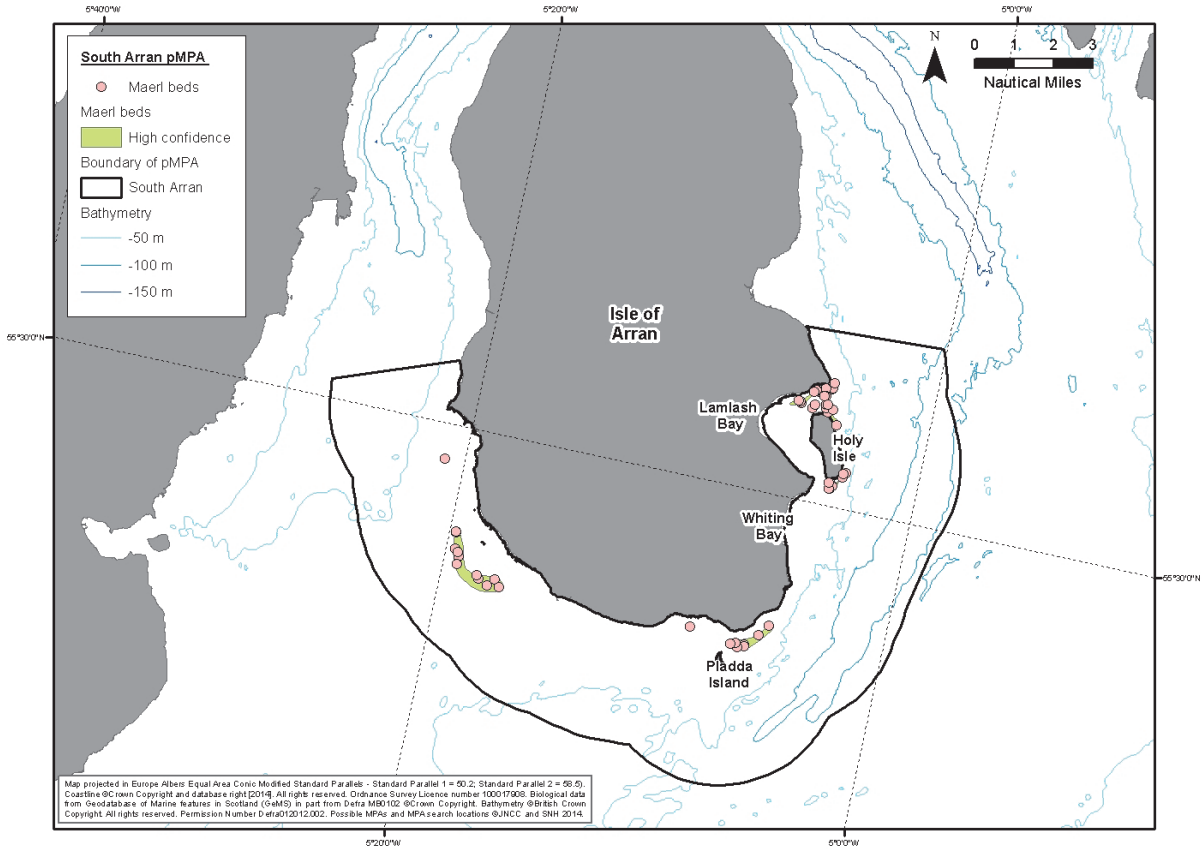

Figure 69. The distribution of kelp and seaweed communities on sublittoral sediment within the South Arran possible MPA.

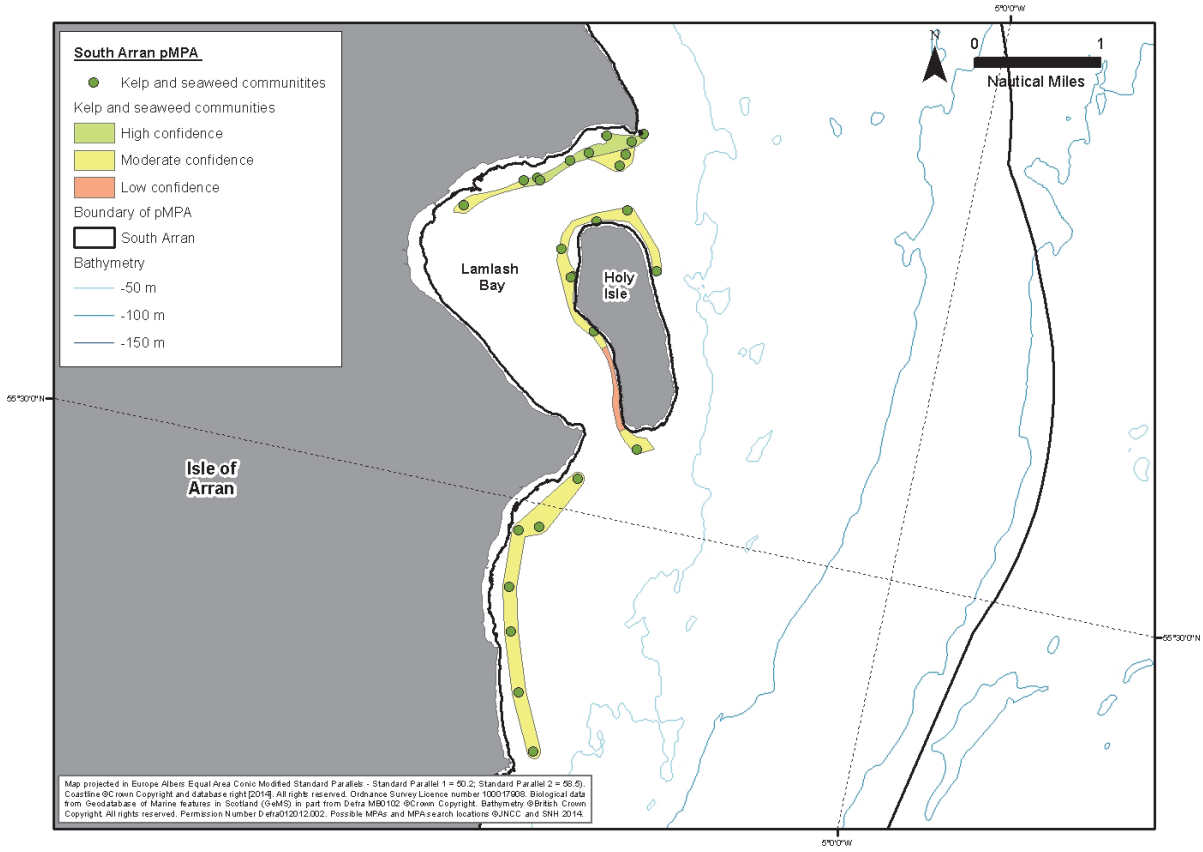

Figure 70. The distribution of kelp and seaweed communities on sublittoral sediment within Lamlash Bay, coded for confidence.

3.8.2.3 Maerl beds

Polygons were drawn based on available records of maerl beds and informed by other possible maerl records from the MNCR database. The new polygons do not differ greatly from the previous polygons in the Lamlash Bay area (Figures 71 and 72). New polygons have been drawn for maerl habitats on the south coast of Arran.

Maerl beds overlap with other similar habitats related by sediment type (**SS.SCS.ICS.MoeVen** and **SS.SCS.CCS.Nmix**) and since all are proposed protected features put forward for this possible Nature Conservation MPA, it may be more sensible to combine them into a single polygon feature, although note they have been kept separate in this study.

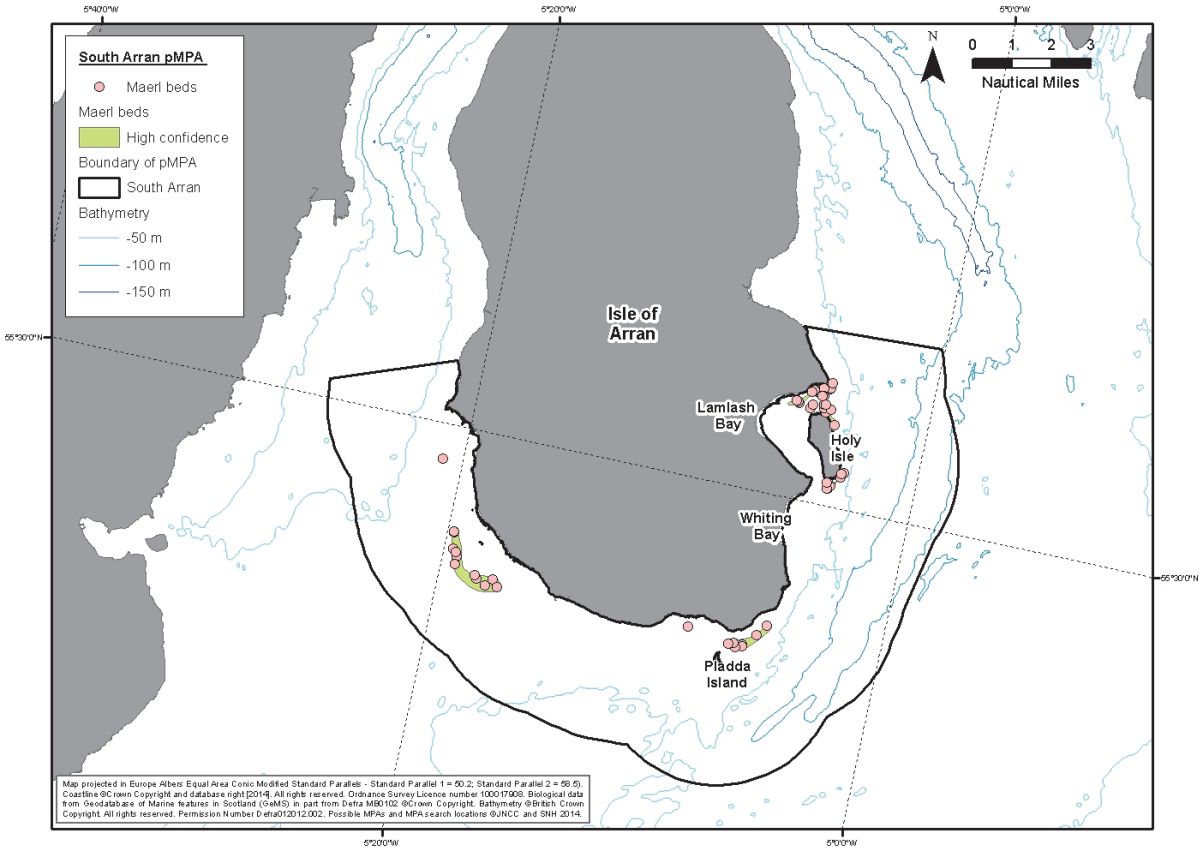

Figure 71. The distribution of maerl beds within the South Arran possible MPA, coded for confidence.

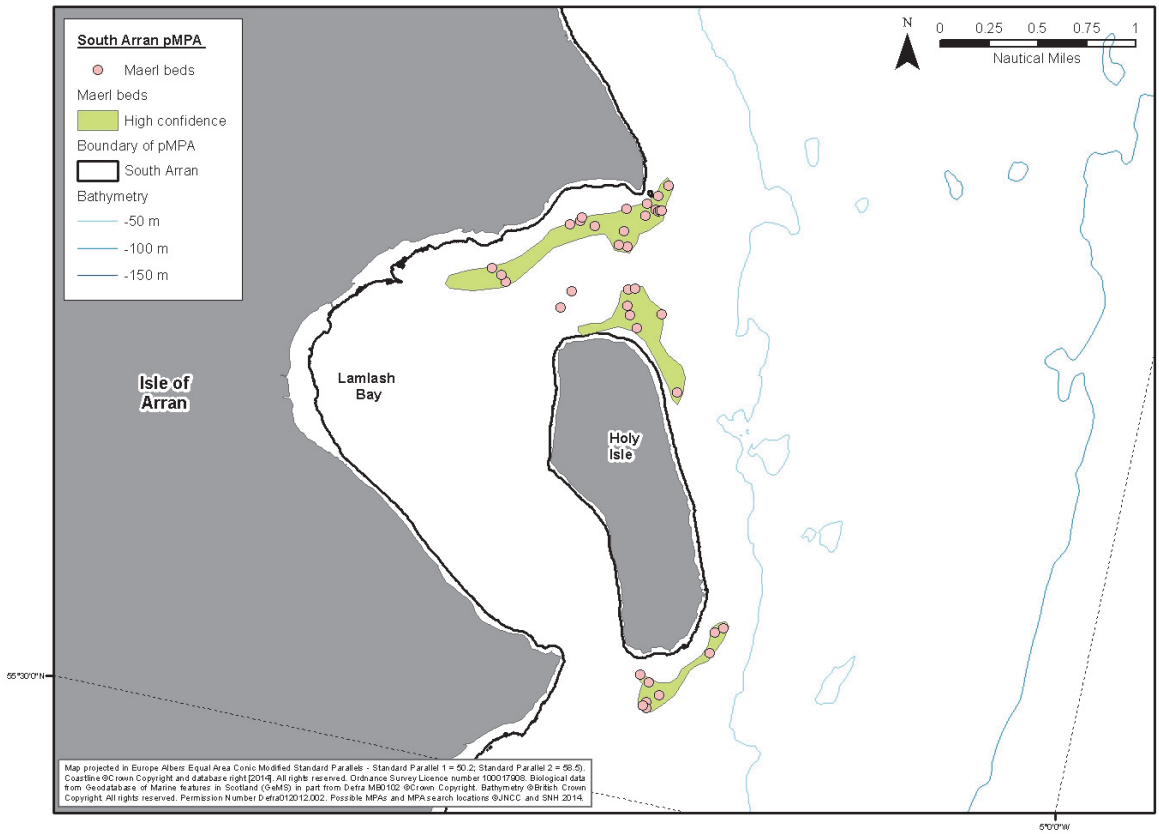

Figure 72. The distribution of maerl beds in Lamlash Bay and environs, coded for confidence.

3.8.2.4 Maerl or coarse shell gravel with burrowing sea cucumbers

There are relatively few records of the maerl or coarse shell gravel with burrowing cucumbers proposed protected feature (**SS.SCS.CCS.Nmix**) and these are closely associated with maerl beds (see previous Section). Two very small polygons have been drawn just south of Lamlash Bay and a larger linear polygons on the west and south coasts of Arran, with the western area probably including some maerl. The areas have not been joined as there is a distinct bathymetric feature separating them. (Figure 73).

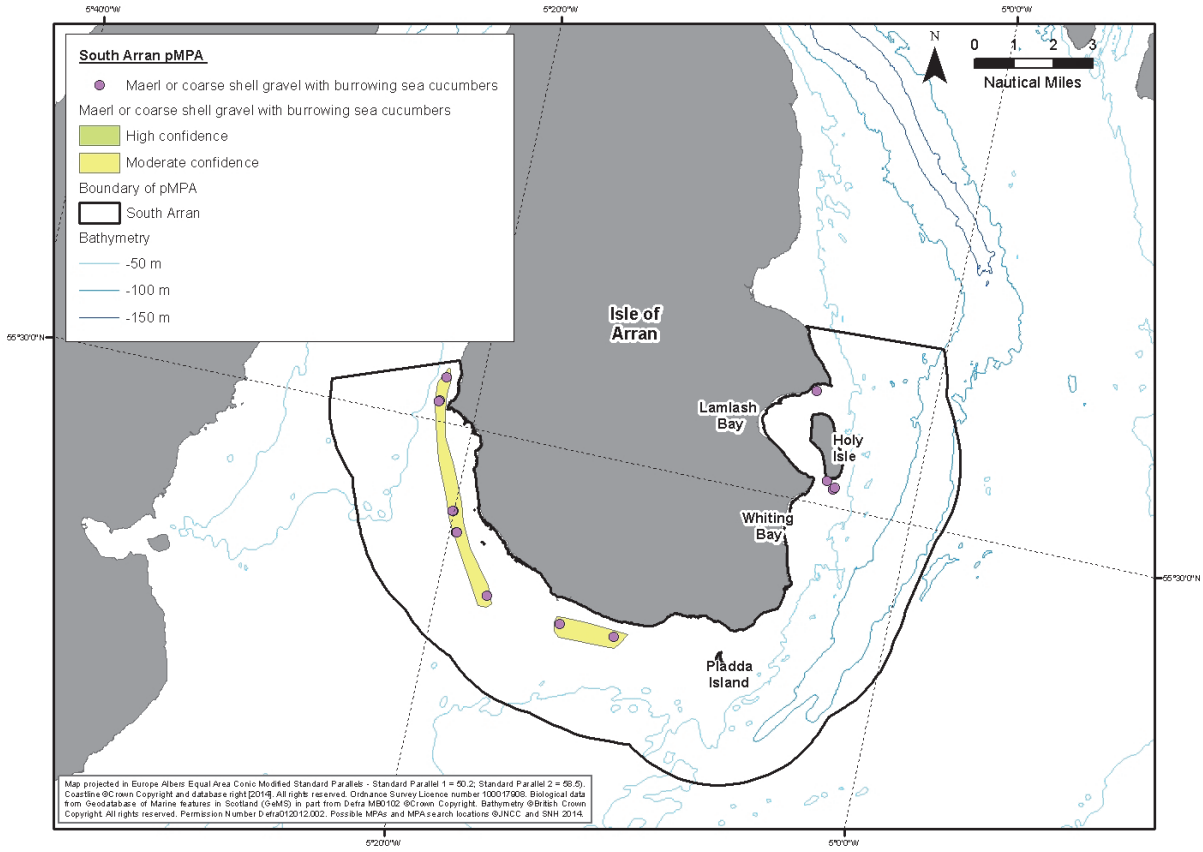

Figure 73. The distribution of maerl or coarse shell gravel with burrowing cucumbers for the South Arran possible MPA, coded for confidence.

3.8.2.5 Ocean quahog aggregations

These scattered records are mostly associated with burrowed mud. This feature is probably under-recorded and no polygon has been drawn for this feature, which are left as points (Figure 74).

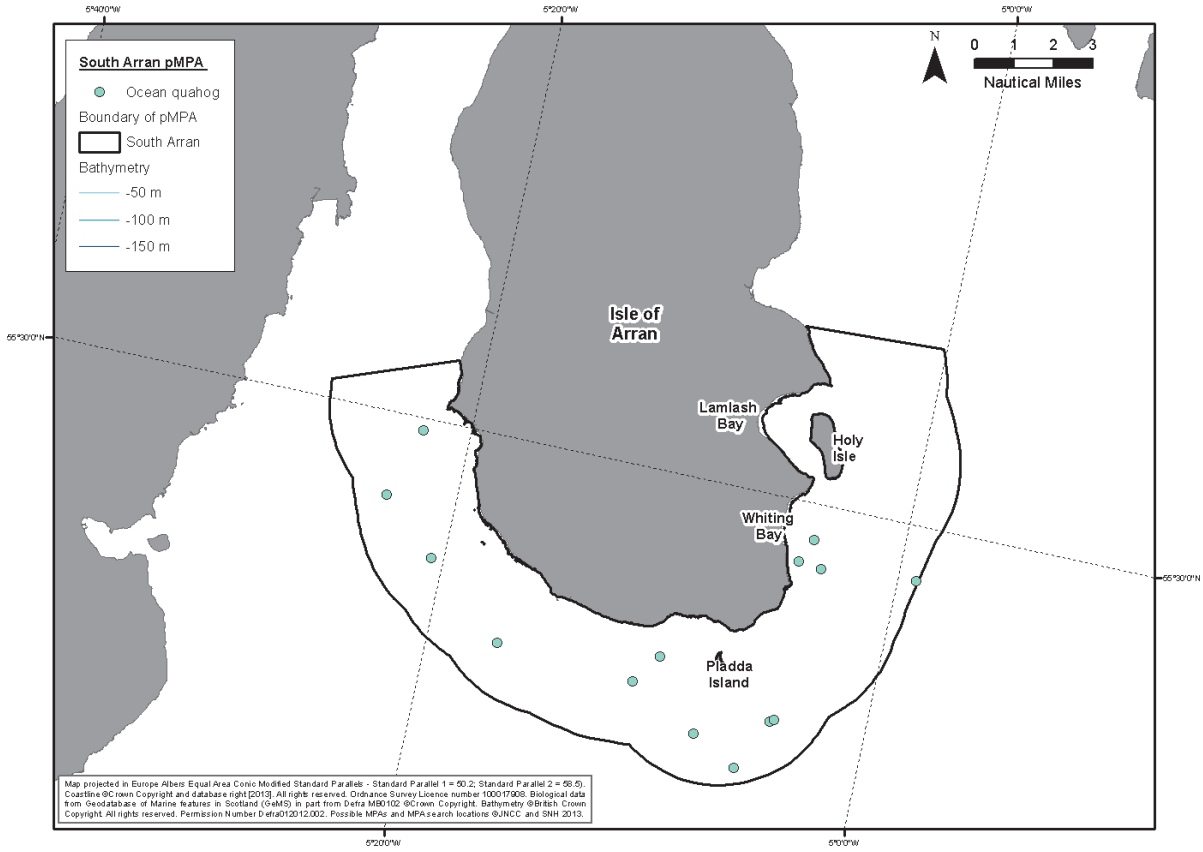

Figure 74. The point distribution of the ocean quahog within the South Arran possible MPA.

3.8.2.6 Seagrass beds

The seagrass records are confined to a few locations along the east coast of Arran. A few extra points from the MNCR database have been included as possible seagrass beds which offer support for the polygons (Figure 75).

The seagrass beds on the south coast of Arran have a very patchy distribution and are divided by rocky outcrops extending from the shore into the shallow sublittoral zone. The distribution has been interpreted from aerial photographs and probably does not represent the true extent of this proposed protected feature (Figures 76 and 77).

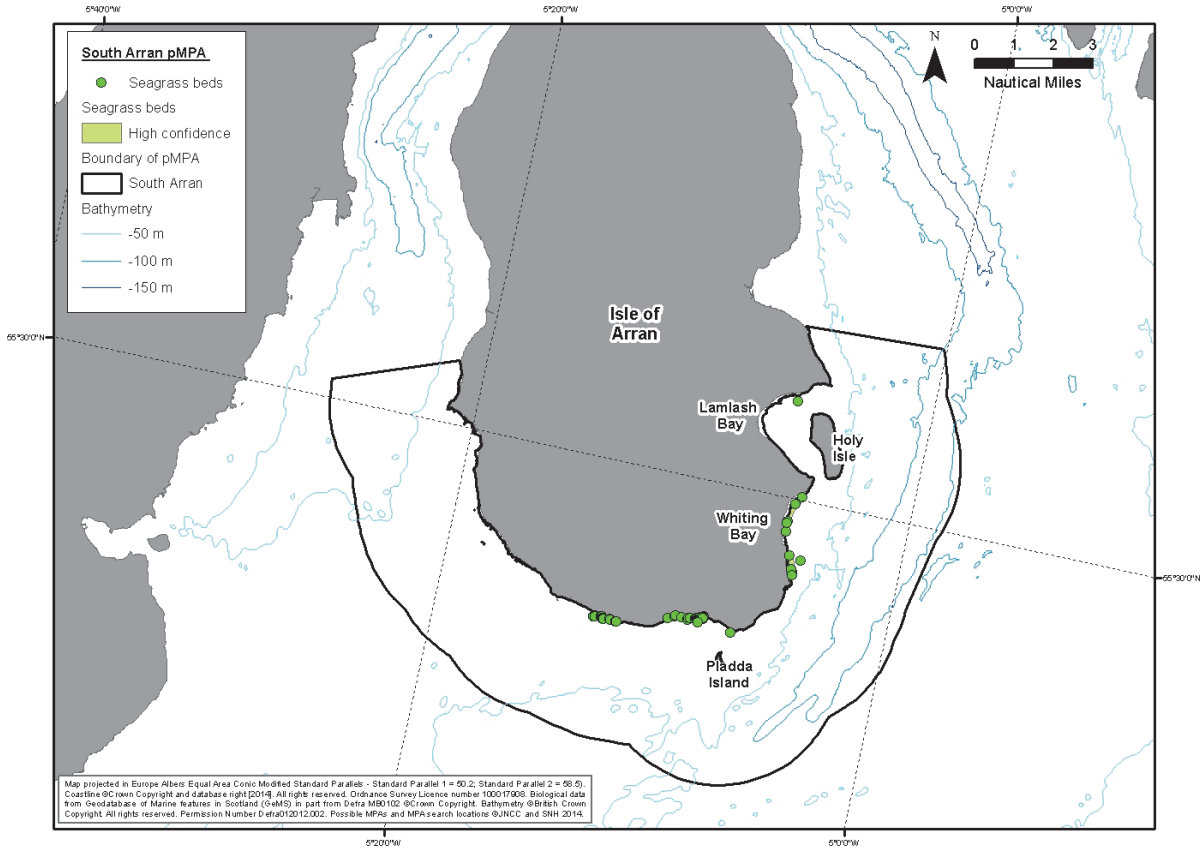

Figure 75. The distribution of seagrass beds within the South Arran possible MPA, coded for confidence.

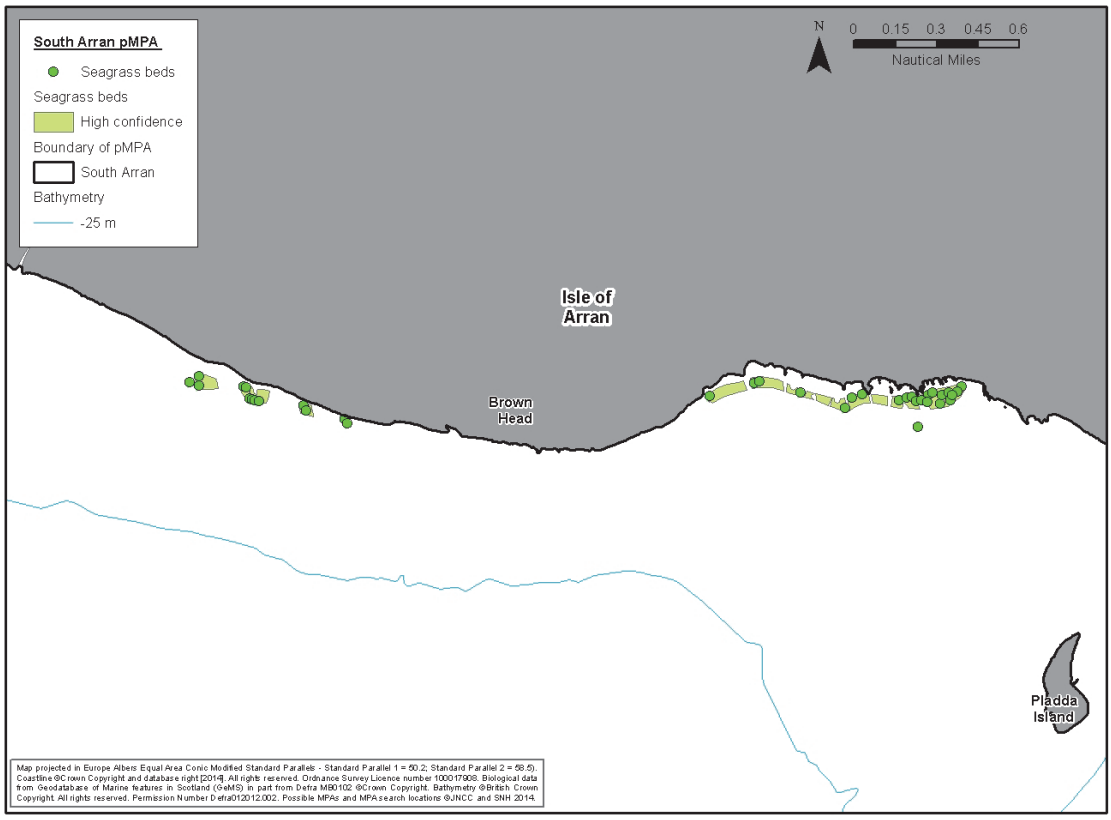

Figure 76. The distribution of seagrass beds on the south coast of Arran, coded for confidence.

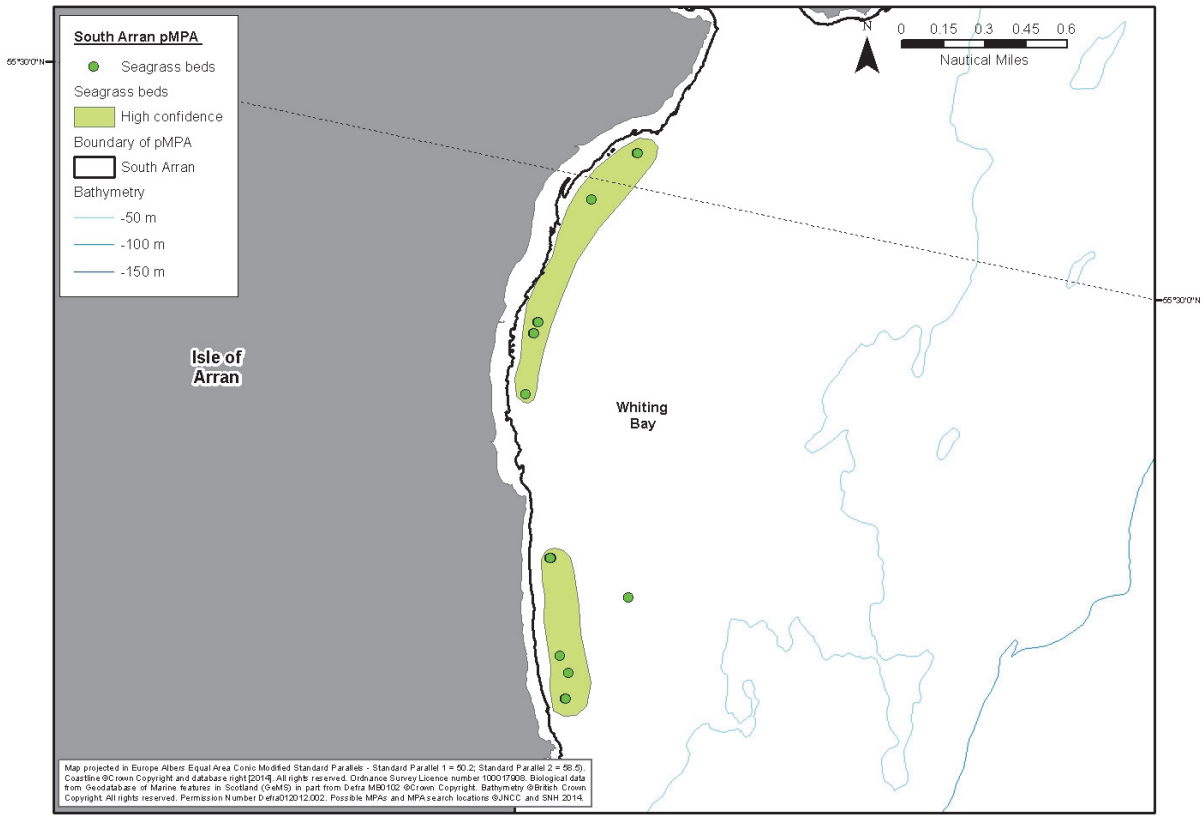

Figure 77. The distribution of seagrass beds on the south east coast of Arran, coded for confidence.

3.8.2.7 Shallow tide-swept coarse sands with burrowing bivalves

The proposed protected feature shallow tide-swept coarse sands with burrowing bivalves (**SS.SCS.ICS.MoeVen**) is another shallow water feature closely associated with maerl and gravelly habitats (see maerl beds above). The distribution is in Lamlash Bay and the south-east coast of Arran (Figure 78).

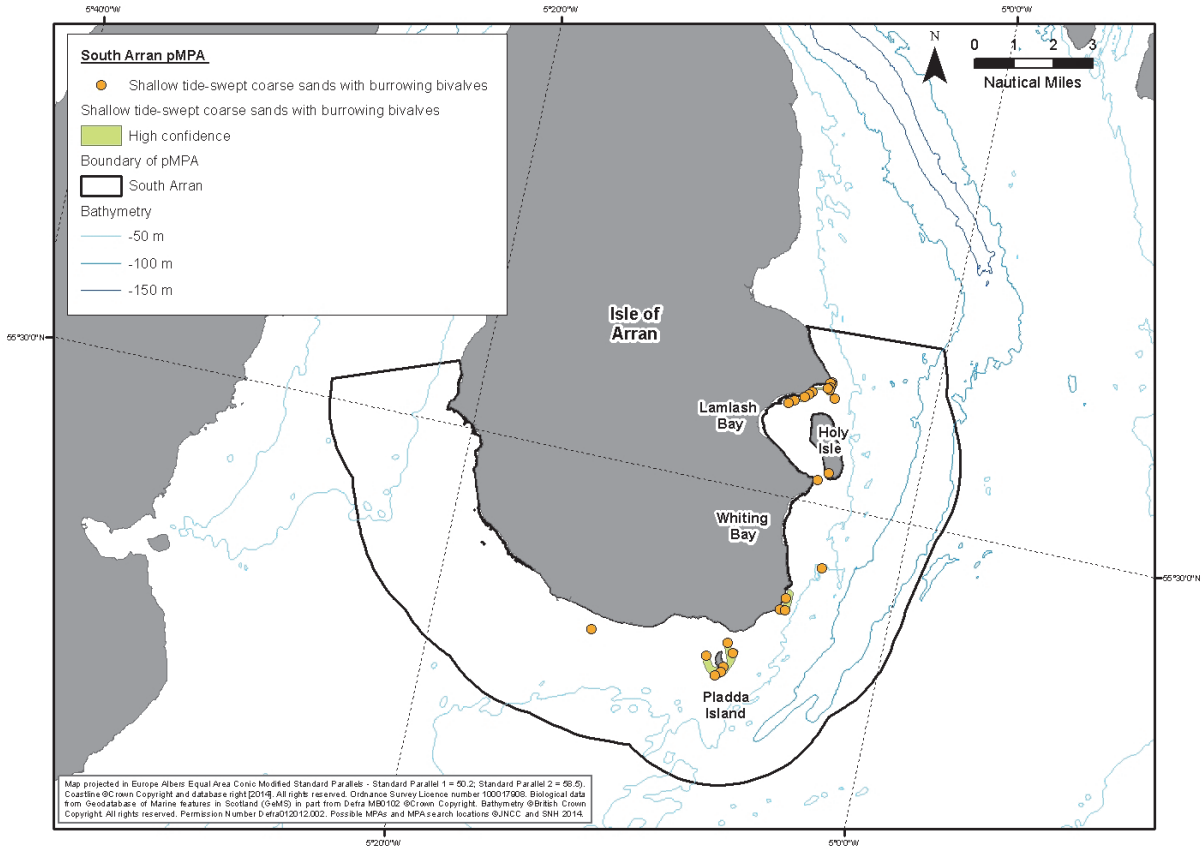

Figure 78. The distribution of shallow tide-swept coarse sands with burrowing bivalves for the South Arran possible MPA, coded for confidence.

3.8.2.8 Burrowed mud component mapping

Most current data from the recent 2013 survey show that the burrowed mud feature points are assigned to the biotope **SS.SMu.CFiMu.SpnMeg**, and there is no longer any discrimination between areas of **SS.SMu.CFiMu.SpnMeg** and burrowed mud.

3.8.2.9 Summary of proposed protected features for the South Arran possible MPA

Most of the offshore area of the South Arran possible Nature Conservation MPA is likely to consist of the burrowed mud proposed protected feature (Figure 79), although it is not certain how homogeneous the area within the polygon boundary is since there is an issue over how the various sample data have been assigned to either “mud” or “burrowed mud” depending on the survey.

The habitats in the mid depth range offshore appear to be of a mixed sediment and records in this zone also include the proposed protected features maerl beds, maerl or coarse shell gravel with burrowing sea cucumbers, and shallow tide-swept coarse sands with burrowing bivalves (Figure 79). These features may be more widespread in this zone than shown by the existing samples.

Inshore areas (especially on the south and east coasts) are sandy and support seagrass beds and kelp and seaweed communities on sublittoral sediment. These proposed protected features may be more widespread than the localised records would indicate.

The distribution of all the proposed protected features is summarised in Figure 79. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

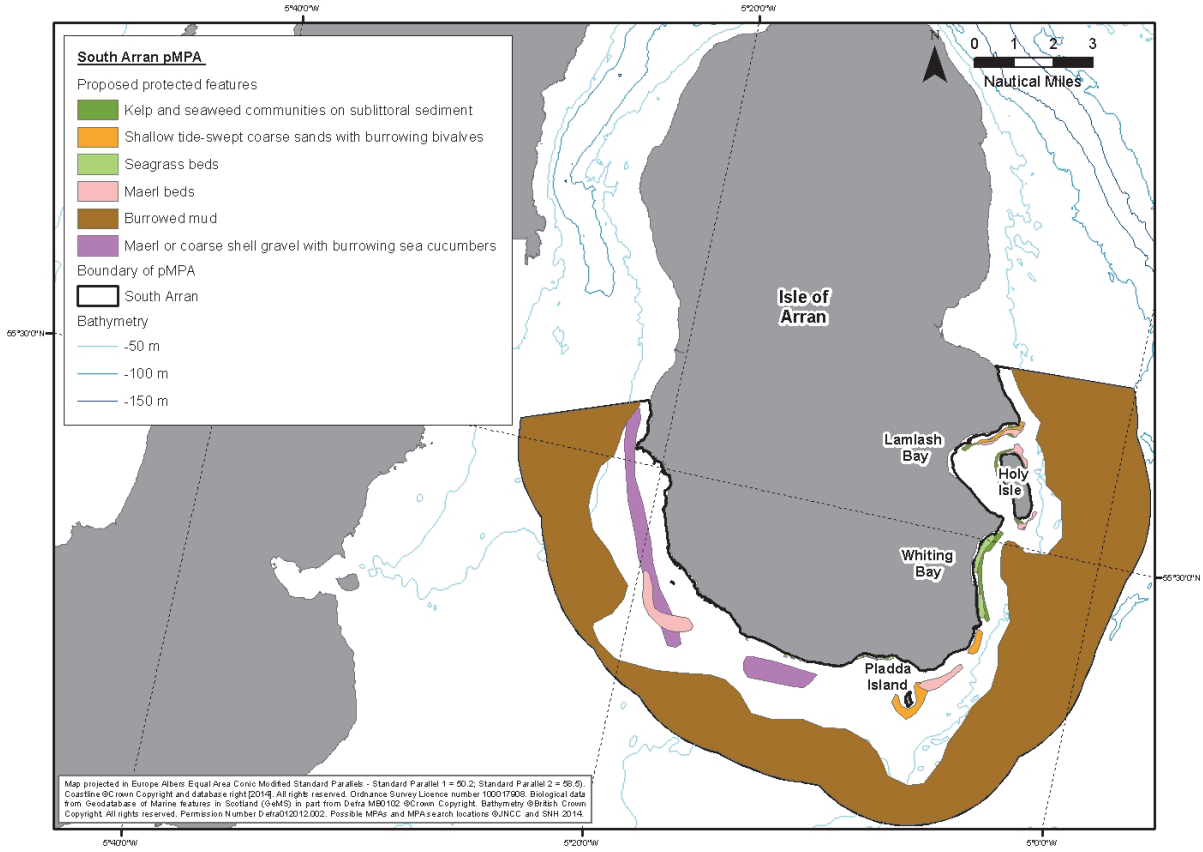

Figure 79. The distribution of all proposed protected features within the South Arran possible MPA.

3.9 Upper Loch Fyne and Loch Goil possible Nature Conservation MPA

The Upper Loch Fyne and Loch Goil possible Nature Conservation MPA was identified for the following MPA search features, which are now referred to as proposed protected features; burrowed mud, flame shell beds, horse mussel beds, and ocean quahog aggregations. Sublittoral mud and mixed sediment communities are not an MPA search feature but have been recommended as proposed protected features as it is considered to add to the broader representativity of the Scottish MPA network (i.e. representative features). The proposed protected features to be mapped within this project are listed in Table 12.

Details of supporting evidence are provided in the Upper Loch Fyne and Loch Goil possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1034853.pdf] with the existing data holdings shown in Figure 80

Table 12: Proposed protected features to be mapped within the Upper Loch Fyne and Loch Goil possible MPA.

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
Upper Loch Fyne and Loch Goil	Burrowed mud	SS.SMu.CFiMu.SpnMeg SS.SMu.CFiMu.MegMax Tall sea pen, *Funiculina quadrangularis* Fireworks anemone, *Pachycerianthus multiplicatus*
	Flame shell beds	SS.SMx.IMx.Lim
	Horse mussel beds	SS.SBR.SMus.ModT SS.SBR.SMus.ModMx SS.SBR.SMus.ModHAs SS.SBR.SMus.ModCvar
	Ocean quahog	*no specific biotope*
	Sublittoral mud and mixed sediment communities (SMS)	SS.SMu.IFiMu[.Ocn] SS.SMu.CSaMu SS.SMu.OMu[.StyPse] SS.SMx.CMx.CIloModHo

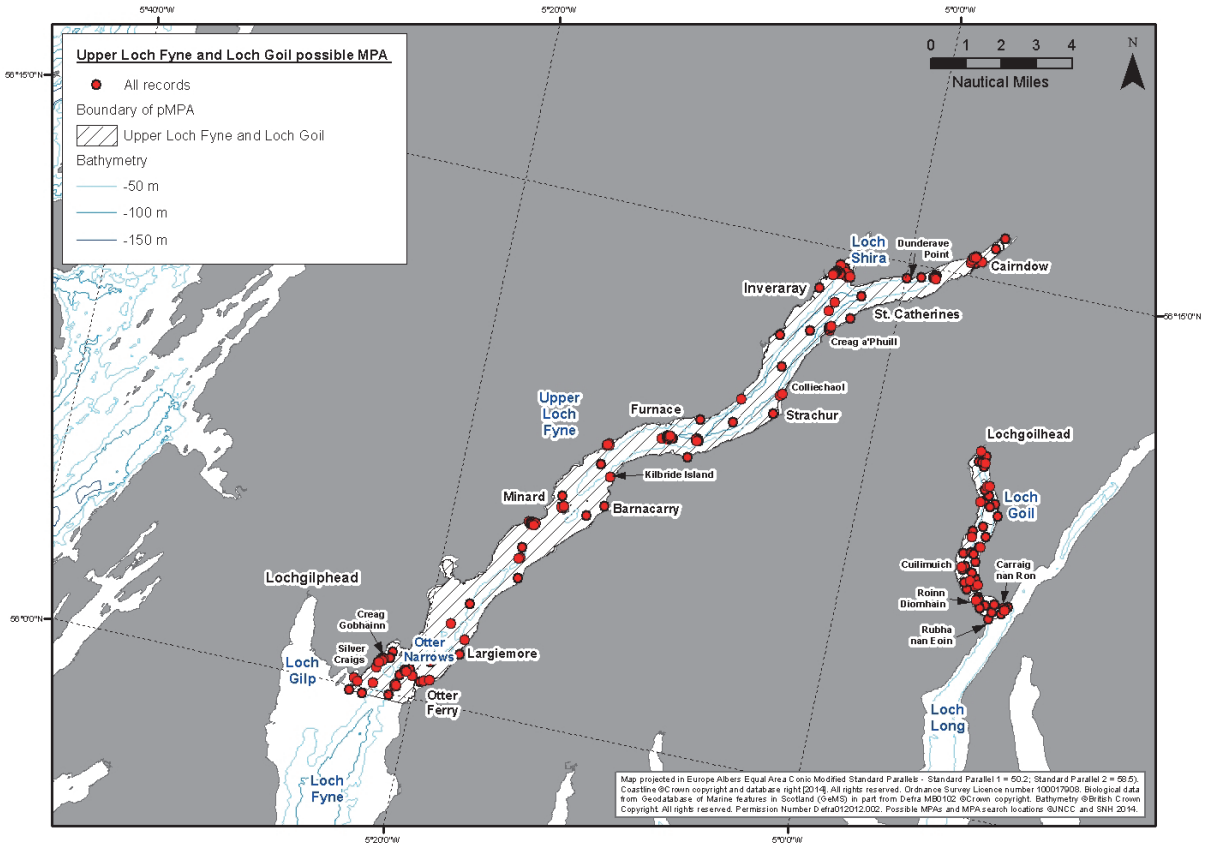

Figure 80. Existing data holdings within Upper Loch Fyne and Loch Goil possible MPA.

3.9.1 Data assessment and requirements for more comprehensive mapping

Loch Fyne and Goil have been well sampled in the past and this facilitated mapping the distribution of the proposed protected features. However, there are no acoustic data for this possible Nature Conservation MPA and the only coverage data that are available for guidance in the construction of polygons are the Defra bathymetry data. These latter data suggest that the topography within these long, narrow physiographic features is quite varied. This makes drawing polygons around widely scattered points uncertain where there are gaps in the data along the lochs.

Added to which, the distinction between burrowed mud, and mud and mixed sediments is not clear cut. The records for these two features, especially within Loch Goil, are intermixed spatially. In Loch Fyne, the mud and mixed sediment records tend to lie close to the coastline (but not always). However, the mud and mixed sediment records are distributed throughout Loch Goil, which has necessitated overlapping polygons.

Note that in most cases a buffer of 30 m around the coastline has been subtracted from the polygons due to uncertainty of the habitats fringing the coastline.

Despite the relative high sampling intensity within the lochs (compared to other sites in this study), there is still confusion between the sediment habitats. Any real distinction (as opposed to apparent differences due to classification issues) may require a more thorough understanding of the fauna associated with the full range of muddy and muddy-sand communities. However, a simpler solution for mapping purposes may be to combine the proposed protected features.

3.9.2 Proposed protected features

3.9.2.1 Burrowed mud

The distribution of the proposed protected feature burrowed mud in the upper region of Loch Fyne is widespread although there is likely to be overlap with mud and mixed sediments around the margin of the loch (Figure 81). The extent and distribution of burrowed mud in Loch Goil is less certain due to the predominance of mud and mixed sediment which is spatially mixed with burrowed mud. The polygons for these two features overlap and the burrowed mud has been assigned moderate confidence.

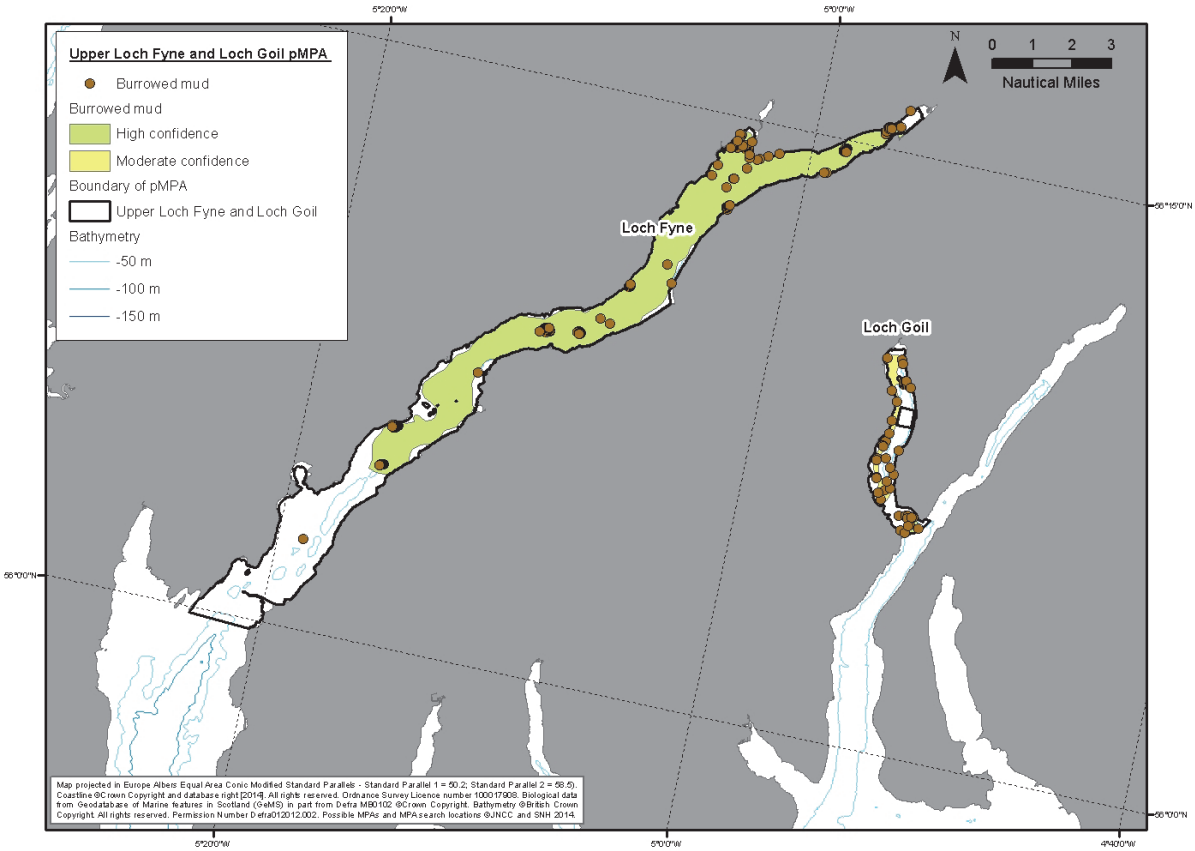

Figure 81. The distribution of burrowed mud within the Upper Loch Fyne and Loch Goil possible MPA, coded for confidence.

3.9.2.2 Sublittoral mud and mixed sediment communities

The predominance of burrowed mud within Loch Fyne and mud and mixed sediment in Loch Goil means that the confidence of mapping mud and mixed sediment is greater in Loch Goil than Loch Fyne (Figure 82). As has been said, the polygon for mud and mixed sediment overlaps burrowed mud in Loch Goil although the polygon confidence for the burrowed mud and mixed sediment community is higher in Loch Goil.

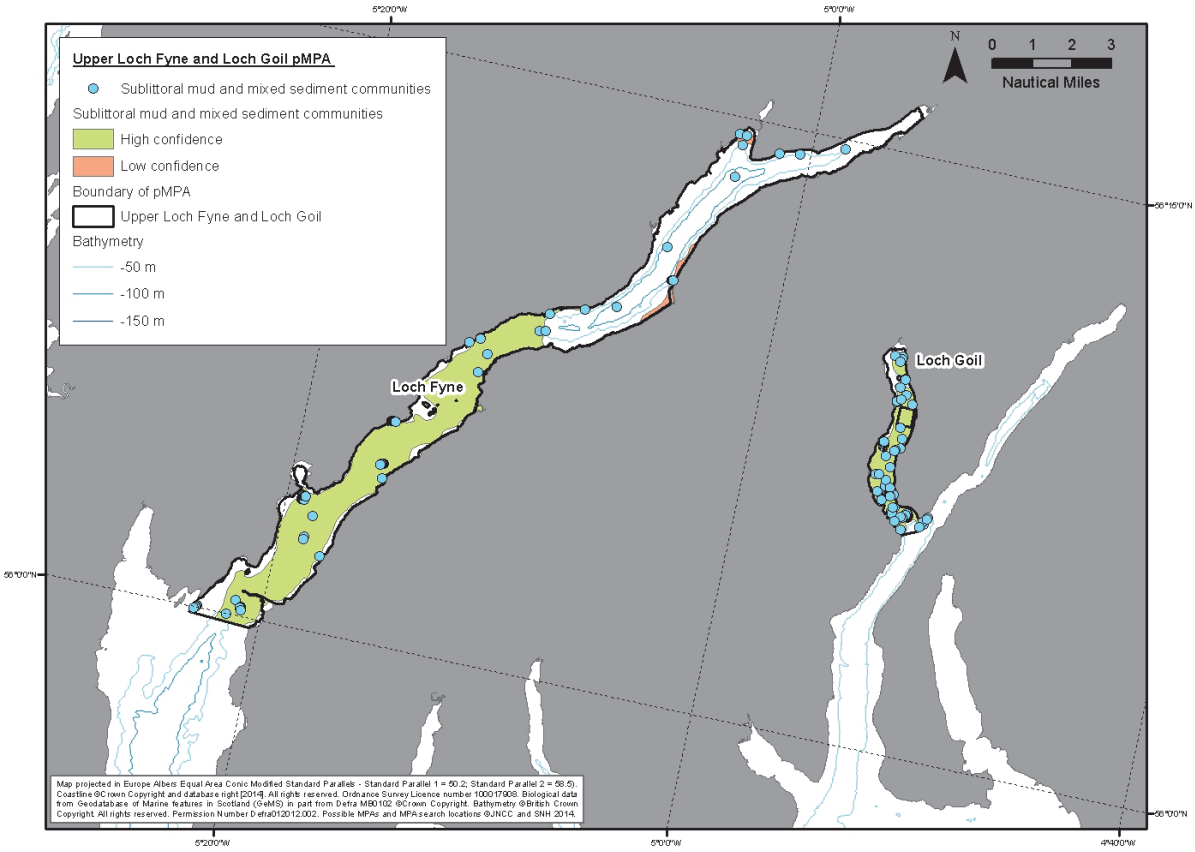

Figure 82. The distribution of sublittoral mud and mixed sediment communities within the Upper Loch Fyne and Loch Goil possible MPA, coded for confidence.

3.9.2.3 Flame shell beds

Although there are a few scattered records for flame shell beds in other parts of Loch Fyne, there is a significant cluster of records from a dedicated survey at the entrance to Upper Loch Fyne for which a polygon has been provided in the database and does not need modification (Moore and Harries, 2012) (Figures 83 and 84).

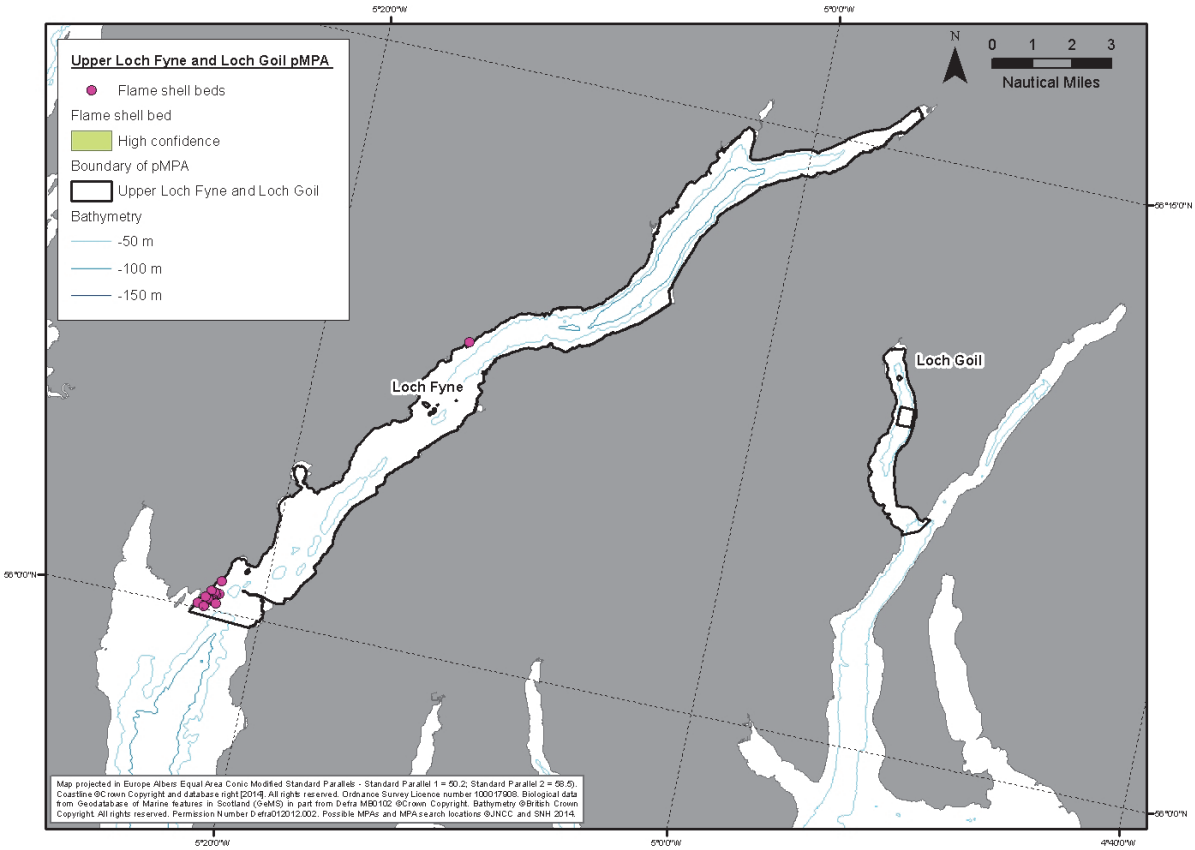

Figure 83. The point distribution of flame shell beds for the Upper Loch Fyne and Loch Goil possible MPA, coded for confidence.

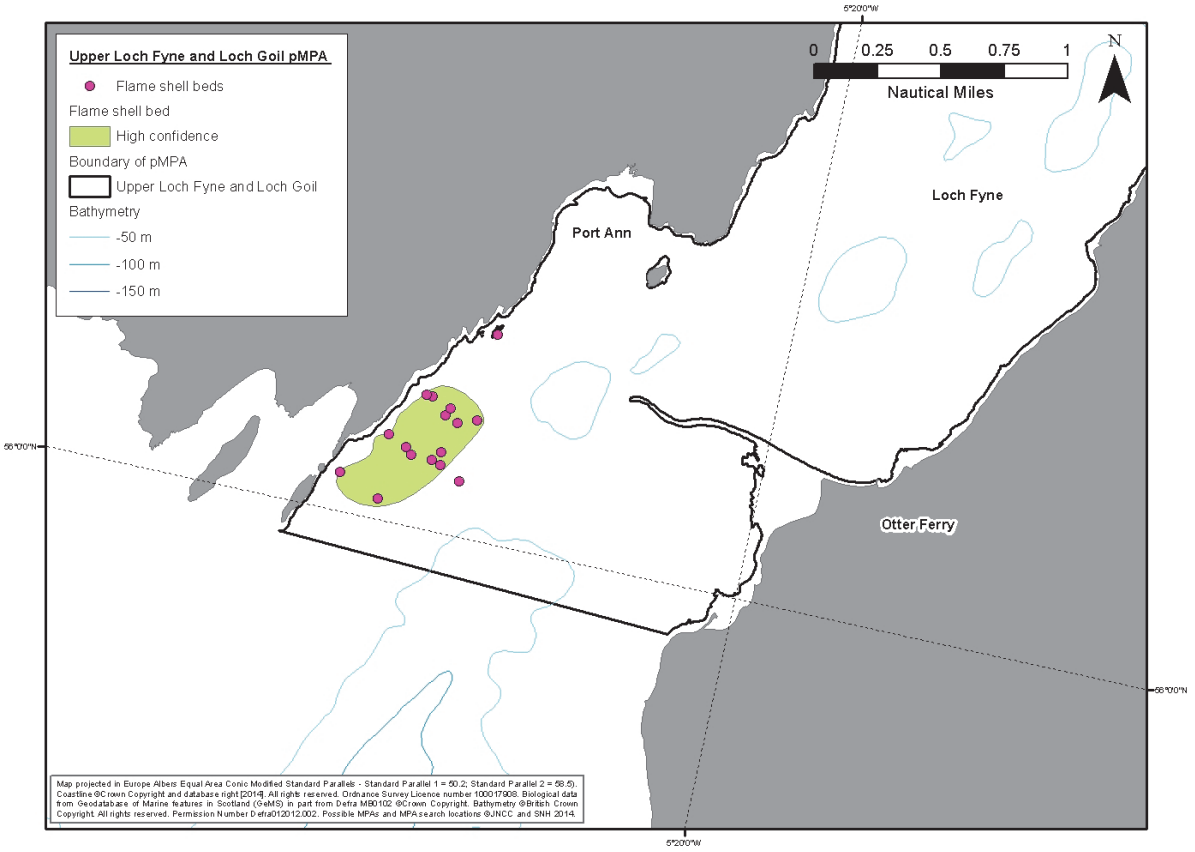

Figure 84. The distribution of flame shell beds for the Upper Loch Fyne

3.9.3.4 Horse mussel beds

Horse mussel bed records are scattered throughout the Lochs Fyne and Goil. There is a cluster of points at the entrance to Loch Goil which may be represented by a polygon. However, it is likely that this simply reflects the dedicated survey of this feature and not the probable distribution of horse mussel beds in the possible Nature Conservation MPA (Figure 85).

3.9.2.5 Ocean quahog aggregations

This species has been recorded sporadically in the lochs and these points are unlikely to represent its true distribution (Figure 85).

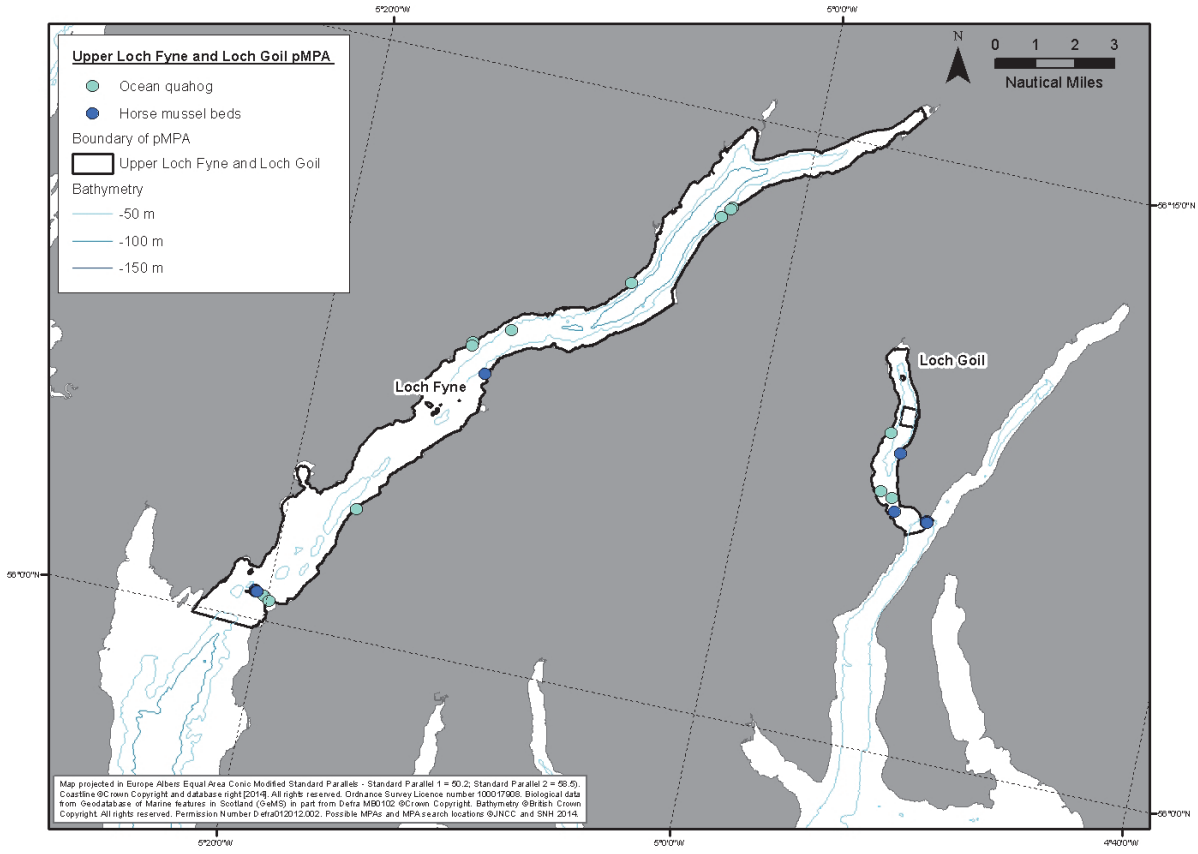

Figure 85. The point distribution of two proposed protected features; horse mussel beds and ocean quahog aggregations within the Upper Loch Fyne and Loch Goil possible MPA.

3.9.2.6 Burrowed mud component mapping

The component biotopes for the burrowed mud proposed protected feature recorded in this possible MPA are **SS.SMu.CFiMu.SpnMeg** and **SS.SMu.CFiMu.MegMax** (with possible overlap with the more generic **SS.SMu.CFiMu**) with some data simply labelled as burrowed mud without further details at the biotope level. Where records are assigned to biotope, it is assumed that these have been assigned appropriately and contain information on the presence and absence of the two primary component biotopes. There is no such information where the data have been assigned to burrowed mud only.

There are two concerns regarding the relevant records for mapping purposes. First, the records of **SS.SMu.CFiMu.MegMax** are sparse and scattered throughout Loch Fyne and

there are no obvious patterns to the distribution of this particular biotope either geographically or with respect to depth and topography. Second, the records of **SS.SMu.CFiMu.MegMax** are often interspersed between other **SS.SMu.CFiMu** biotopes at a very fine scale. Many of the samples in Loch Fyne have been along transects with records taken at intervals of 10 m or less. Other records indicating fine scale heterogeneity are from different surveys but located within 100 m of each other.

This uncertainty of the general presence and absence of **SS.SMu.CFiMu.MegMax** at a broad scale and the heterogeneity at a very fine scale makes polygon mapping of the component biotopes impractical.

3.9.2.7 Summary of proposed protected features for the Upper Loch Fyne and Loch Goil possible MPA

The majority of the sea floor in the Upper Loch Fyne and Loch Goil possible Nature Conservation MPA consists of either burrowed mud or sublittoral mud and mixed sediment communities (SMS) proposed protected features. These two features overlap in their distribution.

The distribution of all the proposed protected features is summarised in Figure 86. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

The pattern of overlap differs between Loch Fyne and Loch Goil with the SMS communities predominating in the lower sections of Loch Fyne, but extending to the upper reaches of Loch Goil.

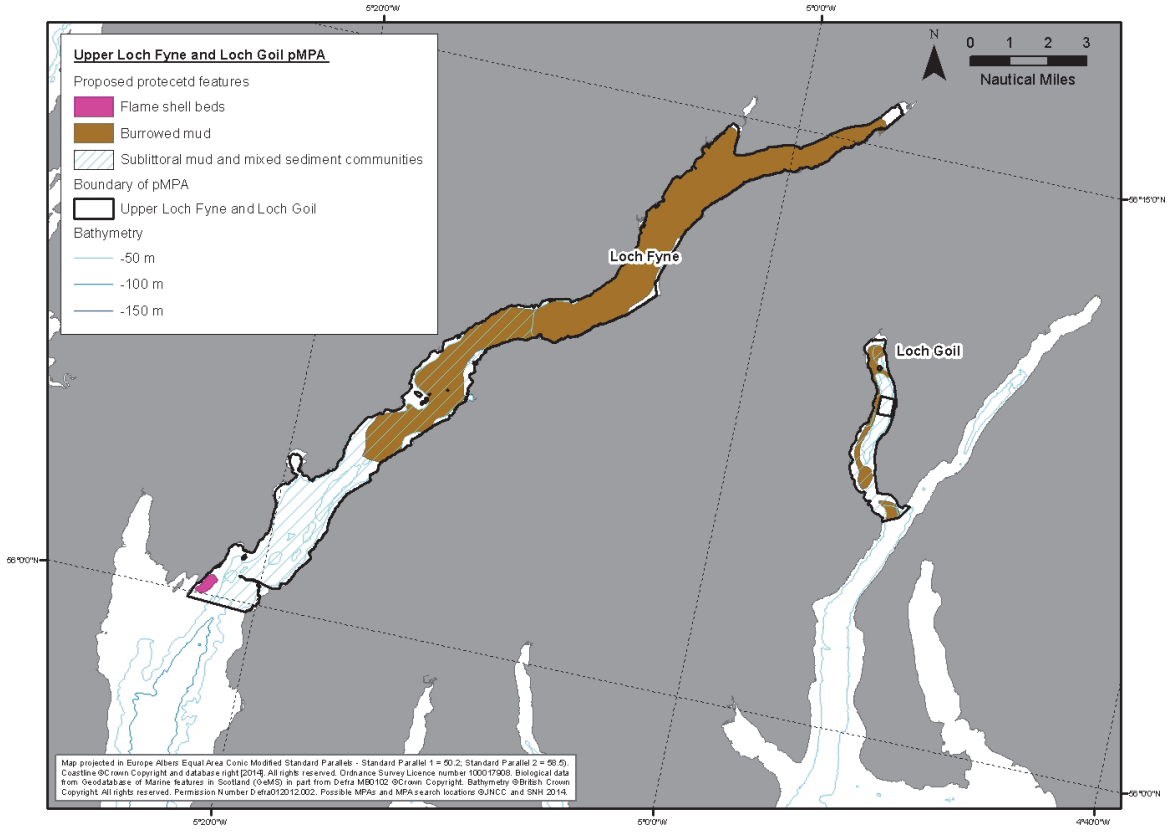

Figure 86. The distribution of some of the proposed protected features within the Upper Loch Fyne and Loch Goil possible MPA.

3.10 Wyre and Rousay Sounds possible Nature Conservation MPA

The Wyre and Rousay Sounds possible Nature Conservation MPA was identified for two MPA search features, which are now referred to as proposed protected features; kelp and seaweed communities on sublittoral sediment, and maerl beds and one geodiversity feature; Marine Geomorphology of the Scottish Shelf Seabed. The proposed protected features to be mapped within this project are listed in Table 13.

Details of supporting evidence are provided in the Wyre and Rousay Sounds possible MPA data confidence assessment [see - http://www.snh.gov.uk/docs/A1033199.pdf with the existing data holdings shown in Figure 87.

Table 13: Proposed protected features to be mapped within the Wyre and Rousay Sounds possible MPA.

Possible Nature Conservation MPA	Proposed protected feature(s)	Component biotopes/ species
The Wyre and Rousay Sounds	Kelp and seaweed communities on sublittoral sediment	SS.SMp.KSwSS
	Maerl beds	SS.SMp.Mrl

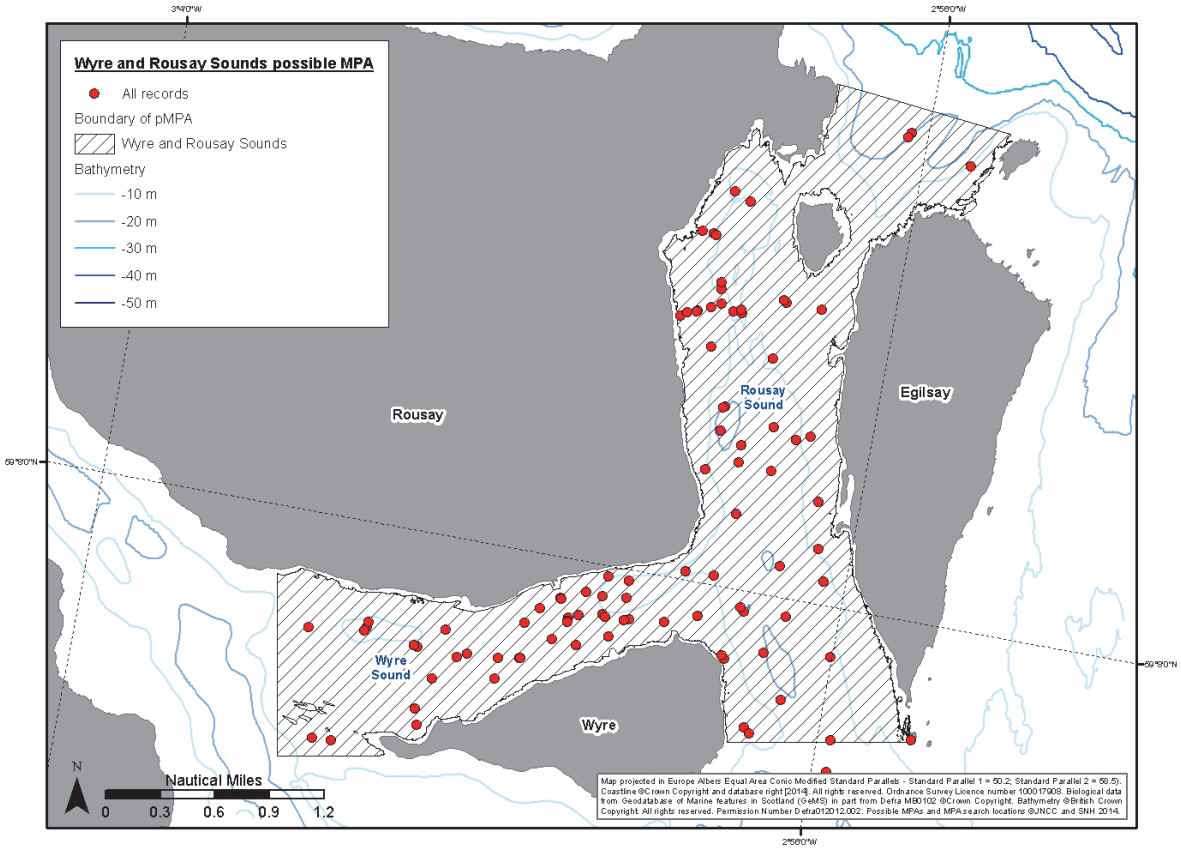

Figure 87. Existing data holdings within the Wyre and Rousay Sounds possible MPA

3.10.1 Data assessment and requirements for more comprehensive mapping

Wyre and Rousay Sounds comprise a small area that is relatively well sampled. The two proposed protected feature habitats (maerl beds and kelp and seaweed communities on sublittoral sediment) probably overlap and merge with sublittoral sediment with no/low cover

of algae or maerl. Because of this, it may be hard to distinguish boundaries with certainty. Aerial photographs were available, but light penetration was restricted to very shallow water and, therefore, the photographs were of no great assistance to delineating the boundaries between the two proposed protected features.

The proposed protected features merge into each other and, unless there is a requirement to distinguish between the two features accurately, it is unlikely that further data collection would be required to refine boundaries of the MPA protected features. However the northern section of Rousay Sound requires sampling to determine the nature of the habitats present there. Additional sampling at the southern entrance to Rousay Sound is needed to determine the distribution of maerl beds.

3.10.2 Proposed protected features

3.10.2.1 Kelp and seaweed communities on sublittoral sediment

The kelp and seaweed communities on sublittoral sediment overlapped with sandy sediments and maerl. Kelp and seaweeds constitute an ephemeral community and these algae can grow thickly over both maerl beds and sediment seasonally.

The distribution of this community (Figure 88) would appear to fringe the maerl beds and form a transitional community (spatially) between maerl and sand.

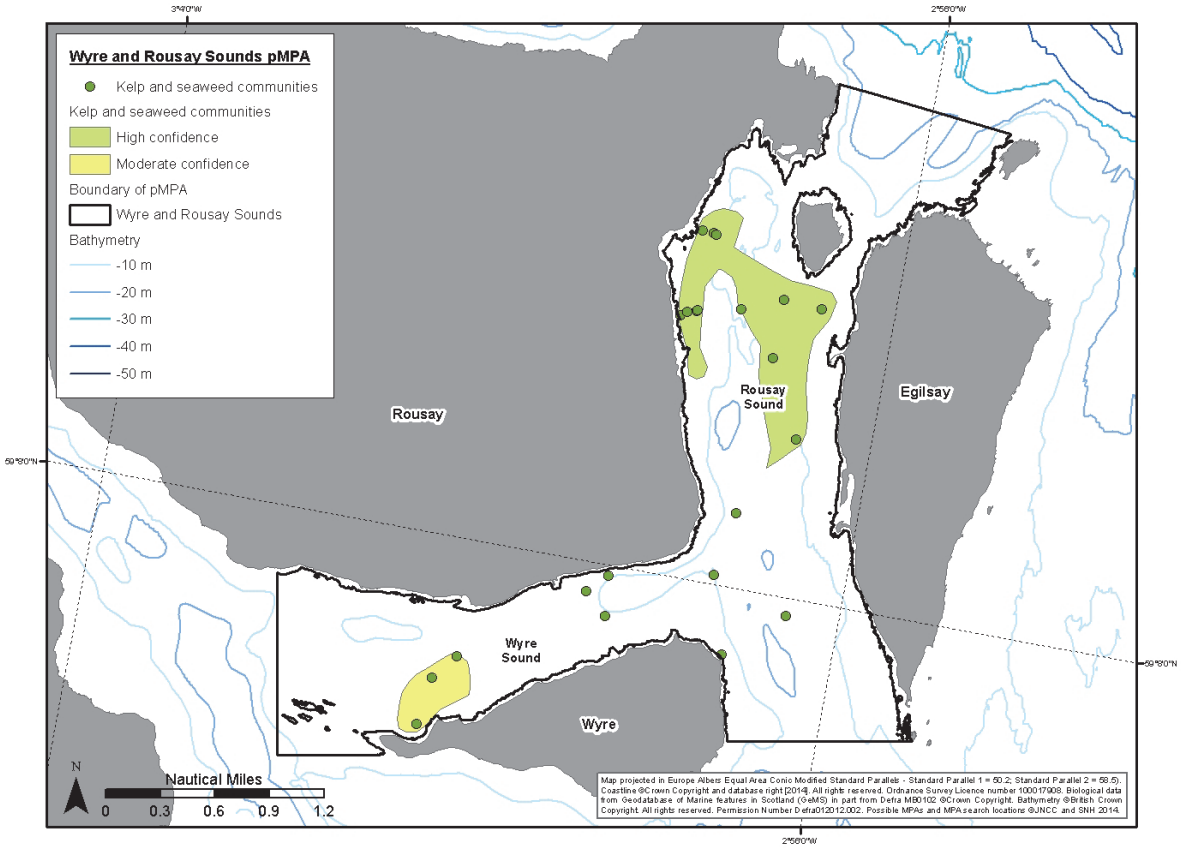

Figure 88. The distribution of kelp and seaweed communities on sublittoral sediment within the Wyre and Rousay Sounds possible MPA, coded for confidence.

3.10.2.2 Maerl beds

Maerl is widespread in the shallows in Rousay and Wyre Sounds and forms the predominant sediment. The polygons for maerl beds overlap with the kelp and seaweed communities on sublittoral sediment (Figure 89).

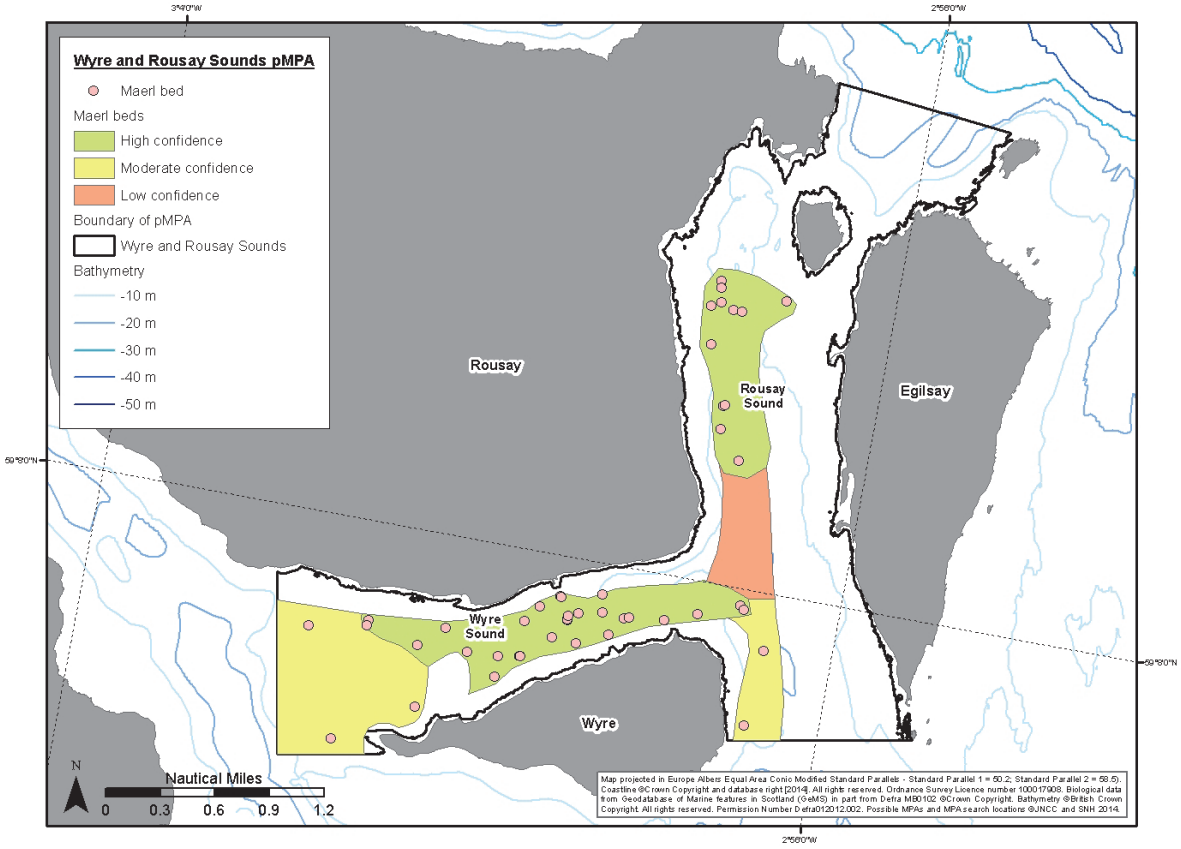

Figure 89. The distribution of maerl beds within the Wyre and Rousay Sounds possible Nature Conservation MPA, coded for confidence.

3.10.2.3 Summary of Proposed protected features for the Wyre and Rousay Sounds possible Nature Conservation MPA

Most of the area, away from the immediate coastal fringe, supports maerl beds, or kelp and seaweed communities on sublittoral sediment or sand with scattered boulders.

The distribution of all the proposed protected features is summarised in Figure 91. The polygons assigned to high or moderate confidence have been combined whilst those assigned low confidence are not shown.

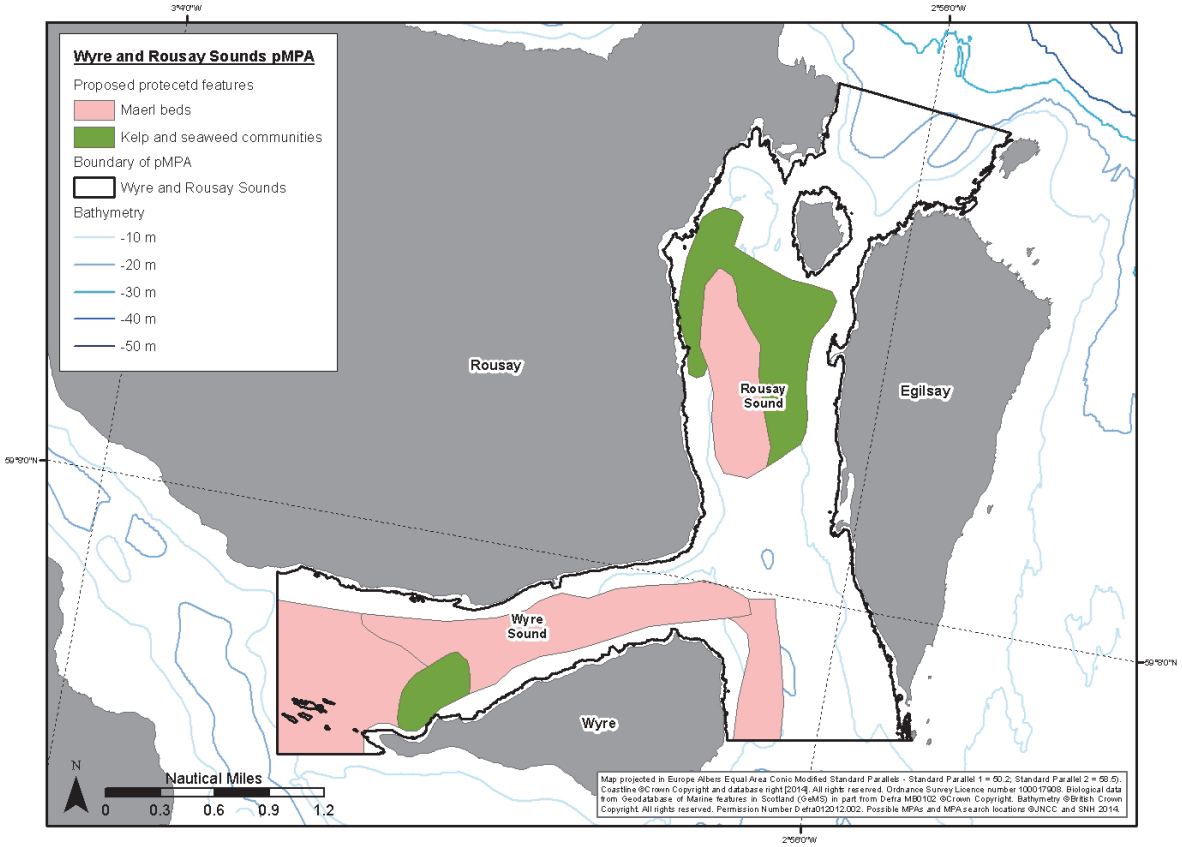

Figure 90. The distribution of all proposed protected features within the Wyre and Rousay Sounds possible MPA. Note that semi-transparent colours have been used to highlight areas of overlap.

4. DISCUSSION

The proposed protected features within 10 of the possible Nature Conservation MPAs have been mapped based on existing data holdings and these polygons will be revised in the future as more data are collected. The overall success of the maps (which depends on the confidence of individual polygons and size of areas where there are gaps in knowledge) varies between sites and between features within each site. A summary of the outcome of the analyses for each site and recommendations for future work for each site is provided in Section 4.4.

4.1 Critique of methods used for drawing polygons

The “by eye” approach for drawing polygons was the only method that could be consistently applied to all of the sites given the varied nature of the data and the incomplete or absent coverage of acoustic data, as has been discussed already in the Methods section. The systematic drawing of polygons “by eye” has the virtue that the polygons are true to the records and the results are reliable in areas where there are plentiful sample data. However, it must be conceded that if these polygons were the result of some statistical analysis instead of “by eye”, they would probably be criticised (rightly) of being “over-fitted” to the data. Note that in some cases where there were sufficient data points a method based on calculated probability images was used to supplement the polygons drawn “by eye”. This information was used largely to subdivide the burrowed mud polygons into their component biotopes.

The “by eye” method is particularly weak in predicting the distribution of habitats where there are no sample records but there is some knowledge of the environmental conditions

(preferably in the form of high resolution coverage of physical habitat parameters). Under these conditions, predictive modelling (such as supervised classification) may be more suitable (see the example in Section 3.5.4).

Modelling techniques produce predictions for the distribution of habitats and create a full coverage for sites. However, the predicted distributions can be very conjectural. It is often the case that, in order to achieve the best fit with the data, some samples are located in areas that have been classified as a different habitat class. This mismatch stands out as an error on maps and it may be more useful to leave un-sampled territory blank and have greater confidence in the areas where there are data as is the case with the systematic "by eye" approach.

It should go without saying that if the full coverage data (e.g. acoustic data) are lacking, methods such as supervised classification will not work at all. This is the case in many of the possible Nature Conservation MPAs in this study, especially in the shallow inshore areas where acoustic coverage is hard to obtain.

4.2 Confidence assessment

The approach adopted was to attempt to be systematic. However, many questions arose whilst completing the assessments of the proposed protected features:

- Does the boundary encompass the likely distribution?
- Is the boundary precise or general?
- Is it accurate or an estimate?
- Is the distribution exclusive to the feature or is the area shared with other habitats?
- If shared, is this with other proposed protected features or non-features?
- Can any statement be made about the possibility of the distribution extending beyond the boundaries?

A single measure cannot adequately reflect confidence since there are so many variables to consider. For example, scale is important: The answers to the above questions will depend to some extent on the size of the area. Very localised features may warrant detailed and precise boundaries whereas features with large areas may be described adequately with polygons that are more general in outline.

The guidance developed in this report was difficult to apply rigidly given the variable nature of the data. The guidance notes are very much "work in progress" and would benefit from further development from experience gained by other analysts working with other case studies.

4.3 Progressing point-to-polygon mapping

Modelling techniques could be applied to the datasets in all of the sites if one of the purposes of mapping was to expand knowledge through a step-wise process of prediction followed by survey and a refinement of the model (and, ideally, a further round of prediction and testing). This sounds as though it would be an expensive and never-ending process. This need not be the case. At the end of each modelling process the predictions would be prioritised (which habitats and boundaries are of greatest interest and least certain) and the next round of survey targeted answering specific questions. This general approach is undoubtedly the most effective way to build up knowledge of the habitat distribution in an area and, importantly, the processes that underpin the distribution. It would also form the basis of effective monitoring of prioritised and significant features of the sites.

The point-to-polygon and predictive modelling approaches are not incompatible: The point-to-polygon approach could be seen as the first stage in planning a route map to gaining knowledge of each site. This first stage could prioritise areas suitable for modelling and subsequent rounds of testing and targeted survey/monitoring.

Note that "modelling" actually covers a range of approaches. Broadly, there are two main types of modelling: The first is based on knowledge of how habitats relate to a range of environmental factors (such as biological region, depth, water "energy" and sediment). This knowledge is usually gained by statistical analysis of records and a theoretical knowledge of the form and function of the key species in the communities. This combined knowledge is then applied to un-sampled areas and tested. The rules of the model are then updated and reapplied to the environmental data.

The second type of modelling, of which supervised classification is an example (see Section 3.5.4) is more "black box": Algorithms, usually those available in specific software packages, are used to establish statistical links between sample data and the environmental coverage. These statistical "signatures" are then used to calculate the most probable distribution of the habitats. This approach to modelling can be very successful for specific areas if certain conditions are met. There must be adequate coverage of environmental data across a range of parameters that can be considered important (directly or indirectly) to the distribution of the key community species. The distribution of the ground truth samples must be representative of the area and not unduly biased towards any particular habitats.

Both techniques can be used along the route map towards gaining knowledge of a site. However, knowledge-based modelling should be the ultimate goal as this is most versatile for management based on an understanding of the functioning of a site, and also most transferable to other sites.

The following is a summary of discussion points for each of the possible Nature Conservation MPAs and an outline of how the point-to-polygon mapping could be progressed beyond this first stage.

4.3.1 Clyde Sill

The polygons of high and moderate confidence for the circalittoral sand and coarse sediment communities are well supported by sample data and the site appears to show a gradual west-east transition from mixed sediment to coarse sediment and then muddy sands. However, bedform feature maps suggest that there are distinct regions within this site and the transition may not be gradual, but patchy with many boundaries, and possibly dynamic over time. In addition it is unknown what the structure and function of the coarse sediment community within this site is and how it relates to the wider environment. Focusing survey effort on selected areas (transects) that combine acoustic and semi-quantitative/quantitative sampling that covers this west-east transition may provide information to help answer these questions.

4.3.2 Fetlar to Haroldswick

The polygons range from high to low confidence and, although the site appears to be well surveyed, there are many gaps in knowledge. This site could, potentially, be largely composed of proposed protected features. Areas that are not proposed protected features are likely to be very closely allied to them and integral to the understanding of them. For example, there is a transition between fine sandy sediment, maerl and gravelly habitats. However the dynamics between these sediments and their communities is unknown. Again, whilst some areas are homogeneous circalittoral sand and coarse sediment, other areas are

likely to be a complex patchwork of rocky outcrops and sediment. The latter is poorly sampled at present. Does this patchwork of sediment qualify as a proposed protected feature and if so, does it significantly add to the diversity and richness of this feature?

For these reasons, this site would be a suitable candidate for comprehensive habitat mapping, including non-proposed protected features. Much of the site already has excellent acoustic coverage.

However, the shallow areas present a problem for survey that is common to many of the other possible Nature Conservation MPA in that there is an extensive indented coastline that is difficult to survey acoustically. Thus, some of the shallow sites with mixed maerl, kelp and seaweed communities on sublittoral sands and other habitats may require a dedicated small boat survey.

4.3.3 Loch Sunart

The polygon mapping of this site should be regarded as incomplete since the two proposed protected features within Loch Sunart (flame shell beds and northern feather star aggregations on mixed sediment) are very patchily distributed and their distribution is poorly captured by sampling alone. It is likely that they are dependent on specific habitat requirements. Additionally, the distribution of northern feather star aggregations may be dynamic and vary over time. The habitat requirements for these two features may be amenable to “rule-based” modelling and the predicted distributions tested by targeted survey.

4.3.4 Loch Sween

Loch Sween has been comprehensively surveyed compared to some of the other possible Nature Conservation MPAs included in this study. However, the polygon boundaries in the shallow regions of the upper lochs are less certain than the deeper central parts of the loch and would benefit from targeted sampling based on aerial photography. Ideally there should be a dedicated over-flight at low tide taking light penetration into consideration.

Another possible area for further investigation is the composition of the shallow and deeper water components of the sublittoral mud and mixed sediment communities through quantitative analysis of sample data.

4.3.5 Lochs Duich, Long and Alsh

Loch Duich has been well sampled and the boundary for burrowed mud and the delineation of communities characterised by *Funiculina quadrangularis* as separate from other burrowed mud communities using supervised classification has been successful.

Loch Alsh is under-sampled and the relationship between topography of the sea floor and the burrowed mud proposed protected feature requires further investigation. The composition of the burrowed mud community may require further analysis and mapping to distinguish and justify any sub-communities that may have relevance to management. The predicted distribution of communities characterised by *Funiculina quadrangularis* is very tentative and should be tested through targeted sampling.

Drop down video and grab sampling could be undertaken as part of comprehensive modelling of all habitats within the lochs based on the acoustic coverage available. The spatial relationship between burrowed mud (and its component biotopes) and its

neighbouring habitats would be a good first step in understanding the processes that have created and may be required to maintain the proposed protected features.

4.3.6 North-west sea lochs and Summer Isles

Although there is a large number of records, there are still many areas that are sparsely sampled, especially given the complexity of the coastline. Features such as maerl beds and kelp and seaweed on sublittoral sediment are probably much more widely distributed than the present polygons would indicate. Thus, this site would also be suitable for modelling the distribution of all habitats followed by targeted survey to test the predictions, especially of those habitats likely to be patchy and isolated, such as maerl.

Burrowed mud and circalittoral muddy sands occur widely and in very different situations. It is likely that these features have a distinct composition in these different environmental conditions and further work using quantitative and semi-quantitative sampling techniques could be used to determine the composition of the communities of these features with the objective of defining and mapping sub units.

4.3.7 Small Isles

The Sound of Canna has been comprehensively sampled and any uncertainty about boundaries is likely to emanate more from overlap between the habitats than sampling effort.

However, the possible Nature Conservation MPA is very large and much is sparsely sampled and so further survey work would benefit some areas. The area south of Rum is one such area. The extensive rocky outcrops are also under-sampled and the relationship between the substratum, depth and the northern sea fan and sponge communities (and other faunal communities) is insufficient to properly map the distribution of this proposed protected feature.

Modelling of all habitats would be a good first step in mapping the areas away from the Sound of Canna. It is less certain if modelling would help separate the features within the Sound of Canna. However, modelling can produce maps of uncertainty and, combined with matrices quantifying overlap between habitats, may help to resolve conceptual issues regarding the relationship between overlapping features.

4.3.8 South Arran

The burrowed mud proposed protected feature is mapped as being extensive offshore partly because muddy sediment records have been regarded as potential burrowed mud and used to guide the polygon boundaries.

The inshore areas have been patchily sampled and the distribution of the proposed protected features is unlikely to be definitive. A comprehensive but rapid prospecting survey (e.g., drop-down video) could firm-up the presence or absence of features within this extensive zone. Ideally, aerial photos taken specifically for the shallow sublittoral also might be commissioned to accompany this survey.

The video survey could be extended along transects into deeper water to investigate the distribution of gravelly sediments in the intermediate depth range.

Modelling without the aid of comprehensive acoustic coverage is unlikely to refine the distribution of the various habitats, including the proposed protected features. This would be an expensive exercise given the large area of the site. However, rule-based modelling of all

habitats might form a good basis for establishing the underlying processes that structure the habitat distribution in this site.

4.3.9 Upper Loch Fyne and Loch Goil

A large part of this possible Nature Conservation MPA is occupied by the proposed protected features burrowed mud or sublittoral mud and mixed sediment communities, with considerable overlap between their distributions.

Modelling without the aid of comprehensive acoustic coverage is unlikely to refine the distribution of the various habitats, including the proposed protected features. This might be considered for this moderately sized site and its linear coastline.

4.3.10 Wyre and Rousay Sounds

Although this is a small site there are still areas with little information available (e.g., the northern section of Rousay Sound). Except for the rocky coastline, the other habitats grade into each other and all the boundaries must be considered “fuzzy” to some extent. If it is important to refine the distribution of these boundaries, then a systematic survey of drop-down video along transects covering the area might be considered.

Aerial photographs of the sound would assist this process. As a general point, advice could be sought about aerial photography for inshore waters: It may be that a more appropriate use of filters specifically to reduce surface reflectance and accentuate light penetration would improve visibility of the seabed in shallow water.

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