Heriot Watt University

Commissioned Report No. 002

Assessment of the Extent of Blue Carbon Habitats and Distribution of Priority Marine Features in Gutter Sound, Orkney

C O M M I S S I O N E D   R E P O R T

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COMMISSIONED REPORT

Summary

Assessment of the Extent of Blue Carbon Habitats and Distribution of Priority Marine Features in Gutter Sound, Orkney

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Keywords

Gutter Sound; Orkney; Blue Carbon; Carbon Sequestration; Maerl; Flame Shell; Horse Mussel; Kelp

Background

Sequestration of carbon dioxide by natural features is a key factor which acts to slow anthropogenic climate change. Destruction and degradation of these sinks will prevent this process, and exacerbate currently rising emissions. The role of marine systems as carbon sinks is becoming increasingly understood, emphasising the need for protection of certain marine features.

The aim of this project was to determine the location of various blue carbon biotopes within Gutter Sound in Orkney, and to estimate the quantity of carbon that is stored. This will allow for future site management of these resources. To explore the area, remotely operated vehicles (ROV) were deployed and *in situ* diver surveys were undertaken. The divers utilised video transects, collected live samples, and took cores to allow for laboratory analysis and the classification of biotopes.

MAIN FINDINGS

- Overall, 8 successful ROV surveys were undertaken in Gutter Sound, with a total of 93 minutes of video footage recorded. This led to the identification of 14 species and 3 different biotopes.

- The dominant biotope identified through analysis of the ROV footage was **SS.SMP.Mrl.Pcal.R** (5 sites) characterised by beds of the Priority Marine Feature (PMF) *Phymatolithon calcareum* (maerl) with red seaweeds in shallow infralittoral clean gravel or coarse sand.

- Additionally identified through analysis of the ROV footage were the biotopes **SS.SMP.KSwSS.LsacR** (2 sites and at the start of ROV drop 8), characterised by *Laminaria saccharina* and red seaweeds on infralittoral sediments, and **SS.SMX.Imx.Lim** (1 site), characterised by infralittoral mixed sediment with *Limaria hians*.

- Analysis of video and image footage collected in three diver surveys reinforced the dominance of biotope **SS.SMP.Mrl.Pcal.R** within Gutter Sound.

- The diver surveys also showed high abundance of *Modiolus modiolus* (SACFOR abundance scale A) at dive site 3 mixed with *Mya truncata* and *P. calcareum*. This habitat could be classified as either **SS.SMP.Mrl.Pcal.R** or **SS.SBR.SMus.ModT**, or be given a classification of both biotopes combined.

- Analysis of 29 minutes and 11 seconds of video footage, 107 still images, 28 quadrat images and samples collected by divers for later analysis, all led to the identification of 67 taxa to species level and 8 taxa to genus level.

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1. INTRODUCTION

1.1 BLUE CARBON

Levels of atmospheric carbon dioxide (CO_2) are now greater than 400 parts per million (ppm) (CO2.earth). This is the highest level it has reached in the last 800,000 years and is more than 42% above the pre-industrial revolution value of 280 ppm. This increase in CO_2 is driven primarily by the burning of fossil fuels but is also significantly affected by changes in land use. Land use change can lead to increased emissions by clearance of natural vegetation and the destruction and deterioration of ecosystems that act as natural sinks of carbon (Solomon *et al*., 2007). Previously, approaches to reducing CO_2 concentrations have focused solely on decreasing emissions, but a more recent approach is to combine reducing anthropogenic sources of CO_2 with encouraging CO_2 storage and uptake by conserving natural ecosystems that have high carbon sequestration rates (Canadell and Raupach, 2008). The role of terrestrial forests as a sink of CO_2 is well known, but often overlooked are the natural carbon sinks that exist within the marine biosphere.

Plant dominated coastal ecosystems play a large role in global sequestration of carbon. These ecosystems store carbon within their above ground biomass (leaves, stems and branches), below ground biomass (litter and dead wood), and in their underlying sediments. This carbon stored in the marine environment is known as blue carbon. The sediments in which sea grass meadows, salt marshes and mangroves grow do not become saturated with carbon like terrestrial soils, as the sediments accrete in a vertical direction in response to rising sea levels. This means that the size of the sediment carbon sink may increase over time. For example, mangrove systems in Belize have accreted carbon deposits over 10 metres thick that are over 6000 years old (McKee *et al*., 2007). Other stores of blue carbon include kelp forests, maerl beds, cold water corals, tubeworm reefs, flame shell beds and brittlestar beds (Burrows *et al*., 2014).

Expanding human populations and the resultant urban development is generating changes in coastal marine environments which can put blue carbon stores at risk. Seagrasses and saltmarsh can be affected by coastal development and erosion leading to a coastal squeeze as the available habitat decreases. Biogenic reefs and kelp beds can be impacted directly by trawling or by increased storminess due to climate change. Calcifying species will be particularly affected by ocean acidification and climate change threatens species found towards the edges of their thermal tolerance zones (Burrows *et al*., 2014). Understanding the amount of carbon each blue carbon system sequesters, as well as where each habitat is located, is vital in protecting these valuable CO_2 sinks.

1.2 ORKNEY ISLANDS

The Orkney Islands in the north of Scotland are a series of approximately 70 islands, 20 of which are inhabited. The islands cover a total area of 974 km^2 and have 1,246 km of coastline. Orkney has a small aquaculture industry and has recently become an important international centre in the renewable energy industry. The waters around the Isles of Orkney contain a rich diversity of wildlife and support a range of rare or vulnerable habitats and species. Habitats known to be present include maerl beds, submerged reefs, tidal rapids, salt marshes, sandbanks, dune systems, and maritime heath and grasslands. There are three Special Areas of Conservation (SACs) and 22 of the habitats are protected as Sites of

Special Scientific Interest (SSSI). Many of these habitats act as sinks for carbon making Orkney a very interesting site for the study of blue carbon (Marine Scotland, 2010).

1.3 PREVIOUS STUDIES

In 1999 Goulding compared maerl beds in Weddel Sound with beds found in Gutter Sound. Dive surveys and core samples showed that Gutter sound contained a high abundance of dead maerl and mollusc shells, whereas Weddel Sound contained a high abundance of live maerl but with sever patches of dead maerl (Goulding, 1999).

Marine Scotland commissioned a survey in 2011 to study priority marine features (PMFs) around the Orkney Islands. Survey areas included Wyre Sound, Shapinsay Sound and the North of Kirkwall Bay. The survey areas were chosen due to the presence of maerl and horse mussels. Results from MNCR phase 2 dive surveys and clump samples showed that as many as 283 different species of Horse Mussels were present in Scapa Flow, making the horse mussel beds one of the most diverse in the UK (Hirst *et al*., 2012).

Another study commissioned by Scottish Natural Heritage in 2014 assessed Horse Mussel beds to the North of Weddel Sound. The survey found 6 biotopes with *M. modiolus* being the most dominant (Sanderson *et al*., 2014). This study will be discussed further in section *4.1.2*.

1.4 PRIORITY MARINE FEATURES

Orkney is a hotspot for priority marine features due to the high diversity of benthic habitats found between the many islands. Figure 1 shows the location of known priority marine features in the Scapa Flow area.

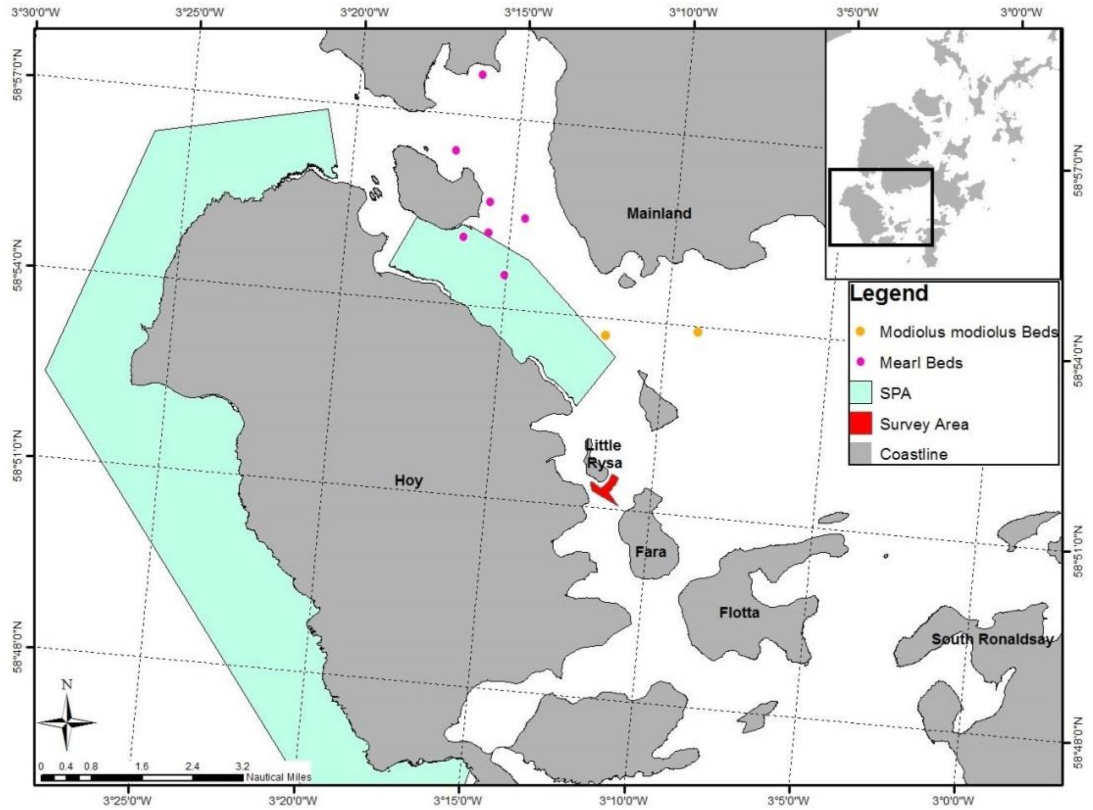

Figure 1: Priority marine features near the survey area in Orkney, UK.

1.4.1 Maerl Beds

Maerl beds are functionally and structurally complex habitats formed by marine algae. They create a complex architecture that supports a very rich diversity. Maerl thalli and the remains of dead maerl build up on the sediments to produce carbon deposits with a three dimensional structure (Hall Spencer, 1998). The maerl thalli grow very slowly and deposits can take several hundreds of years to develop (Biomaerl, 1998). Because of this, they are seen as a non-renewable resource and one of high importance. Maerl beds are fragile and can support rare and scientifically interesting species making them particularly important in international conservation (Barbera *et al*., 2003).

Maerl acts as effective stores of marine carbon as they form a long lasting calcium carbonate skeleton. The matrix structure can also trap associated calcifying biota. Despite the slow rate of deposit accretion (0.25mm/yr), maerl beds trap a large amount of carbon as they have a large area: volume ratio and beds are extensive. Maerl can produce 407 g C m-2 yr-1 which becomes trapped within each deposit. The carbon budgets for maerl beds can be calculated using knowledge of accretion rate, bed position and extent, proportion alive or dead, primary productivity and deposit depth (Kamemos *et al*., 2003).

There are currently 353 records of maerl beds in Scotland, but these have little information of the extent or proportion of live/dead maerl. If each bed is assumed to have an extent of 20,000 m^2 (based on four beds for which the extent is well known) this gives a total Scottish maerl bed area of 7.06 km^2. There is also little information on maerl bed thickness. If a thickness of 60cm is taken as the average, there is a total volume of 4.23km^2 alive or dead maerl in Scotland. These numbers are likely to be underestimates as there are many undiscovered mearl beds, and the average extent and thickness is based on a relatively few number of beds (Burrows *et al*., 2014).

Maerl is threatened in the short term by dredging, trawling and sedimentation; and in the long term by ocean acidification. The maerl forming species, *Lithothamnion corallioides* and *Phymatolithon calcareum*, are now included in Annex V of the EC Habitats Directive, and in the UK maerl biotopes are protected as a key habitat by the Joint Nature Conservation Committee's interpretation of the Habitats Directive (Wilson *et al*., 2004). Sedimentation and physical impacts will prevent the future growth of Maerl deposits, stopping the growth of this carbon store. Ocean acidification may also cause the breakdown of the deposits, releasing the carbon that was trapped (Burrows *et al*., 2014).

1.4.2 Horse Mussel Beds

The horse mussel *Modiolus modiolus* is found around Scotland in the shallow subtidal zone. Horse mussels are found mainly on the northern and western coasts, including the Shetland and Orkney Islands (Mair *et al*., 2000). In some areas beds are dense enough to be regarded as biogenic reefs, sometimes covering large areas. The largest horse mussel bed in Scotland covers 3.85km^2 (Hirst *et al*., 2012), but most beds are less than 1 km^2 (Burrows *et al*., 2014).

M. modiolus is a relatively slow growing, long lived bivalve with sporadic recruitment. This gives it a low area-specific carbonate production rate. In the Firth of Lorn this was measured to be approximately 330 g $CaCO_3$ m^{-2} yr^{-2}, which equates to about 40 g C m^{-2} yr^{-1} (Collins, 1986). The length of time that horse mussel shells persist after death depends on a large number of factors. This is mainly determined by rates of physical abrasion, chemical dissolution and bioerosion (Smith and Nelson, 2003). In shallow waters off the Scottish west coast the shells are attacked by a number of bioeroding organisms, but below the euphotic zone key bioeroders are absent and degradation rates are lower (Akpan and Farrow, 1985). The majority of carbonate degradation takes place at the interface between the sediment and water. Long term preservation requires burial below this zone which normally occurs due to a large scale physical event of sediment slide. However, even at the sediment water interface complete shell destruction due to bioerosion may require centuries if not millennia to occur (Smith and Nelson, 2003).

1.4.3 Flame Shell Beds

Flame Shells, *Limaria hians*, are small (4cm long) bivalve molluscs that live in hidden nests known as byssus nests, which they create out of stones, shells and other materials around them. When a number of these nests come together they form a dense bed which stabilises the sea bed. Various animals and plants are able to attach to the beds surface, and other animals can live under or within the nest material (Tyler-Waleters *et al*., 2012). *L. hians* have been reported to occur in densities of up to 700 individuals m^{-2}, but usually occur at several hundred individuals m^{-2} (Hall-Spencer and Moore, 2000).

There is little data on growth or settlement rates for *L. hians*. In 2009 Trigg and Moore showed that nest regrowth over cleared areas was slow, averaging only at about 3.2 cm per year. This illustrates the vulnerability of the beds to physical disturbance such as dredging. There is also little data on the taphonomy of the shells, but as they are thin and delicate it is not expected that they last for very long after death. Burrows *et al* (2014) calculated that for a *Limaria* individual of 10g tissue weight, the shell would weigh approximately 1.72g, which is used as the carbonate content for flame shells. There are currently 7 known *L. hians* beds in Scotland with a summed estimate of 748.3 t $CaCO_3$.

1.4.4 Kelp and Seaweed Communities

Kelp forests usually dominate the shallow rocky coasts of cold water marine habitats. They are made up primarily of brown algae from the order Laminariales and they produce one of the largest biogenic formations in the benthic environment. Kelp forests support a high rate of primary productivity, an increased secondary productivity, and create a habitat structure that supports a range of marine organisms (Steneck, 2002).

Using aerial photography and quadrat sampling it has been estimated that Scotland contains approximately 10 million tons of subtidal kelp over an area of 2900km^2 (Walker and Richardson, 1955). *Laminaria* has been estimated to produce between 110 and 1780 g C m^{-2} yr^{-1} (Mann, 2000). Over 80% of kelp production enters the detrital food web as only a small amount is grazed directly by herbivores. Much of this detritus is fed on by detrital grazers, suspension feeders and general consumers of organic material. The contribution of the carbon within kelp to long term deposits is not yet well understood but it is likely to depend on its incorporation into sediments (Burrows *et al*., 2014).

Kelp forests are dynamic systems that vary at different times in different locations. They are highly susceptible to changes in the marine environment, such as alterations in the local chemistry, physical nature, or biology of the environment. Because of this, kelp loss of over tens to hundreds of kilometres can occur in a single year (Wernberg *et al*., 2013). The main threats that kelp forests currently face include nutrient loading from coastal runoff, removal of apex predators, cultivation and harvesting, and climate change (Smale *et al*., 2013). In some areas kelp is absent when all factors seem ideal for it to thrive. These are known as kelp barrens and are thought to be caused by the overgrazing of sea urchins and other herbivores. Kelp barrens are not currently common around the United Kingdom, but the removal of urchin predators could well cause a consequential decline (Stenneck *et al*., 2002).

1.4.5 Survey Overview

The present study was undertaken with the objective to (**1**) identify the benthic habitats present in Gutter Sound and (**2**) assess the amount of carbon stored in those habitats in order to inform policy makers on the importance of blue carbon storage. Figure 2 shows the survey area in which the present study was undertaken. The area is 0.284 km^2 in size and is located South of the island Rysa Little in Gutter Sound, Orkney. Methods include deployment of eight ROV drops and divers to further groundtruth the area.

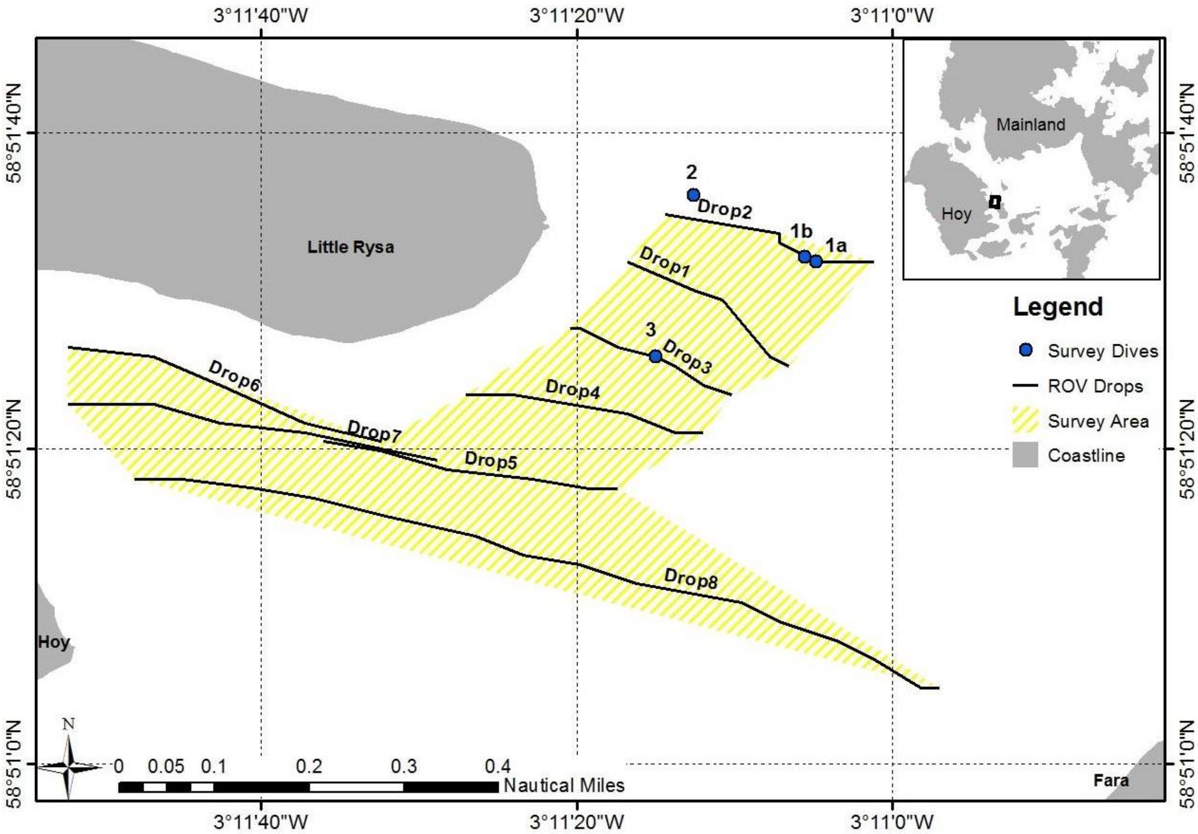

Figure 2: Survey area in Gutter Sound, Orkney.

1.4.6 Human Activities in Gutter Sound

Gutter sound is known for being close to the site of the mass scuttling of the German Imperial High Seas Fleet in 1919. It was a focal point for salvage activities where lots of scrap remains were thrown overboard. As a result, there is a field of debris within gutter sound. Because of this, scuba diving is a key activity in the area (ORCA Marine).

There are a number of underwater cables and pipelines in the area, which can be seen in figure (?) below. There is also a ferry crossing from the mainland to Hoy, which passes directly over the survey area. Dredging activities take place a few miles away from the study site, and there is also a tidal lease area to the South. Aquaculture is common in the region, focusing on finfish such as Atlantic salmon and lumpsucker (Aquaculture Scotland.gov).

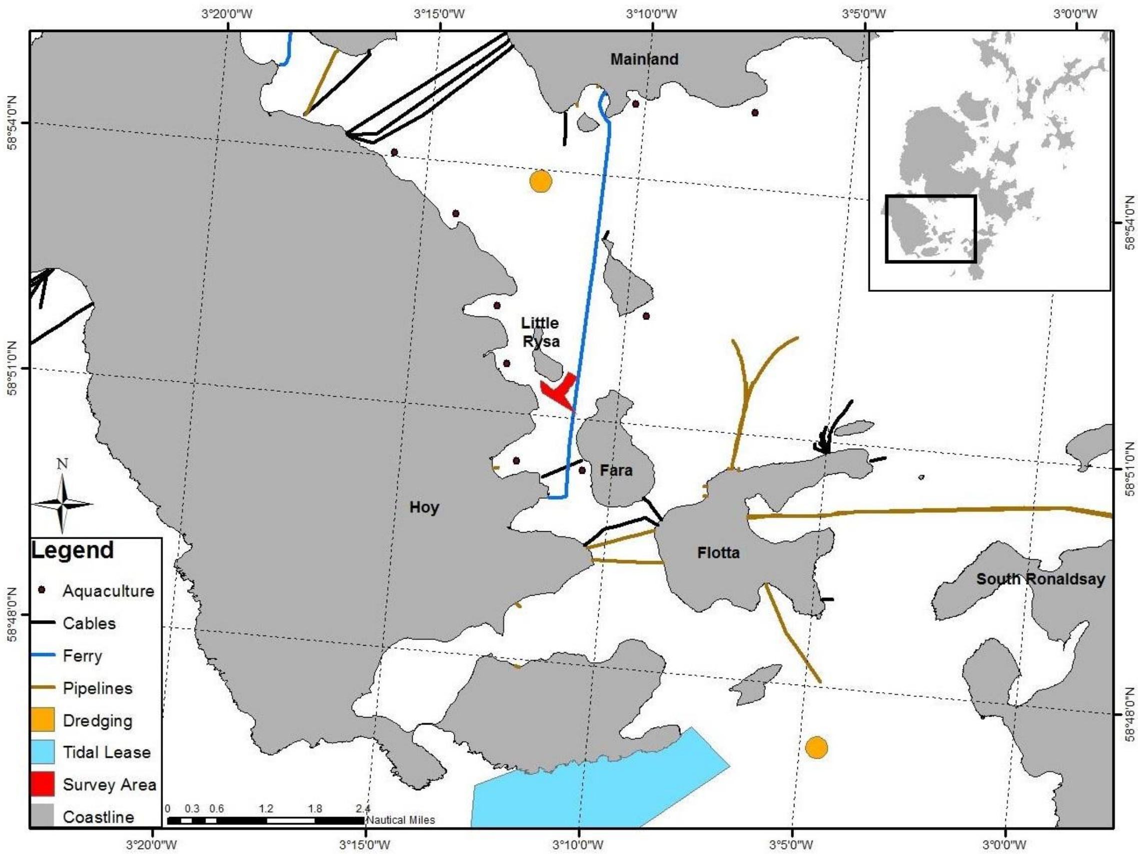

Figure 3: Human activities near the survey area in Orkney, UK.

1.4.7 Physical Characteristics of the Survey Area

Gutter Sound is a narrow sea channel of about 1 km width flowing between the south of the Island Rysa Little, the north of the island Fara and to the east of the island Hoy in Orkney. The depth of the study area ranged from 6 to 18 metres (figure 4)

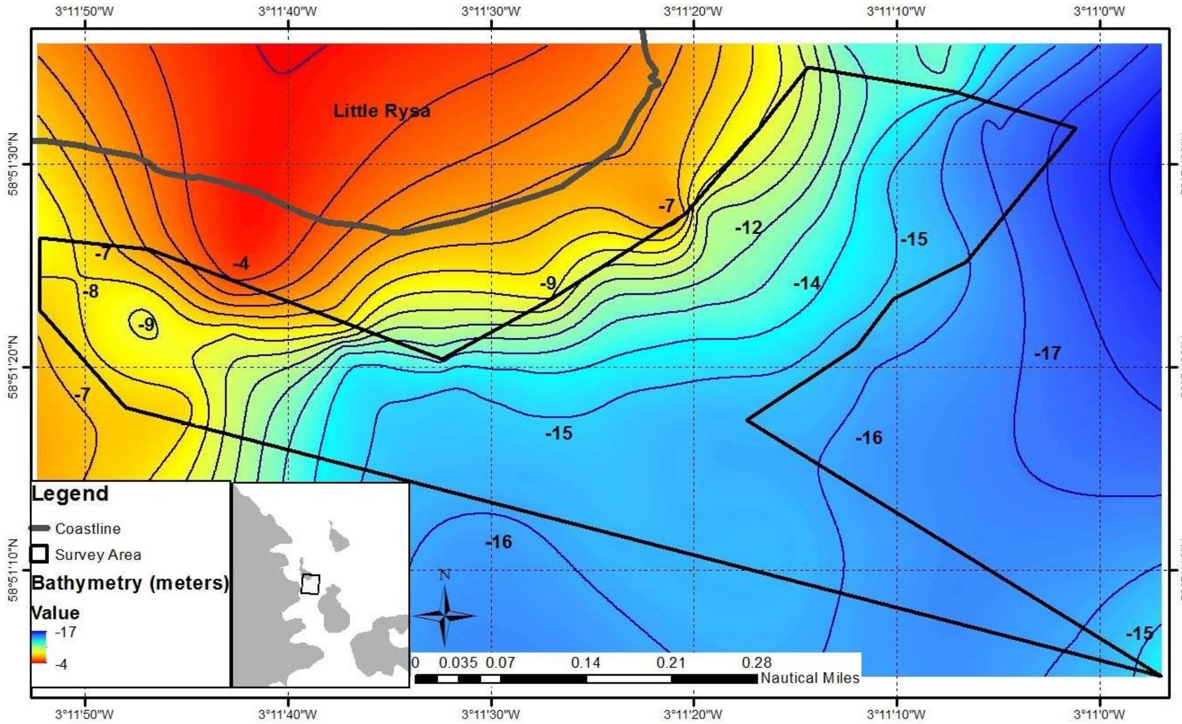

Figure 4: Bathymetry of the study area in Gutter Sound, Orkney.

2. METHODOLOGY

Heriot Watt University carried out a survey of the Gutter Sound between 18th April and 21st April. 8 ROV tows were conducted to estimate the existence (extent) of blue carbon habitats. Two locations from the ROV data were selected to further investigate Mearl beds and other habitats of high importance using dive surveys.
The vessel Challenger operating out of Stromness harbour was used on 18th and 19th of April 2016 for the ROV and dive surveys.

2.1 ROV SURVEYS

For recording and real-time observation, a VideoRay Explorer remotely operated vehicle (ROV) (figure 5) system was connected to a camcorder with a 40 meter neutrally buoyant umbilical tether that carried the video signal to the Control Panel. Due to the weather conditions the ROV was attached to a metal cage and used as a simple drop down video system.

The ROV was suspended from the boat and allowed to run with the current or wind for 7 – 29 minutes while recording footage along a transect. Due to the weather and technical problems, much of the video is of poor quality. Before each deployment a 'clapper board' with the date, time, station number and location was recorded to determine the beginning of a new station. The position (GPS), time (GMT) and depth were recorded at the beginning and end of each drop, as well as regular recordings approximately every two minutes. Once the ROV settled on the seabed it was towed close to the seabed while substrate types and main taxas were recorded into a field log.

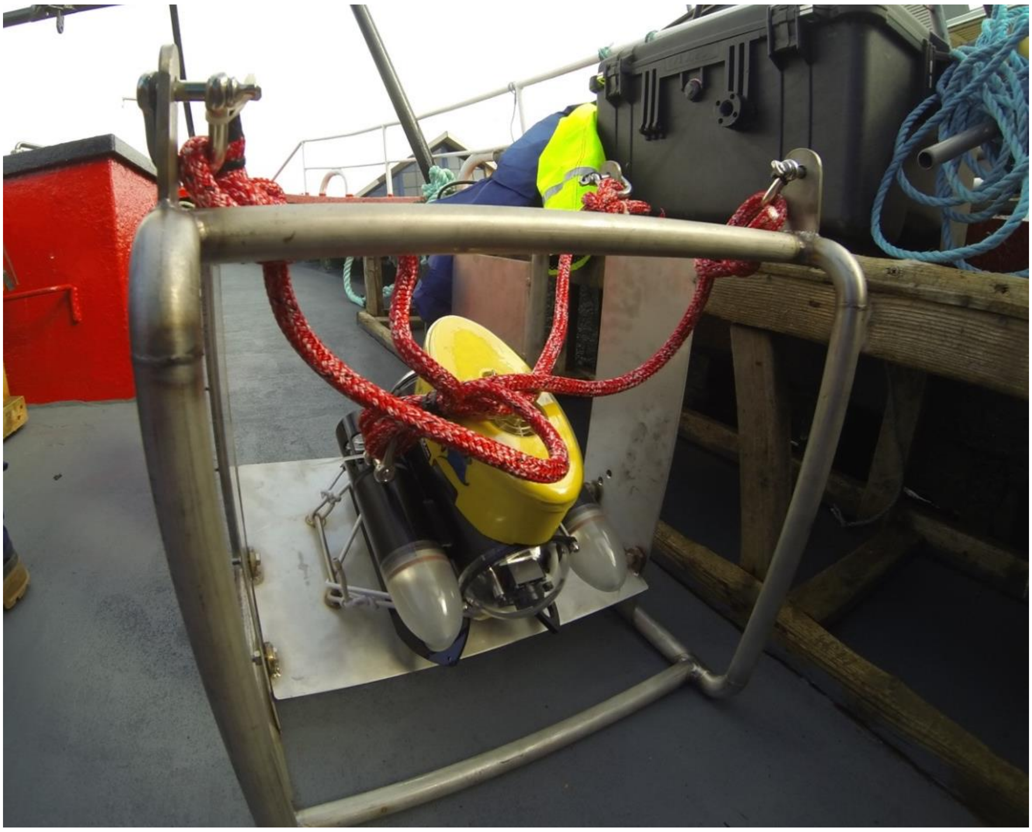

Figure 5: VideoRay Explorer attached to metal cage used during ROV survey deployed from the vessel Jean Elaine.

Eight ROV stations were recorded in total (figure 1). Ulead Video Studio SE DVD was used to analyse the footage.

2.2 DIVER SURVEYS

Diver surveys were carried out in three different locations, determined from the initial results of ROV surveys. The purpose of the diving survey was to have in-situ access of the blue carbon storage quality and validate ROV footage. The initial plan was to deploy divers at two locations, but due to misinterpretation of the footage, the second dive location was missing valuable biodiversity interest, resulting in the determination of a third location. (figure …)

The diving team was comprised of 3 divers. The first diver laid out a 25m transect line, carrying out a MNCR-style phase 2 in-situ survey important for habitat identification. The first diver also collected samples for lab identification from dive location 1 and 2 as well as still photographs using a (Nikon D200). On the second phase of the survey, two divers entered the water with the first diver setting 10 random allocated photo quadrats (0.25x0.25) using a (Nikon D200), whilst the second diver filmed a 1m band either side of the 25m transect line using a hand-held video camera (Canon LEGRIA HF S30).

2.2.1 Core analysis

The second dive team also collected two 30cm core samples of valuable maerl bed, as well as an extra core sample for PSA examination for dive locations 1 and 3.
All the techniques stated above were primarily planned to take place in two diving locations.

2.3 SURVEY LIMITATIONS

Weather and environmental conditions
Video footage collected from the ROV deployment did not have the ideal environmental conditions. Large waves and strong winds caused the boat to drift, resulting in blurry videos and difficulty in habitat identification

2.3.1 Dive Surveys issues

Incorrect interpretation of the video footage lead to divers being dropped at a poor location with little ecological interest. Also in dive 1 still photo quadrats couldn't been taken due to cameras flash malfunction.

2.3.2 Core samples

One of the most important variable of the research was the core samples. These were unable to be examined for PSA (Post Settlement Alluvium), organic matter and carbonate concentration analysis due to lack of lab instrumentation.

3. RESULTS

3.1 ROV VIDEO ANALYSIS

ROV footage was collected from eight stations within the Gutter Sound survey area with different depths ranging from 4.3 to 18.3 meters. Video log, species lists and substrate type and photos of each habitat type can be found in the appendix. Three different habitat types were found in the Gutter Sound area (after consideration of ROV footage as well as *in situ* diver observations and still photographs), consisting mainly of *Phymatolithon calcareum* maerl beds together with *Limaria hians*, *Modiolus modiolus* and *Mya truncata*. Table 1 shows the biotope descriptions along with the number of stations where the habitat type was found. Due to poor video quality and high winds, some of the ROV footage was insufficient to use for biotope classification alone, leading to the use of still photographs and *in situ* diver observations for biotope classification at respective stations.

Maerl beds of the species *Phymatolithon calcareum* were characteristic of the whole survey area, with some stations showing less dense and more widely scattered maerl distributions than other stations. Stations 2, 3 and 8 showed the most dense maerl aggregations with numerous *Echinus esculentus* and *Asterias rubens*, abundant Rhodhophycae, *L. hians* nests and *M. modiolus* beds within the maerl. Based on ROV footage analysis, the station with the highest species richness was station 8, with very dense beds of *P. calcareum* mixed with Rhodophycae, with large numbers of Pectinidae scallops. One individual each of *Marthasterias glacialis* and *Luidia ciliaris* were also found. The first few minutes of the footage at station 8 showed a different habitat type, namely Kelp and seaweed communities on sublittoral sediment (**SS.SMp.KSwSS**) consisting mainly of large seaweeds such as *Desmarestia viridis* and *Saccharina latissima* in sandy sediment. Station 2 and 3 were also surveyed by divers as discussed in section (3.2). ROV footage revealed numerous *E. esculentus* and *A. rubens* at this site along with patchy maerl beds which led to the overall biotope classification of **SS.SMP.Mrl.Pcal.R.** This classification was also representative of site 4 and 5 which were also very diverse stations with occasional *D. viridis* and frequent to occasional *S. latissima*. *P. calcareum* was frequent at both sites; however diver surveys showed *L. hians* nests within the maerl together with *M. modiolus* beds. Nevertheless the biotope classification of **SS.SMP.Mrl.Pcal.R** seems most fitting.

Drop 1 was given the habitat classification of **SS.SMx.Imx** which is infralittoral mixed sediment high in different sizes of shell fragments together with pebbles and sand. Rhodophycae sp. were common at this site along with *E. esculentus* and numerous *A. rubens*. The diver survey revealed the presence of some *L. hians* nests. The overall scarcity of brown seaweeds, besides some frequent *S. latissima* led to the classification of this habitat into infralittoral mixed sediment.

ROV drops 6 and 7 were categorised into **SS.SMP.KSwSS.LsacR** which is a habitat of *Laminaria saccharina* and red seaweeds on infralittoral sediments, although *D. viridis* was overall more abundant than *L. saccharina* at both sites. Rhodophycae sp. were frequent, *P. calcareum* was occasional to rare with frequent *Ulva lactuca* at drop 6. The sediment was sandy with some shell fragments.

Table 1: Biotopes found in Gutter Sound, Orkney, UK.

Biotope	Description	Count
SS.SMP.Mrl.Pcal.R	*Phymatolithon calcareum* Maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand.	4
SS.SMP.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments.	2
SS.SMx.Imx.Lim	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment	1
SS.SMP.Mrl.Pcal.R combined with **SS.SBR.SMus.ModT**	*Phymatolithon calcareum* Maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand and *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	1

3.2 DIVER SURVEY ANALYSIS

Three Marine Nature Conservation Reviews (MNCR) were undertaken in the Gutter Sound area, ranging from a depth of 12.5-17m. Diver survey station details taken can be found in section 7.2.2. A full species list can be found in section 7.6.

Dive survey site 1 was characterised as a generally flat profile with depths which ranged between 16-17m from the sea surface. The substrate was mixed with mainly coarse shell gravel and some coarse sandy patches. Overlying the sediment was 50-60% coverage of *L. hians* nests. In between this were areas with large shell fragments of *M.modiolus*. Hydroid colonies of *Halecium halecium* and *Kirchenpaueria pinnata* were found on some of the large shell pieces. Clusters of siphons of *M. truncata* were found coming out of the sediment. Other mobile fauna found in this site included *E. esculentus*, *Crossaster papposus* and *A. rubens*. Crustaceans found included *Macropodia sp* and *Inachus sp*. Other sediment dwelling organisms found at dive site 1 include *Lanice Conchilega*.

Dive survey site 2 was characterised as a shallow profile with a depth range between 12-13m. The majority of the substrate was sparse shell fragments with dominated disarticulated shell valves. There was a small amount of *L. hians* nest material (~5-10%) which was made up of bound red algae (*Phyllophora crispa*) and some large shell pieces. Siphons of *M. truncata* bivalves were found coming out of the sediment, similarly to dive site 1. No *P. calcareum* was found at dive site 2 and therefore it was decided that a third dive site would be necessary.

Dive site 3 ranged from a depth of 12.5- 13.1m. The area was characterised by 30% *P. calcareum* with coarse sand and empty shells, according to *in situ* observations. The species which were characteristic of the site include *P. calcareum, M. Truncata, M. modiolus* and *L. hians*. Other common species were *Cerianthus llodii, Palaemon serratus, Pagarus bernhardus* and *A. rubens*. Frequently occurring species included a variety of decapods and Pelecypods. *Pecten maximus* and *Pholis gunnellus* were rare at this site. Other present species included *H. halecium, K. pinnata* and *Nemertesia ramosa*.

Dive survey site 1 and 3 were classified as biotope **SS.SMP.Mrl.Pcal.R** (*P.calcareum* maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand). Dive survey site 2 was classified as **SS.SMx.Lim** (*L. hians* on sublittoral mixed sediment).

3.3 ESTIMATED CARBON BUDGET OF GUTTER SOUND

Unfortunately the weather conditions have been quite unsuited for ROV work which lead to a somewhat blurry ROV picture. As a consequence, species and habitat identification on the basis of the recorded videos were difficult and therefore not reliable data. Furthermore, the collected core samples could not be analysed in the laboratory in Edinburgh. Hence, all calculations of blue carbon storage in Gutter Sound are a mere estimation.

3.3.1 Maerl

Maerl (*Phymatholiton calcareum*) has been found at all drops and diving stations in different abundances. The habitat seen in five drops has been classified as **SS.SMP.Mrl.Pcal.R**. (LINK TO HABITAT MAP). Drops 2, 3 and 8 showed at least 20% cover and drop 5 showed 10-19% cover which lead to the conclusion that a maerl biotope of approximately 0.189 km² is located in Gutter Sound. Additionally, a thorough dive survey revealed a maerl cover of 30% on about 50 m² (dive site 3) which can be considered as a proper maerl bed.

3.3.1.1 Total estimated volume of maerl beds

As the core samples could not be analysed and the depth of the sample was insufficient, the average depth of 60 cm for maerl beds as mentioned in Burrows et al. (2014) will be used. The only reliable data cover an area of merely 50 m², thus the volume of this part is $50\,m^2 \cdot 0.6\,m = 30\,m^3$. Extended to an estimation for the whole area where maerl in considerable amount has been found would give a volume of $0.189\,km^2 \cdot 0.0006\,km = 0.113\ \cdot 10^{-3}\ km^3$ which is approximately 2.7% of the estimated volume of maerl beds for the whole of Scotland (Burrows at al., 2014). Again, this would be an estimate for the best case, which is a true maerl bed for the whole area. Considering the fact that drop 4 only revealed a potential 5-9% maerl cover and drop 5 10-19%, the true volume should be lower. Should only 50% of the complete maerl biotope area have a maerl cover of more than 30% the total volume would be $0.189\,km^2 \cdot 0.0006 km \cdot 0.5 = 56.7 \cdot 10^{-6}\,km^3$. In case of a maerl bed cover (not maerl biotope cover) of 70% the volume would be as high as $0.189\,km^2 \cdot 0.0006 km \cdot 0.7 = 79.4 \cdot 10^{-6}\,km^3$.

3.3.1.2 Estimation of the standing stock of carbon

The mass of maerl is estimated to be around $866.7\,\frac{Kg}{m^3}$ and the proportion of carbon in the skeletal mass of maerl is 12% (Burrows et al., 2014). That means that we can assume a verified standing stock of $0.8667\,\frac{t}{km^3} \cdot 30 \cdot 10^{-9} km^3 \cdot 0.12 = 3.12\,t$. Again, an extended estimation for the whole area delivers different results dependent on the true percentage of maerl bed cover. Presuming the unlikely case that the maerl bed would cover the whole area of 0.189 km², the standing stock of carbon would be as high as $0.8667\,\frac{t}{km^3} \cdot 0.113 \cdot 10^{-3} km^3 \cdot 0.12 = 11\,800\,t$ which would contribute to the total standing stock of maerl in Scotland by 2.7%. If 70% of our area would hold a true maerl bed, the amount of carbon locked in the maerl bed would be $0.8667\,\frac{t}{km^3} \cdot 79.4 \cdot 10^{-6} km^3 \cdot 0.12 = 5\,780\,t$, plus a fraction of this for the rest of the area. Should the maerl bed only cover 50% of our designated **SS.SMP.Mrl.Pcal.R** habitat, the quantity of standing carbon stock would be at least $0.8667\ \frac{t}{km^3} \cdot 56.7 \cdot 10^{-6} km^3 \cdot 0.12 = 2\,950\ t$. Again, these figures are a mere estimation since better data was not available. Additionally, the composition of the cores could not be taken into account as the composition and proportions of sediment remains unknown. Furthermore, maerl-associated organisms have been ignored in this calculations.

3.3.1.3 *Sequestration from maerl*

The yearly sequestration rate is dependent on the proportion of live maerl in the maerl bed area. Due to the absence of a core analysis, this proportion remains unknown. According to Burrows et al. (2014), the yearly carbon sequestration rate for *P. calcareum* lies inside the interval of 9.5 and 29.3 $\frac{tC}{yr\ km^2}$. Assuming a mean percentage of live maerl of 20-30% in the maerl biotope, the yearly carbon sequestration rate would lie between $9.5\ \frac{tC}{yr\ km^2} \cdot 0.189\ km^2 \cdot 0.2 = 0.359\ \frac{tC}{yr}$ and $29.3\ \frac{tC}{yr\ km^2} \cdot 0.189\ km^2 \cdot 0.3 = 1.66\ \frac{tC}{yr}$. If a mean percentage of 50-60% live maerl is assumed, the yearly carbon sequestration rate would be as high as $9.5\ \frac{tC}{yr\ km^2} \cdot 0.189\ km^2 \cdot 0.5 = 0.898 \frac{tC}{yr}$ to $29.3\ \frac{tC}{yr\ km^2} \cdot 0.189\ km^2 \cdot 0.6 = 3.32 \frac{tC}{yr}$. However, this is only valid if the whole area is covered by a maerl bed. The true figures lie probably below this upper limit of 3.32 $\frac{tC}{yr}$.

3.3.2 *Kelp*

Kelp has been found in abundance on several drops which lead to the conclusion that the zone closest to Little Rysa (LINK TO HABITAT MAP) consists of habitat **SS.SMP.KSwSS.LsacR** and could be considered as a kelp forest. The main species identified in the blurry ROV footage were *D. viridis* and *S. latissima*, both in abundances of over 20% within the assumed kelp forest and of 5-10% in the rest of the surveyed area. Here, only the area with at least abundant (20%) SACFOR classification has been taken into account. The estimated area of the kelp forest in Gutter Sound is 0.08238 km².

3.3.2.1 *Standing stock of kelp carbon*

According to Burrows et al. (2014), the standing stock of kelp can be estimated as $94 - 187\ \frac{gC}{m^2}$ for areas where kelp is at least abundant (>20% cover). Using this values the standing stock of kelp in Gutter Sound can be calculated as 7.744 – 15.405 tC. However, the standing stock of kelp changes every year with yearly variations of 40% to 200% (Burrows et al., 2014).

3.3.2.2 *Kelp sequestration*

As a consequence of the high yearly variation in standing stock of kelp and of the fact that probably only a small proportion of kelp production ends up in the sediment, it has been decided to abandon further calculations.

3.3.3 Horse Mussels

Horse mussels (*Modiolus modiolus*) could be identified in drop 2, 3, 4 and 8 with different abundances (abundant for drop 3 and occasional for drops 2, 4 and 8). Using the published figures for carbonate content (2219 g per m² for 125 individuals) and keeping in mind that 12% of the carbonate is carbon, the local patch of relatively high horse mussel abundance could store between $\frac{2219\,g}{125\,ind.} \cdot 10\,ind. \cdot 0.12 = 21.3\,g$ and $\frac{2219\,g}{125\,ind.} \cdot 90\,ind. \cdot 0.12 = 191.72\,g$ per m². Previous surveys estimate the extent of this horse mussel bed at 0.15 km² (Sanderson et al., 2014), suggesting that the stored carbon in Gutter Sound could be estimated as 21.3 - 191.72 metric tons. Regarding the yearly sequestration rate, *M. modiolus* contributes in general relatively little as they are a long-lived and slow growing species.

3.3.4 Flame Shells

Flame shells (*Limaria hians*) have been found on drop 1, 2, 3 and 8 with an abundance of $1-9\ {}^{ind.}/_{100\,m^2}$ for drop 1 and 8 and of $1-9\ {}^{ind.}/_{m^2}$ for drop 2 and 3 which has been verified by collected samples. The shells of *L. hians* contain 1.7 g $CaCO_3$ per individual (Burrows et al., 2014) which transfers to $12\% \cdot 1.7 = 0.2$ g C per individual. Even the same abundance over all of zone 3 was assumed this would lead to only 17-154 Kg of Carbon stored in *L. hians* shells. More likely, the abundance is less than the recorded number of individuals in the diving stations. As a consequence, the carbon sequestration potential of flame shells within Gutter Sound can be disregarded.

3.3.5 Overall Estimation of Blue Carbon in Gutter Sound

An addition of all previously calculated figures reveals the high uncertainty following from the difficulties in the data collection. However, the lower bound for carbon stored in Gutter sound can be estimated with a high probability as 2 979.23 tons, whereas the upper bound could be any figure between 5 987.28 and 12 007.28 tons of carbon. The yearly sequestration rate of carbon in Gutter Sound is at least 0.36 tons but could be as high as 3.32 tons, dependent on the proportion of live maerl, the yearly kelp forest extent and the small amounts coming from other species living in these habitats.

4. DISCUSSION

4.1 BIOTOPE FEATURES IN GUTTER SOUND

Figure 6 shows an estimated distribution of habitats found in the Gutter Sound survey area. During the ROV surveys and the in situ diver surveys, several priority marine features (PMFs) were identified. Four habitats of conservation importance were found in the survey area, namely *P. calcareum* (maerl) beds, *L. hians* nests, *M. modiolus* beds and kelp and seaweed communities mainly consisting of *S. latissima* and *D.* viridis The biotope classification was based on ROV and diver surveys with subsequent analysis of diver's videos and images. Due to the poor quality of the ROV footage, stations which were not surveyed by divers could not be classified with a high level of confidence due the lack of valuable data. A preliminary biotope map has nevertheless been produced in this report (figure 6).
The following sections outline the estimated distribution of each habitat in Gutter Sound as well as the conservation importance of each priority marine feature.

4.1.1 Phymatolithon calcareum Maerl Beds

Maerl beds are relatively abundant around Orkney, Shetland and on Scotland's west coast. With more than 100 sites stated, Scotland has a greater abundance of maerl than any other European country (Scott and Moore, 1996). Maerl beds support a rich biodiversity as they act as an important habitat for a wide range of marine species and plants which live in or on the maerl beds (Hall-Spencer et al, 2010). Moreover, maerl acts as an important nursery ground for numerous marine taxa including molluscs and crustaceans (Hall-Spencer et al, 2010). These beds are significantly impacted by activities such as scallop dredging, construction

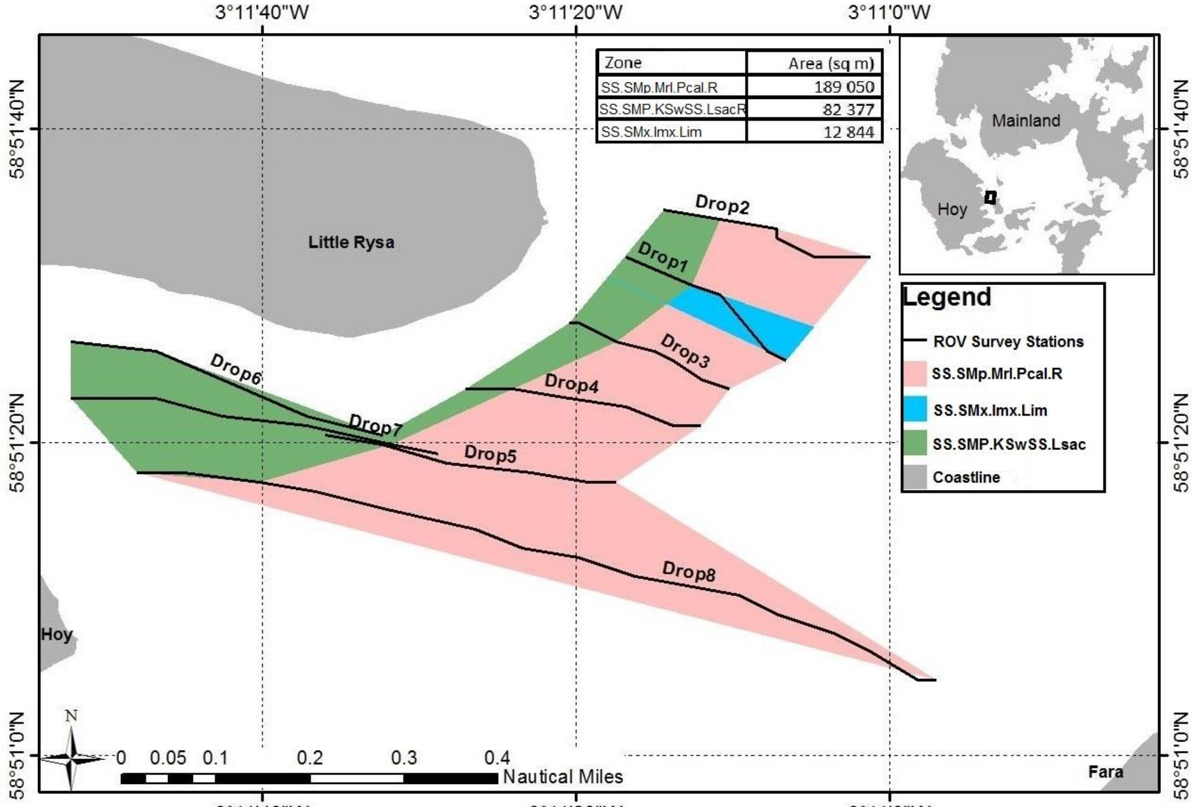

Figure 6: Biotope distribution in the survey area in Gutter Sound, Orkney.

projects and fish-farming (Hall-Spencer et al, 2006). Maerl is particularly sensitive to substratum loss, smothering, suspended sediment rise, abrasion and physical disturbance, as this can inhibit light from reaching live maerl and hence stop photosynthesis (Jones et al, 2000). Temperature rise of the sea water may also impact maerl beds due to their fragmented ranges and poor distribution (Blake and Maggs, 2003).

In the present study, maerl was found alongside *L. hians* nests and *M. modiolus* beds, suggesting that maerl offers a preferred habitat for other benthic organisms. *M. truncata* was also observed in high abundance near maerl beds. Figure … shows the estimated extent of *P. calcareum* in Gutter Sound with some ROV stations showing a higher density of maerl than others. Drops 2, 3, 4, 5 and 8 were classified as **SS.SMP.Mrl.Pcal.R** while station 3 contained a mixture of biotopes **SS.SMP.Mrl.Pcal.R** and **SS.SBR.SMus.ModT** which became apparent during the diver surveys as discussed in the following section 4.1.2. The densest maerl cover was observed at drops 2, 3, and at the end of drop 8 with common to abundant cover, while drops 4 and 5 showed only occasional to frequent cover. The total area of maerl habitat was estimated to be 0.189 km^2.

4.1.2 Modiolus modiolus Beds

M. modiolus, another PMF found during the survey, form beds which are frequent in Orkney and the Shetland Islands (OSPAR, 2009). Horse mussels are home to a very diversity rich community which gain shelter in the gaps between horse mussel shells and their byssus threads (OSPAR, 2009). Horse mussel byssus threads also show importance as they have a stabilising effect on the seabed by binding living animals, dead shells and particles together (OSPAR, 2009). Horse mussels are particularly sensitive to substratum loss, abrasion and physical damage (OSPAR, 2009). Extreme physical activities, for example impacts from towed fishing gear, have shown to significantly damage individual horse mussels despite their low fragility (OSPAR, 2009).

In the present study, *M. modiolus* was found in high densities at dive site 3 and was given a SACFOR abundance estimate of A (abundant). A previous survey commissioned by SNH identified a horse mussel bed in the Gutter Sound area of approximately 0.15 km^2 (Sanderson et. al, 2014) (figure…). The habitat classified by Sanderson *et. al* (2014) was identified as **SS.SBR.SMus.ModT** (*M. modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata). This classification very well describes the habitat found at dive site 3, with the exception for the presence of maerl and *M. truncata* mixed within the mussels. Figure… (picture) shows the general habitat composition leading to the habitat classification of this site as both **SS.SMp.Mrl.Pcal.R** and **SS.SBR.SMus.ModT**.

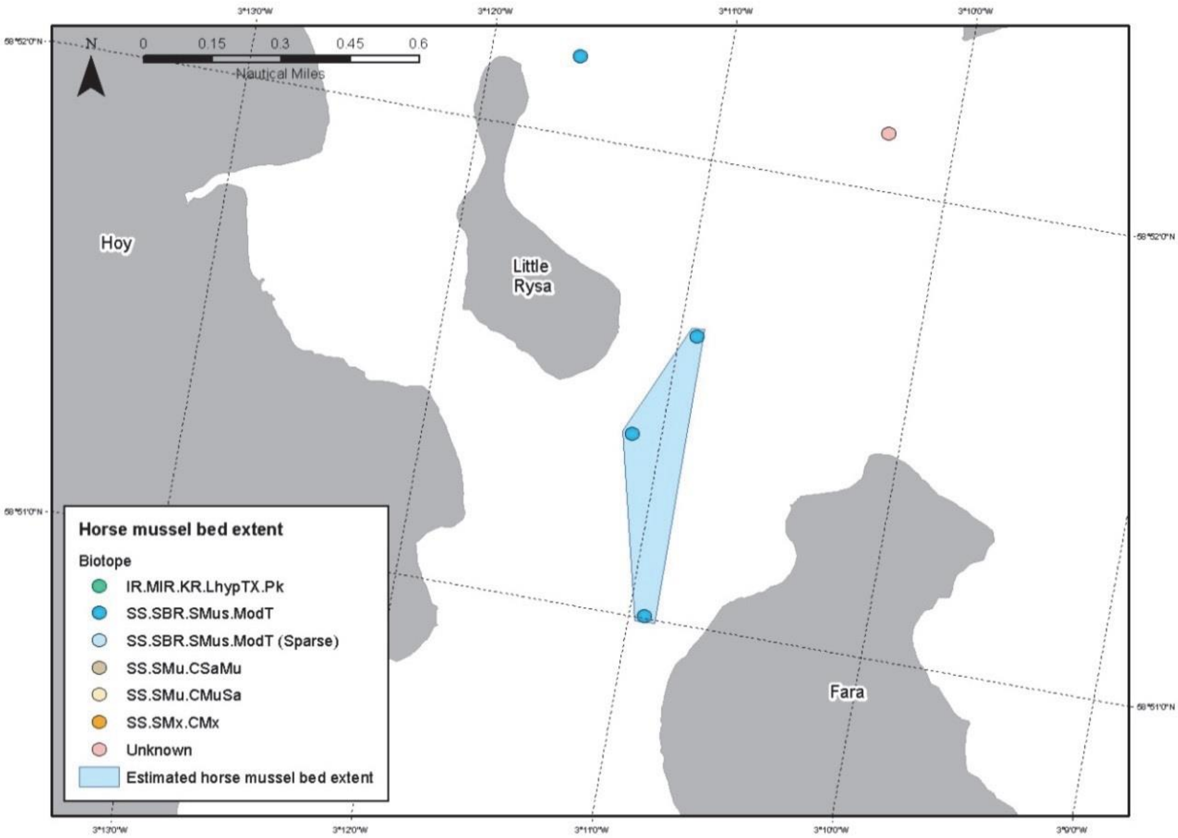

Figure 7: Estimated horse mussel bed extent found during a previous survey in Gutter Sound. Map taken from Sanderson et. al, 2014.

4.1.3 Limaria hians Nests

L. hians, the flame shell scallop, create nests built from shells, stones and other materials which all combine to form a dense flame shell bed (SNH, 2015). These provide a habitat for many different species of algae and invertebrate species as well as acting as efficient hunting grounds for juvenile fish (SNH, 2015). L. hians are particularly impacted from bottom trawling and dredging and the extent of the impact is so significant that extensive beds are currently rare to find (SNH, 2015). Therefore their conservation and protection is very important in order to avoid any further declines flame shell bed extent.

4.1.4 Kelp and seaweed communities

The sugar kelp *S. latissima* was the most dominant type of kelp present in the survey area. *D. viridis* and *S. latissima* were among the main species of large brown seaweeds found in Gutter Sound, with abundance highest at ROV drops 6 and 7 in shallow areas near the shores of Rysa Little (figure… zones). The habitat of the kelp zone was identified as **SS.SMP.KSwSS.LsacR** (*L. saccharina* and red seaweeds on infralittoral sediments) and spans an area of 0.082 km^2.

S. latissima can reach ages of 2-4 years and can grow to large sizes if left undisturbed. Similar to most other macrophytes, *S. latissima* is very vulnerable to increased wave action and is therefore limited to the sheltered areas near the shore (Lancaster et. al, 2014).

4.2 FUTURE MANAGEMENT OF GUTTER SOUND

Due to the high diversity of sensitive benthic marine species in Gutter Sound, future management should take the importance of such habitats into consideration. The four priority marine habitats found within the survey area of the present study show the conservation importance of this particular site for biodiversity as well as carbon sequestration purposes.

The total carbon sequestered in the Gutter Sound area could range from 3 000 t to 12 000 t of carbon, with up to 3 t being added each year. These figures show the importance of well-functioning and productive benthic ecosystems.

Benthic habitats suffer most damage by direct removal of seabed structures, such as removal by dredgers or direct harvesting of valuable ecosystem engineers. Besides the direct impacts of physical damage, dredging activities even in nearby areas could cause resuspension of sediment which may settle on the maerl and reduce the organism's ability to photosynthesise.

High organic carbon input is also a threat to the more sensitive taxa. Eutrophication deriving from fish farms could cause growth of harmful algal mats which could cause smothering of the seabed when the algal mats begin to die and reduce oxygen during decomposition. Any benthic organisms beneath such algal mats would suffer reduced light penetration and suffocation (Birkett et. al, 1998).
Although no shell fish farms are known to be in the immediate surrounding of the Gutter Sound area, case studies have reported alteration of sediment structure due to accumulation of faeces and pseudofaeces on top of the maerl reducing photosynthesis and smothering the organisms on the seabed (Birkett et. al, 1998).

Any present or future fish and shellfish farms should therefore be monitored closely in order to mitigate against any impacts on vulnerable benthic habitats.

While no dredging is taking place in Gutter Sound at this point in time, a high amount of scallops in the area suggest that there is a possibility scallop dredging occurring in the future. A high degree of conservation management such as the establishment of a no take zone in the area would prevent such destructive fishing practices.

4.3 HUMAN ACTIVITIES

During the ROV survey and in situ diver surveys, no strong human impacts were apparent in the survey area. The impacts of bottom trawling are very obvious to spot and would cause immediate destruction of habitats within the path of the trawler. Indirect impacts such as sediment plumes settling on the benthic habitats were also not observed which suggests no damaging fishing practices taking place in the area, as per figure…. The possible impacts of the nearby salmon farms are less obvious and require further study in order to be determined with certainty.

4.4 FURTHER WORK

The survey undertaken in Gutter Sound was bound to a very tight schedule and the results were affected by adverse weather conditions. Calmer weather during the ROV survey would have allowed for more drops to be undertaken and would have resulted in clearer images.

Due to the boat drifting at high speeds, the ROV footage was of low quality causing many species to remain unidentified.
Maerl beds were associated with *L. hians* and *M. modiolus* assemblages at the dive stations. Since maerl was also found at many of the ROV drops, it is likely that associated fauna was present at other stations but was overlooked due to poor video quality. The resulting species lists therefore do not represent the actual diversity of species and further work is needed to assess the biodiversity of other survey stations.

Unfortunately, due to the adverse weather conditions and the short time spent groundtruthing the survey area, the carbon storage estimates may well be far off the actual values. Due to time constraints, particle size analysis and carbon analysis of the sediment and maerl cores could not be undertaken as planned. An estimation of organic and inorganic carbon used for calculations is therefore based on previous surveys rather than the actual values. Further survey work could include remote grab samples from several survey stations taken from a range of habitats in order to provide the data needed to accurately measure the amount of carbon sequestered on the seafloor.

The biotope classifications available were often not a perfect fit for the habitats and species found in Gutter Sound. This was especially the case for station 3 where divers identified three priority marine features in one habitat. Further work is needed to enhance the biotope classification guide to suit the large biodiversity of our seas.

5. CONCLUSIONS

The biotopes present in Gutter Sound are of high conservation importance. The present study has shown the high biodiversity and large potential for blue carbon sequestration. It is estimated that between 3 000 t and 12 000 tons of carbon are stored within the maerl beds, horse mussel beds, flame shell nests and kelp communities. Future management of such resources should ensure a protection status is granted in order to maintain or enhance the amount of carbon sequestered each year.

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7. APPENDIX

7.1 SURVEY LOG

18th April to 21st April 2016

Survey Team: Heriot-Watt University: Bill Sanderson (Reader), Joanne Porter (Senior Lecturer), Andrew Want, Regina Classen (Lead), Lotte Abels (Researcher), Oscar Crehan (Researcher), Rebecca Jaconelli (Researcher), Maria Maily (Researcher), Tasos Mqaltadakis (Researcher), Hannah Hood (Researcher).

Overview: On 18th 2016 April Heriot Watt University carried out ROV video tows south east of Rysa Little in the Gutter Sound, Orkney. Due to bad weather conditions only 8 ROV stations were conducted. Two sites were selected for dive surveys the following day, for closer analysis of the *Phymatolithon calcareum* maerl beds. Samples were analysed in the lab for species identification until return to the Heriot Watt Riccarton campus on the 21st of April 2016.

Monday 18th April

11:00 Departure from Stromness marina on the vessel Jean Elaine travelling to Gutter Sound. Short detour to drop gear for a different study.
13:06 First ROV drop commenced.
15:39 ROV survey ended (8 stations completed).
17:00 Arrival back at Stromness marina.

Tuesday 19th April

11:00 Departure from Stromness marina
3 members of the group stayed behind at the ICIT to work on the Report.
11:09 Dive 1a commenced (Corresponding ROV station Drop 2)
12:08 Dive 1a ended
12:36 Dive 1b commenced (Corresponding ROV station Drop 2)
13:18 Dive 1b ended
14:26 Dive 2 commenced (Corresponding ROV station Drop 1)
15:15 Dive 2 ended
15:44 Dive 3 commenced (Corresponding ROV station Drop 3)
16:28 Dive 3 ended
17:30 Arrival back at Stromness marina

Wednesday 20th April

Report work at ICIT.

7.2 SURVEY STATION DETAILS

7.2.1 ROV Station Details

Video File Name (Duration)	Station Number	Start Time (UTC)	End Time (UTC)	Start coordinates (Latitude)	Start coordinates (Longitude)	End coordinates (Latitude)	End coordinates (Longitude)	Depth range (meter)
140306008 (~7 minutes)	Drop1	13:06	13:13	58°51'31" N	03°11'16" W	58°51'25" N	03°11'06" W	-9 to -15.9
140306009 (~8 minutes)	Drop2	13:25	13:33	58°51'34" N	03°11'14" W	58°51'31" N	03°11'01" W	-10 to -18.3
140306011 to 140306014/ (~11 minutes)	Drop3	13:38	13:49	58°51'27" N	03°11'20" W	58°51'23" N	03°11'10" W	-7 to -15.2
140306016 to 10430617/ (~10 minutes)	Drop4	13:55	14:05	58°51'23" N	03°11'27" W	58°51'21" N	03°11'12" W	-9 to -15.7
140306019 to 140306020/ (~10 minutes)	Drop5	14:13	14:23	58°51'20" N	03°11'37" W	58°51'12" N	03°11'07" W	-13.5 to -15.7
140306022 to 140306023/ 9 minutes	Drop6	14:32	14:41	58°51'26" N	03°11'52" W	58°51'20" N	03°11'32" W	-4.3 to -12.7
140306026 to 140306027/ (~9 minutes)	Drop7	14:47	14:56	58°51'22" N	03°11'52" W	58°51'19" N	03°11'28" W	-7.3 to -14.6
140306029 to 140306032/ (~29 minutes)	Drop8	15:11	15:40	58°51'18" N	03°11'48" W	58°51'04" N	03°10'57" W	-7.3 to -16.7

7.2.2 In Situ Dive Survey Details

Dive Number	Corresponding ROV station	Latitude	Longitude	Start time (UTC)	End time (UTC)	Depth (in meters)	Methods	Observation
1a	Drop2	58°51'53" N	03°11'04" W	11:09	12:08	17	MNCR record, Still photos, Samples for ID	Maerl bed, *Limaria hians* nests, *Modiolus modiolus* beds
1b	Drop2	58°51'52" N	03°11'05" W	12:36	13:18	17	Video, 2 cores, 1 PSA core	Maerl bed, *Limaria hians* nests, *Modiolus modiolus* beds
2	Drop1	58°51'36" N	03°11'12" W	14:26	15:15	13	MNCR record, Still photos, Samples for ID	*Limaria hians* nests
3	Drop3	58°51'25" N	03°11'15" W	15:44	16:28	13,1	MNCR record, Quadrats, Video, 2 cores, 1 PSA core, Samples for ID	Maerl bed, *Limaria hians nests*, *Modiolus modiolus* beds

7.3 VIDEO AND STILL IMAGES FILE NAMES AND DURATION

	Dive 1 a	**Dive 1 b**	**Dive 2**	**Dive 3**
Divers Still Images File Names	Dive_Stills_Dive_1a (1) to Dive_Stills_Dive_1a (52)		Dive_Stills_Dive_2 (1) to Dive_Stills_Dive_2 (53)	Quadrat_Images_Dive_3 (1) to Quadrat_Images_Dive_3 (27) in JPG and NEF format
Divers Video File Names (Duration)		Video_1_Dive_1b (02:52)		Video_1_Dive_3 (10:17)
		Video_2_Dive_1b (02:04)		Video_2_Dive_3 (06:13)
		Video_3_Dive_1b (08:25)		

7.4 SPECIES ABUNDANCE LIST FOR ROV STATIONS WITH ASSOCIATED SACFOR ABUNDANCE SCALE

Species	ROV Station							
	Drop 1	**Drop 2**	**Drop 3**	**Drop 4**	**Drop 5**	**Drop 6**	**Drop 7**	**Drop 8**
Phymatolithon calcareum	O	C	C	O	F	O	R	A
Rhodophyceae sp.	C	C	A	A	C	F	F	C
Laminaria digitata			R	R				
Desmarestia viridis	R	O	O	R	R	A	C	F
Saccharina latissima	R	O	R	R	R	A	C	F
Ulva lactuca					R	F		R
Limaria hians								O
Modiolus modiolus				O				O
Balanus sp.			1					
Echinus esculentus	7	9	5	28		2	5	106
Asterias rubens	35	16	7	12	4	6	6	13
Luidia ciliaris								1
Pectinidae sp.				2		1		22
Marthasterias glacialis								1
Substrate	**Drop 1**	**Drop 2**	**Drop 3**	**Drop 4**	**Drop 5**	**Drop 6**	**Drop 7**	**Drop 8**
Boulders			5	10				
Cobbles			5	5				
Pebbles	15		5	5				10
Sand	50	50	30	40	80	90	90	60
Shell	35	50	55	40	20	10	10	30

7.5 ROV STATION DESCRIPTION AND BIOTOPE CLASSIFICATION

Station	Substrate	Biota	Biotope	Protected Feature
Drop 1	Mixed substrate of coarse sand and empty shells with some pebbles	Presence of numerous *Asterias rubens* with some *Echinus esculentus* and *Limaria hians*. There was also: common Rhodhophycae; occasional *Phymatolithon calcareum*; rare *Desmarestia viridis* and *Saccharina latissima*	SS.SMX.Imx.Lim	Maerl, *Limaria hians*
Drop 2	Mixed substrate between empty shells and coarse sand	Presence of numerous *Echinus esculentus* and *Asterias rubens*. *Modiolus modiolus* was found mixed with *Mya truncata* and *Phymatolithon calcareum*. There was also common Rhodhophycae, occacional *Desmarestia viridis* and *Saccharina latissima*	SS.SMP.Mrl.Pcal.R	Maerl, *Limaria hians*, *Modiolus modiolus*
Drop 3	Mixed substrate of empty shells and coarse sand with some boulders, cobbles and pebbles	Presence of some *Echinus esculentus* and *Asterias rubens* and one balanus sp. *Modiolus modiolus* was found mixed with *Mya truncata* and *Phymatolithon calcareum.* There was also: abundant Rhodhophycae; occasional *Desmarestia viridis* and rare *Saccharina latissima* and *Laminaria digitata*	SS.SMP.Mrl.Pcal.R and SS.SBR.SMus.ModT	Maerl, *Modiolus modiolus*
Drop 4	Very mixed substrate of coarse sand and empty shells with some boulders, cobbles and pebbles	Diverse station with numerous *Echinus esculentus*, *Asterias rubens* and a couple of Pectinidae sp. There was also: abundant Rhodhophycae; rare *Saccharina latissima* and *Desmarestia viridis*, *Phymatolithon calcareum*, and *Modiolus modiolus*; and rare *Laminaria digitata*	SS.SMP.Mrl.Pcal.R	Maerl, *Modiolus modiolus*
Drop 5	Coarse sand with empty shells	Some *Asterias rubens* present. There was also common: Rhodhophycae; frequent *Phymatolithon calcareum*; rare *Desmarestia viridis* and *Saccharina latissima*; and rare *Ulva lactuca*	SS.SMP.Mrl.Pcal.R	Maerl

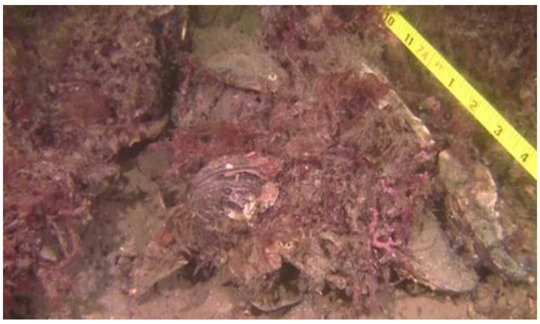
Drop 6	Majority coarse sand with some empty shells	Presence of some *Echinus esculentus* and *Asterias rubens* as well as one scallop. There was also: abundant *Desmarestia viridis* and *Saccharina latissima*; frequent *Ulva lactuca* and Rhodhophycae; and occasional *Phymatolithon calcareum*	SS.SMP.KSwSS.LsacR	Maerl
Drop 7	Majority sand with some empty shells	Presence of some *Echinus esculentus* and *Asterias rubens*. Common *Desmarestia viridis* and *Saccharina latissima* and frequent Rhodhophycae were also present. *Phymatolithon calcareum* was rare.	SS.SMP.KSwSS.LsacR	Maerl
Drop 8	Mixed substrate of mainly sand, some empty shells and pebbles	Very diverse station with numerous Scallops, *Echinus esculentus*, *Asterias rubens*. There was also: abundant *Phymatolithon calcareum*; common Rhodhophycae; frequent *Desmarestia viridis* and *Saccharina latissima*; and occasional *Modiolus modiolus* and *Limaria hians* . Also present *Marthasterias glacialis*, *Luidia ciliaris* and *Ulva lactuca* (R)	SS.SMP.Mrl.Pcal.R and SS.SMP.KSwSS.LsacR at start point	Maerl, *Modiolus modiolus, Limaria hians*

7.6 ANALYSIS OF DIVE SURVEY IN SITU MNCR FORMS, VIDEO AND IMAGE ANALYSIS AND SAMPLE ANALYSIS

Species	SACFOR ranking		
	Dive 1	**Dive 2**	**Dive 3**
Hydractinia echinata	R	R	
Halecium beanii	R	P	
Halecium sp.	O	O	P
Kirchenpaueria pinnata	O	O	P
Nemertesia ramosa	P	P	P
Plumularia setacea		P	
Cerianthus lloydii		O	C
Adamsia carciniopados	P		
Terebellidae indet	P	P	F
Lanice conchilega	F	O	P
Pomatoceros triqueter	O	O	
Balanus crenatus			F
Balanus balanus		P	
Amphipoda indet	P		
Palaemon serratus			C
Paguras bernhardus	P	O	C
Galathea intermedia	P		F
Galathea dispersa	P		
Pisidia longicornis	P	P	F
Hyas araneus	P	P	F
Ebalia sp.	R		
Inachus dorsettensis	O	O	F
Macropodia rostrata		O	
Liocarcinus depurator			F
Carinus maenas		R	F
Macropodia sp.	O		P
Garidion stereni	P		
Pinnotheres sp.	P		
Leptochiton asellus	P	P	
Tonicella marmorea	P	P	
Emarginula fissura	P		
Gibbula magus		R	
Tectura virginea	P		
Buccinum undatum	R	P	O
Polycera faeroensis	P		
Archidoris pseudoargus	R		
Modiolus modiolus	O		A
Limaria hians	C	O	C
Aequipecten opercularis	O	O	F
Pecten maximus	O	R	R

Mya truncata	F	O	A
Hiatella arctica	P	P	
Anomia ephippium	P	P	
Scrupocellaria sp.	O		
Parasmittina trispinosa	P		
Fenestrulina malusi	P	P	
Cribulina cryptoecium	P		
Haplopoma graniferum	P		
Escharoides mamillata		P	
Antedon bifida	O	O	F
Luidia ciliaris	O	R	F
Astropecten irregularis		R	
Crossaster papposus	R		F
Henricia sp.	R		
Asterius rubens	O	O	C
Marthasterias glacialis	R		
Ophiura sp.	P		
Ophiothrix fragilis	O	P	
Echinus esculentus	O	O	O
Polyclinum aurantium		P	
Clavelina lepadiformis	R	P	
Pholis gunnellus			R
Gobiidae indet			F
Pomatoschistus pictus		O	
Phyllophora crispa	P	P	
Corallina officinalis	P		
Phymatolithon calcareum	P		C
Plocamium cartilagineum		O	
Laminaria saccharina	P	R	
Desmarestia viridis		O	O
Lineus longissimus	R	P	
Harmothoe sp.	P	P	
Pandalus montagui	P		
Pandalus hypsinotus	P		
Pseudoprotella phasma		P	

7.7 PHOTO BIOTOPE CLASSIFICATION TABLE

Biotopes	Description	Still Photo
SS.SMP.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments. Found at drop 6, drop 7, drop 8 at start point	
SS.SMp.Mrl.Pcal.R	*Phymatolithon calcareum* Maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand. Found at drop 2, drop 3, drop 4, drop 5, drop 8	
SS.SMx.Imx.Lim	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment. Found at drop 1	
SS.SBR.SMus.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata. Found at drop 3 (or dive site 3)	

7.8 CARBON STORAGE CALCULATIONS SUPPLEMENTARY INFORMATION

7.8.1 Standing stock of maerl carbon in Gutter Sound, depending on the extent of the maerl bed within the maerl biotope.

% cover of total area	**Standing Stock (tC)**	**% cover of total area**	**Standing Stock (tC)**
50	2 950	80	7 550
60	4 250	90	9 560
70	5 780	100	11 800

7.8.2 Minimum yearly carbon sequestration rate (in tons) of kelp within Gutter Sound, depending on the proportion of live maerl and the extent of the maerl bed within the maerl biotope.

	20% live maerl	**30% live maerl**	**50% live maerl**	**60% live maerl**
50% cover	0.18	0.269	0.449	0.539
70% cover	0.251	0.377	0.629	0.754
100% cover	0.359	0.539	0.898	01. Aug

7.8.3 Maximum yearly carbon sequestration rate (in tons) of kelp within Gutter Sound, depending on the proportion of live maerl and the extent of the maerl bed within the maerl biotope.

	20% live maerl	**30% live maerl**	**50% live maerl**	**60% live maerl**
50% cover	0.545	0.831	Jan 39	Jan 66
70% cover	0.776	Jan 16	Jan 94	Feb 33
100% cover	01. Nov	Jan 66	Feb 77	Mrz 32

7.8.4 Calculation of the total standing stock of carbon within Gutter Sound

	Minimum standing stock (tC)	**Likely maximum standing stock (tC)**	**Absolute maximum standing stock (tC)**
Maerl	2 950	5 780	11 800
Kelp	Jul 74	15. Apr	15. Apr
Flame shells	/	0.15	0.15
Horse mussels	21. Mrz	191.72	191.72
Sum	2 979.04	5 987.28	12 007.28