Solway Firth SAC / Allonby Bay pMCZ Rocky Scar Grounds and Annex I Reef Drop-down Video Survey

Final Report

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J. O'Dell, W.J. Hawes, A. Shakspeare, M. Axelsson, S. Dewey

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Natural England Project manager

Joe Turner

Contractor

Seastar Survey Ltd.

Ocean Quay, Belvidere Road, Southampton, SO14 5QY

email: maxelsson@seastarsurvey.co.uk

Author

J. O'Dell, W.J. Hawes, A. Shakspeare, M. Axelsson, S. Dewey

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Further information

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Executive Summary

Background

The Solway Firth is a large, complex estuary and one of the more important and least industrialised estuarine areas in Europe (JNCC 2015a). The Solway Firth Special Area of Conservation (SAC) was designated under the Natura 2000 programme due to the following Annex I qualifying features; estuaries; sandbanks which are slightly covered by seawater all the time; mudflats and sandflats not covered by seawater at low tide; Atlantic salt meadows; and *Salicornia* and other annuals colonising mud and sand. In addition, present as a qualifying feature, but not a primary reason for selection, is the Annex I habitat 'reefs.'

The Allonby Bay pMCZ extends over 39 km^2 of Cumbria's coastline up to 5.5 km offshore, encompassing the entirety of Allonby Bay. The pMCZ is proposed in order to provide protection to a number of features of conservation interest including blue mussel beds, honeycomb worm (*Sabellaria alveolata*) reefs and peat and clay exposures as well as a number of broadscale habitats.

In order to inform site condition monitoring, Seastar Survey Ltd. were contracted by Natural England to undertake a drop-down camera survey of both the Solway Firth SAC and the Allonby Bay pMCZ in order to define the distribution and extent of any subtidal rocky scar grounds communities present.

Main Findings

- A total of 62 transects were attempted throughout the survey areas using Seastar Survey's own HD Freshwater Lens Camera System (FLCS), with a total of 269 discrete video clips achieved.
- In the Allonby Bay pMCZ the seabed was found to be dominated by gravelly mixed sediments, while the Solway Firth survey area was characterised by sands and muddy sands.
- Soft sediments were generally species poor, while coarse sediments – usually consisting of cobbles and pebbles – were generally characterised by encrusting fauna, sparse hydroids, *Alcyonidium diaphanum*, ascidians and highly mobile epifauna.
- Rocky scar ground was observed on 7 of the 12 achieved transects in Allonby Bay, and 3 transects in the Solway Firth SAC survey area, though areas of sparse pebbles on soft sediment were more widespread.
- Areas of rocky scar ground have been generated by extending a 300 m radius from any point source at which the seabed was shown to be composed of greater than 10 % cobbles.
- Areas of rocky scar ground were concentrated primarily west of Dubmill Point and around Dubmill Scar), and in the centre and south of Allonby Bay. In contrast to previous surveys, no rocky scar ground was observed in the west of the Allonby Bay pMCZ in the vicinity of Maryport Roads.
- Fauna on areas of rocky scar ground was relatively sparse, featuring robust, scour-tolerant species such as hydroids, *A. diaphanum*, encrusting sponge and the ascidian *Dendrodoa grossularia*.
- Patches of *S. alveolata* were observed in Allonby Bay, and a *Mytilus edulis* bed was observed in the Solway Firth survey area.
- A preliminary assessment of condition has been made for the rocky scar ground observed
- It is recommended that future monitoring incorporate camera deployments and infaunal sampling with broad-scale acoustic techniques to enable changes in sediment composition, including areas of rocky scar ground, to be readily identified.

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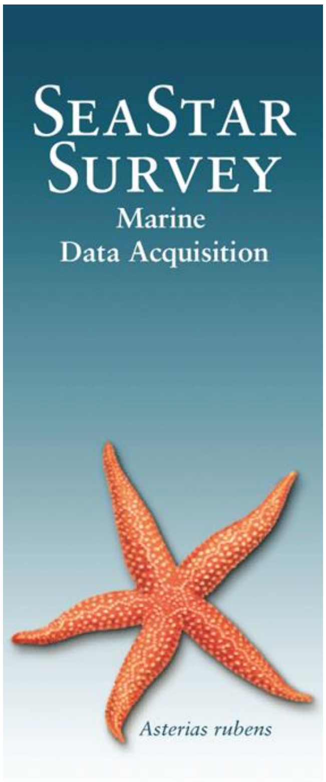
PROJECT PERSONNEL

This report and the survey detailed within was undertaken by Seastar Survey Ltd. for Natural England. All of the Seastar Survey Ltd. personnel involved in the project are listed below.



Project Tendering	Steven Dewey
Survey Team	Alex Shakspeare
	William Hawes
	Juliet Wilson
	Jim Kerr
Data Analysis	
Video analysis	Jen O'Dell
	Alex Shakspeare
GIS processing	Steven Dewey
	Jen O'Dell
Report Writing	
Lead author	Jen O'Dell
Additional authors	William Hawes
	Alex Shakspeare

1 Introduction

1.1 Project background

The EU Habitats Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements and sets out measures to maintain or restore natural habitats and species of European Union interest at favourable conservation status. Under the Habitats Directive, Natural England has statutory responsibility to advise relevant authorities as to the conservation objectives for European marine sites in England and to advise as to any operations which may cause deterioration of natural habitats or disturbance of species for which these sites have been designated. This information is a key component of any management schemes which may be developed for these sites.

The Solway Firth is a large, complex estuary and one of the more important and least industrialised estuarine areas in Europe (JNCC 2015a). The Solway Firth Special Area of Conservation (SAC) was designated under the Natura 2000 programme due to the following Annex I qualifying features; estuaries; sandbanks which are slightly covered by seawater all the time; mudflats and sandflats not covered by seawater at low tide; Atlantic salt meadows; and *Salicornia* and other annuals colonising mud and sand. In addition, present as a qualifying features, but not a primary reason for selection, is the Annex I habitat ‘reefs’ (JNCC, 2015a).

At the time of writing, Allonby Bay proposed Marine Conservation Zone (pMCZ) is being consulted on for the second tranche of MCZs. The pMCZ is proposed in order to provide protection to a number of features of conservation interest including blue mussel beds, honeycomb worm (*Sabellaria alveolata*) reefs and peat and clay exposures as well as a number of broad scale habitats (ISCZ, 2011).

Coarser sediments such as gravels (>2 mm) and cobble (>64 mm) are relatively uncommon in the estuary, and the majority of pebble, cobble, and boulder are related to eroded glacigenic deposits (Barne *et al.*, 1996). Small areas of cobble and pebble outcrops known as ‘scars,’ which generally occur as a result of erosion of glacial material backing the site are present, however they are not a major component of the area (Cutts & Hemingway, 1996). Whilst the majority of these scar grounds are associated with the glacial and fluviglacial material located in the inner estuary, extensive areas of ‘rocky scar ground’ also occur on the Cumbrian coast in the mid to outer estuary between Silloth and Maryport (Cutts & Hemingway, 1996).

In order to inform site condition monitoring, Seastar Survey Ltd. were contracted by Natural England to undertake a drop-down camera survey of both the Solway Firth SAC and the Allonby Bay pMCZ in order to define the distribution and extent of any subtidal rocky scar grounds communities present.

1.2 Survey areas

The Solway Firth is a large macrotidal estuary situated on the west coast of Britain and forms part of the border between England and Scotland, between Cumbria and Dumfries and Galloway. It stretches from St Bees Head, just south of Whitehaven in Cumbria, to the Mull of Galloway, on the western end of Dumfries and Galloway (Figure 1.1). The SAC covers a total of approximately 436.4 km^2 (JNCC, 2015a).

The Allonby Bay pMCZ is situated on the south coast of the Solway Firth, adjacent and south of the Solway Firth SAC. The pMCZ stretches for approximately 9 km along the coast from Dubmill Point in the north to just north of Maryport in the south (Figure 1.1). The site extends from the intertidal zone to approximately 5.5 km off the Cumbrian coast to depths of 6 m (DEFRA, 2015) and covers an area of approximately 40 km^2 (Godsell & Fraser, 2013).

1.3 The environment

1.3.1 Geological and sedimentary environment

The Solway is a large shallow complex estuary formed by a variety of historical physical influences including glaciation, river erosion, sea level change and geological barriers from hard rock outcrops. Of the few examples of this type of estuary in Great Britain, the Solway Firth is the largest (Brown *et al.*, 1997).

Permo-Triassic rocks underlie much of the Solway Firth but the area is largely devoid of exposed bedrock (Barne *et al.*, 1996). The coasts of the Solway Firth are made up of terraced alluvium, overlain locally by peat bogs. The intertidal part of the estuary is a complex of low, largely mobile sand banks separated by winding channels. Isolated shingle areas associated with the banks are the result of the winnowing of coarser material out of the underlying glacial till. Saltmarshes line the intertidal areas which pass landward into a series of Holocene terraces formed of sandy loam. The terraces, which occur parallel to and behind the current shoreline of sand and shingle beaches to the south of the Waver estuary down to Maryport, have been raised into position by the rebound of the earth’s crust following the melting of the last ice sheet (Barne *et al.*, 1996; English Nature, 1997).

The estuary is characterised by extensive areas of sandflats and mudflats, which are collectively considered to be the third largest such area in the UK (Davidson *et al.*, 1991). The extensive intertidal flats found in the Solway are particularly important and these areas are highly dynamic and mobile and are generally characterised by fine sands and silt. The inner estuary tends to be characterised by finer sandy sediments whilst the outer estuary has somewhat coarser sediments. The sediment deposits within the sandbanks of the Solway are somewhat coarser than those found in most estuaries, with a mean grain size of approximately 100 µm (Black *et al.*, 1994). Overall the estuary is characterised by sandier sediments rather than muds, which is unusual in estuarine habitats with reduced salinity; this is due in part to a relatively reduced mud input from rivers (Allen, 2006).

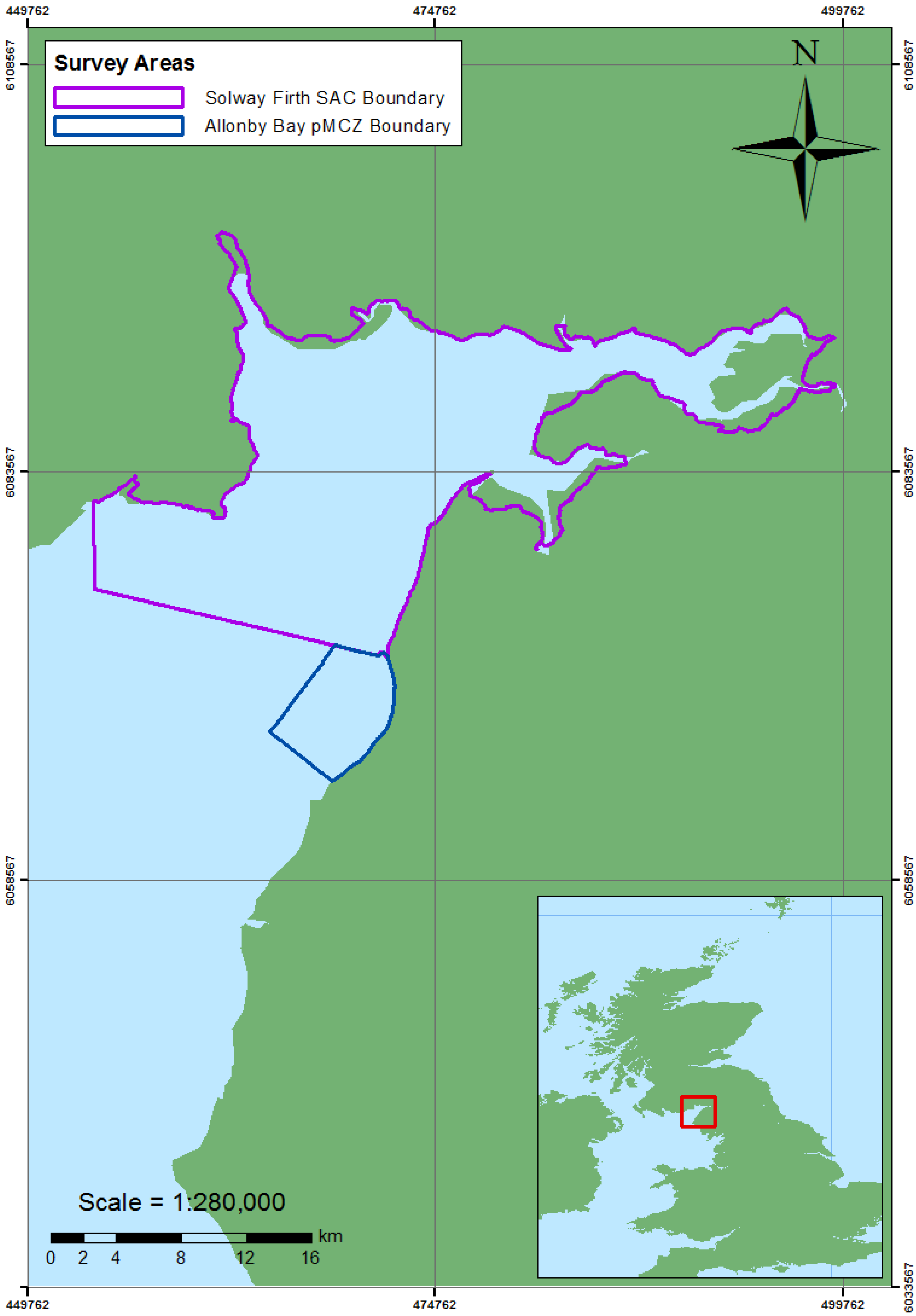


Figure 1.1: Location of the Solway Firth SAC and the Allonby Bay pMCZ

Subtidal sediments in the Solway Firth include fine and medium sands, sandy muds, sandy gravel and cobbles (Allen, 2006). Hard substrata are limited in extent, forming only a small proportion of the total area of the seabed in the outer Solway, and consist mainly of exposures of boulder clay, which are known locally as ‘scars’ or ‘rocky scar ground’ (see section 1.3.3.1). Once exposed, the clay is usually eroded from the boulder interstices, leaving extensive areas of boulder shores. Outcrops of bedrock are highly localised. In some areas, the movement of sediments means that scar exposures may appear suddenly, only to be smothered again by sediment shortly afterwards (Perkins, 1973; Cutts and Hemmingway, 1996; Allen, 2006).

Although coarse sediment habitats are relatively uncommon in the Solway Firth, a range of coarse sediment types can be found, ranging from shingle and pebble beaches to cobble and boulder scars (Cutts and Hemmingway, 1996). The majority of rocky scar grounds are associated with the glacial and fluviglacial material located in the inner estuary. Extensive areas of rocky scar ground also occur on the Cumbrian coast in the mid to outer estuary between Silloth and Maryport, particularly west and north of Dubmill Point (Allen, 2006). In this region such material may have been eroded from raised shingle structures under the dunes, or transported from the offshore scar grounds and carried landwards by storm waves (Cutts & Hemingway, 1996).

The Allonby Bay pMCZ is predominantly sandy in character (Godsell & Fraser, 2013) but an area of cobble and boulder scars composed predominately of coarser sediment with some subtidal sand and mud has been recorded at an area known as Maryport Roads (Godsell & Fraser, 2013). Further areas of cobble and boulder scar ground have been recorded south of Dubmill Point (Allen, 2006), and coarse sediments partially composed of potential cobble reef have been recorded in the inner bay (Godsell & Fraser, 2013).

1.3.2 Physical environment

The Solway Firth is one of the largest macrotidal estuaries in the Irish Sea, and contains one of the largest continuous areas of inshore sublittoral and littoral habitats in Britain. The sublittoral sediment sandbanks of the Inner Solway are separated by six river channels and are extremely dynamic and mobile reflecting the complex hydrodynamic regime of the Firth (Cutts and Hemingway, 1996; LIFE, 2000). Admiralty Charts show that most of the Solway Firth is less than 10 m deep, while the inner Solway rarely exceeds 5 m.

The estuary has a large tidal range with differences between mean low and high water spring tides of approximately 6.7 m in Kirkcudbright Bay and 8.4 m at Silloth, although this reduces to around 3.6 m further upstream toward the head of the estuary (Cutts and Hemmingway, 1996). Due to the enclosed nature of the Irish Sea the Solway is generally sheltered from Atlantic swells with fetch lengths ranging from between 200 – 300 km. Wave height and direction within the Solway is largely dependent on the aspect and fetch whilst the prevailing winds for the outer Solway are from the north-west in winter, and south-west in summer (Babtie *et al.*, 1989; Barne *et al.*, 1996; Allen, 2006). The strong currents (which exceed 2 m/s) and therefore the predominantly sandy nature of the inner Solway Firth is primarily due to its funnel-like shape (Barne *et al.*, 1996). Considerable seasonal fluctuations in water temperature have been recorded, due to the shallow nature of the estuary (Natural England and SNH, 2010).

The Solway Firth contains areas of both erosion and accretion, and its natural development has been modified by land claim in parts of the coastal zone. As the longshore drift of sediment is into the estuary, accretion in general is probably greater in volume than erosion. Locally, however, erosion may be significant (Barne *et al.*, 1996). Tidal currents and waves generated by the prevailing westerly winds move sediments into the Solway Firth, but transport rates are low north of Silloth (Barne et al., 1996).

1.3.3 Biological environment

In addition to being designated an SAC, the Upper Solway Flats and Marshes have designated a wetland of international importance under the Ramsar Convention, and a Special Protection Area (SPA) under the Birds Directive. Similarly, the Inner Solway has been designated as a Site of Special Scientific Interest (SSSI) notified under the Wildlife & Countryside Act 1981 (Allen, 2006; Natural England and SNH, 2010).

The shallow sublittoral sediments of the Solway Firth are important for fisheries in the Solway and also as spawning and nursery grounds for the Irish Sea in general (SFP, 1996). The Solway Firth provides migratory passage for the Annex II species sea lamprey (*Petromyzon marinus*) and river lamprey (*Lampetra fluviatilis*), to and from spawning and nursery (Natural England and SNH, 2010; JNCC, 2015a). The estuary is also important for migrating fish, particularly sea trout (*Salmo trutta*) and salmon (*Salmo salar*) (Natural England and SNH, 2010). The estuary supports additional fish populations including allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*), which migrate through the Solway Firth to freshwater breeding grounds (Natural England and SNH, 2010).

The site also supports other typical estuarine fish populations, such as flounder and other flatfish including plaice, sole and dab (Axelsson *et al.*, 2006; Natural England and SNH, 2010). The mudflats and sandflats of the inner estuary provide nursery and feeding grounds for commercially and recreationally important fish species, particularly shellfish such as the cockle *Cerastoderma edule*, as well as providing a significant food source for birds (Natural England and SNH, 2010). The whole estuarine complex is important for wintering wildfowl (ducks, geese and swans) and waders, and is a vital link in a chain of west coast UK estuaries used by migrating waterbirds (Natural England and SNH, 2010).

The sublittoral sediment communities of the inner estuary are typically sparse but become richer towards the outer estuary due to less extreme environmental conditions and a more varied substrate (Perkins and Williams, 1966; Perkins, 1968; Cutts and Hemingway, 1996; LIFE, 2000). In the Inner Solway sublittoral habitats are largely restricted to the channels; these have been found to be generally impoverished hard substrata and are very restricted within the enclosed inner Solway (Perkins and Williams, 1966).

Benthic communities within the inner Solway are characterised by typical estuarine assemblages, with fauna typically dominated by a mix of polychaetes and bivalves, together with large numbers of the burrowing amphipods *Corophium volutator* and *Bathyporeia* spp. (Perkins 1973; Barne *et al.*, 1996). Abundance and species diversity is low throughout the Solway Firth (Axelsson *et al.*, 2006), however it has been reported that species diversity increases in the sublittoral towards the outer Solway (Perkins and Williams, 1966; Perkins, 1968; Cutts and Hemingway, 1996; LIFE, 2000; Axelsson *et al.*, 2006). The fauna of the mobile mid-channel sandbanks is generally less rich than that of the comparatively stable fringing sandbanks (Rendall & Bell, 1993).

The sublittoral zone of the outer Solway has been found to be richer than the barren channels of the inner Solway, with fine sand sediments characterised by the bivalves *Mactra stultorum* and *Donax vittatus*, medium sands by the bivalve *Spisula solida*, and muddy sands by the polychaete *Nephtys* spp. and the bivalves *Nucula sulcata*, *Abra albida* and *Angulus tenuis* (Perkins & Williams 1966; Perkins 1973).

1.3.3.1 Rocky scar ground and Annex I reef communities

While hard substrata are limited in extent in the Solway Firth (Perkins 1973; Allen, 2006), the Annex I habitat ‘reefs’ are a secondary qualifying feature of the SAC (JNCC, 2015a). Reefs are defined by the JNCC (2015b) in relation to SAC selection as;

Rocky marine habitats or biological concretions that rise from the seabed. They are generally subtidal but may extend as an unbroken transition into the intertidal zone, where they are exposed to the air at low tide. Intertidal areas are only included within this Annex I type where they are connected to subtidal reefs. Reefs are very variable in form and in the communities that they support. Two main types of reef can be recognised: those where animal and plant communities develop on rock or stable boulders and cobbles, and those where structure is created by the animals themselves (biogenic reefs).

Ecological subdivisions for Annex I Reef include bedrock, stony and biogenic reefs. Rocky scar ground is a sub-feature of stony reefs. Rocky scar grounds are an important habitat within the Solway supporting a relatively rich and varied fauna (Allen et al, 1999). Perkins (1986) defines the term 'scar' as;

A hard substratum emergent from the widespread areas of mobile sand and liable to periodic inundation by the sand. While some may be composed of one type of substratum, others may be a mixture of two or more.

Lancaster (2009) additionally states that scars are remnants of glacial deposits; areas of cobbles, boulders and pebbles on otherwise sandy substrata. Isolated outcrops of hard substrata in largely sedimentary environments provide discrete potential habitats for epifaunal communities (Irving *et al,* 1996).

Areas of rocky scar ground increase the biodiversity of the Solway Firth area as they support a range of other species characteristic of harder substrata which may not be otherwise present. The benthic communities occurring on the scar grounds in the Solway Firth SAC and the Allonby Bay pMCZ are known to be both diverse and productive (Perkins, 1973). The communities recorded from sublittoral scar grounds are essentially similar to those normally found in sublittoral rocky areas, with rich and well developed epifaunal communities characterised by the sponge *Halichondria panicea*, the hydroid *Abietinaria abietina*, the polychaete *Sabellaria alveolata*, the gastropod *Buccinum undatum*, the horse mussel *Modiolus modiolus*, the bryozoan *Flustra foliacea* and the ascidian *Dendrodoa grossularia*, particularly in areas where the boulder clay had remained free of sand inundation for an extended period (Perkins, 1981). Sublittoral scar grounds are also considered to be important for the presence of commercially important species such as the edible crab *Cancer pagurus* and lobster *Homarus gammarus*, and for the fish that use them as feeding grounds (Perkins, 1986). The rocky scar grounds in the Solway Firth have been associated with other habitats of conservation importance, such as biogenic reefs. Biogenic reefs are defined by Holt *et al.* (1998) as;

Solid, massive structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms.

The most important biogenic reef forming species in UK inshore waters include the polychaete worms *Sabellaria alveolata* and *S. spinulosa*, and the mussels *Mytilus edulis* and *Modiolus modiolus*. Biogenic reefs can have a number of important effects on the physical environment, serving to stabilise sands, gravels and stones, providing hard substrata for attachment of sessile organisms and may be an important source of food for other organisms (Holt *et al.*, 1998).

Extensive areas of *S. alveolata* reef have been recorded on the Cumbrian coast of the Solway Firth, including the rocky scar grounds off Dubmill Point (Allen *et al.*, 1999; Allen *et al.*, 2002). *Sabellaria alveolata* is particularly abundant in this region as it favours fairly exposed conditions with relatively high water current velocities where the water holds a high load of sand and food particles in suspension. The species requires a hard substratum (including rocky scar ground) on which to form reefs. Many rocky scar sites also provide suitable substrate for *Mytilus edulis* beds to develop (Natural England and SNH, 2010).

Few studies have investigated the distribution and extent of subtidal rocky scar ground. Cutts and Hemingway (1996) reported scar ground in the vicinity of Maryport Roads, at Dubmill Scar and in the Silloth Channel, while Allen (2006) delineated four main areas of scar ground throughout the southern side of the Solway Firth and Allonby Bay (Figure 1.2).

The distribution of rocky scar grounds – and associated biogenic reef – appears to exhibit a degree of temporal variability in the SAC (Allen, 2006). Additionally, the species richness of rocky scar ground communities appears to be dependent on the frequency of inundation by sand (Perkins, 1986). Where scars remained free from sand cover for long periods, the biota recorded has been reported as being similar to communities present in sublittoral rocky areas, with between ten and 100 times the biomass of adjacent sands (Perkins 1981).

Rapid changes in species composition and abundance on rocky scar ground has been documented in the Solway Firth. A rapid disappearance of *Lanice conchilega* from a site at Siddick in 1987 coincided with a large settlement of *M. edulis* in the same area (Perkins, 1986; Cutts and Hemingway, 1996). Perkins (1986) has also charted the progression of a scar ground community from being characterised by the breadcrumb sponge *Halichondria panacea* in 1970 to being dominated by the barnacle *Balanus crenatus* in 1973 to a mixture of *H. panacea* and *S. alveolata* in 1975. This is hypothesised to be due not only to the effects of sand inundation, but to fluctuations in the abundance of vagile species which prey on sessile organisms inhabiting the rocky scar ground (Cutts and Hemingway, 1996).

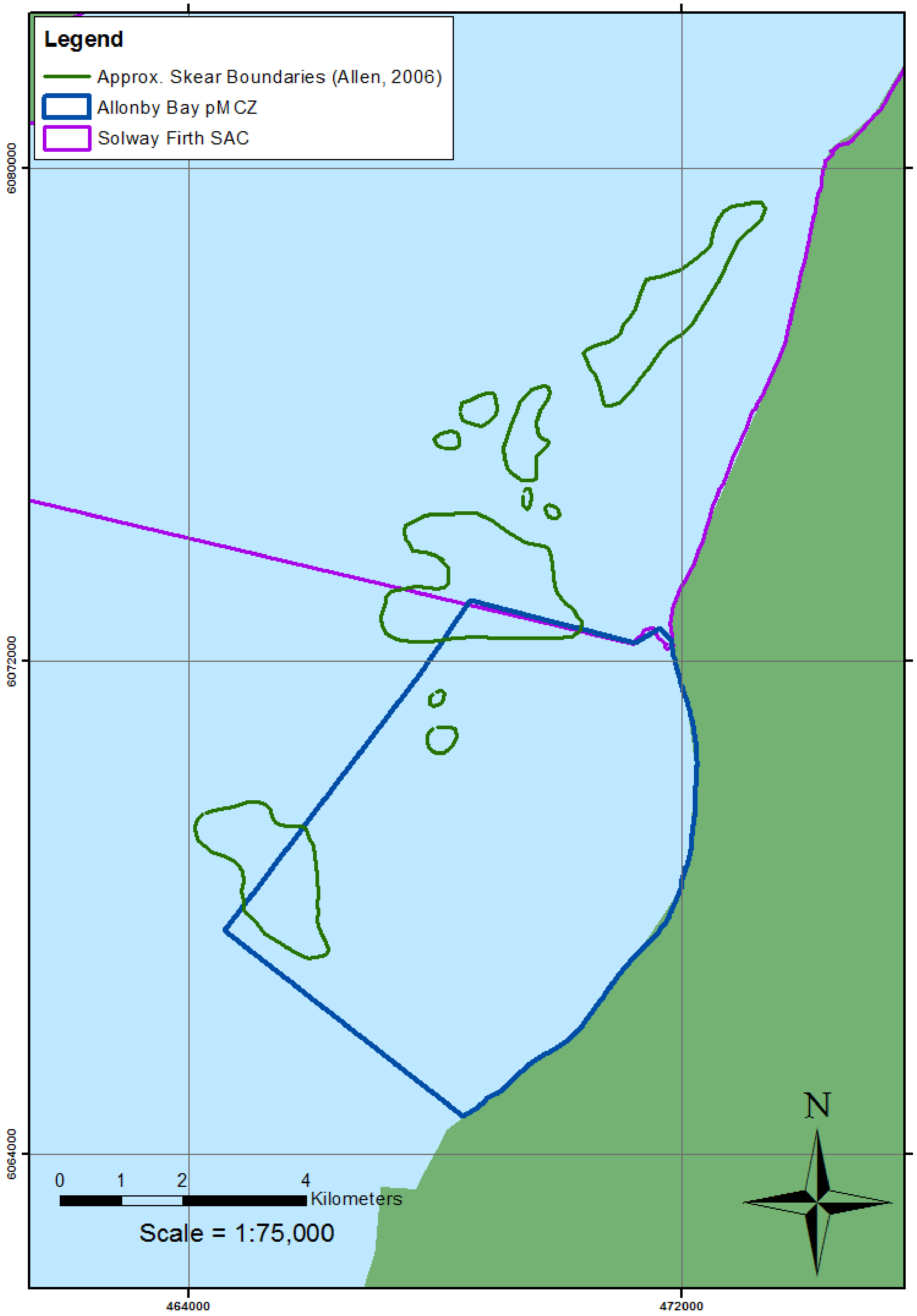


Figure 1.2: Rocky scar ground boundaries in the Allonby Bay pMCZ and Solway Firth SAC as defined by Allen (2006)

1.4 Survey aims

The overall aim of this contract was to undertake a drop-down camera survey in order to inform condition monitoring of the subtidal rocky scar ground communities within the Solway Firth SAC and Allonby Bay pMCZ. The attributes to be assessed during the survey were as follows;

- Extent and distribution of subtidal rocky scar ground
- Biotope composition of subtidal rocky scar ground
- Extent and distribution of characterising biotopes
- Species composition of characterising biotopes

2 Methodology

The survey was originally planned to take place in summer 2014, however due to a combination of logistical and weather constraints this was not possible. It was agreed with the client that, rather than postponing the survey until summer 2015, work be conducted in autumn 2014 and winter 2014-15, weather conditions permitting. The surveys were conducted on board Seastar Survey's own vessel SV '*Mariner*', and took place across three phases.

Phase I mobilised on 14th October 2014 with survey work taking place on 16th and 17th October 2014.

Phase II of the survey was mobilised on 20th November 2014 and operations in the Allonby Bay survey area were conducted opportunistically on the afternoon of the second mobilisation day. The remainder of operations during Phase II took place in the Solway Firth.

Phase III was mobilised in Maryport on 17th January 2015 and operations took place on four days from 19th January to 23rd January 2015. Demobilisation was carried out on 23rd January. No survey operations were undertaken on 18th January due to poor weather.

2.1 Overall approach to sampling design

The survey plan was designed to assess the extent and distribution of subtidal rocky scar ground communities within the Allonby Bay pMCZ and Solway Firth SAC using high resolution video footage.

Camera stations for the Allonby Bay pMCZ survey area were selected following a review of the literature and existing data supplied to Seastar Survey by Natural England. Camera transects were selected to investigate priority areas specified by the client, to revisit previous survey locations, and to achieve coverage of other identified potential areas of subtidal rocky scar ground communities. Seastar Survey utilised a stratified systematic approach to sampling design, aiming to sample at a range of water depths and predicted sediment types whilst targeting areas of potential rocky scar ground.

Two days were allocated for survey work in Allonby Bay. The aim was to revisit sites surveyed by Allen (2006) and to fill in gaps from the 2011 Environment Agency survey (Godsell & Fraser, 2013). Following a review of the available data, it was ascertained that the largest areas of potential rocky scar grounds were likely to be found at Maryport Roads, in the southwest of the pMCZ, and to the south of Dubmill Point in the north of the pMCZ. These were therefore the priority areas for survey.

Prior to the commencement of survey operations a total of 21 video transects were planned within the Allonby Bay pMCZ, generally orientated in the direction of the expected predominant tidal currents. Four stations were selected within the areas of predicted coarse sediment in the inner bay, however as it was expected that visibility would decrease towards the shore (Allen, 2006), these sites were lower priority. The proposed sampling locations are shown in Figure 2.1. Full details of planned sampling locations are given in Appendix I.

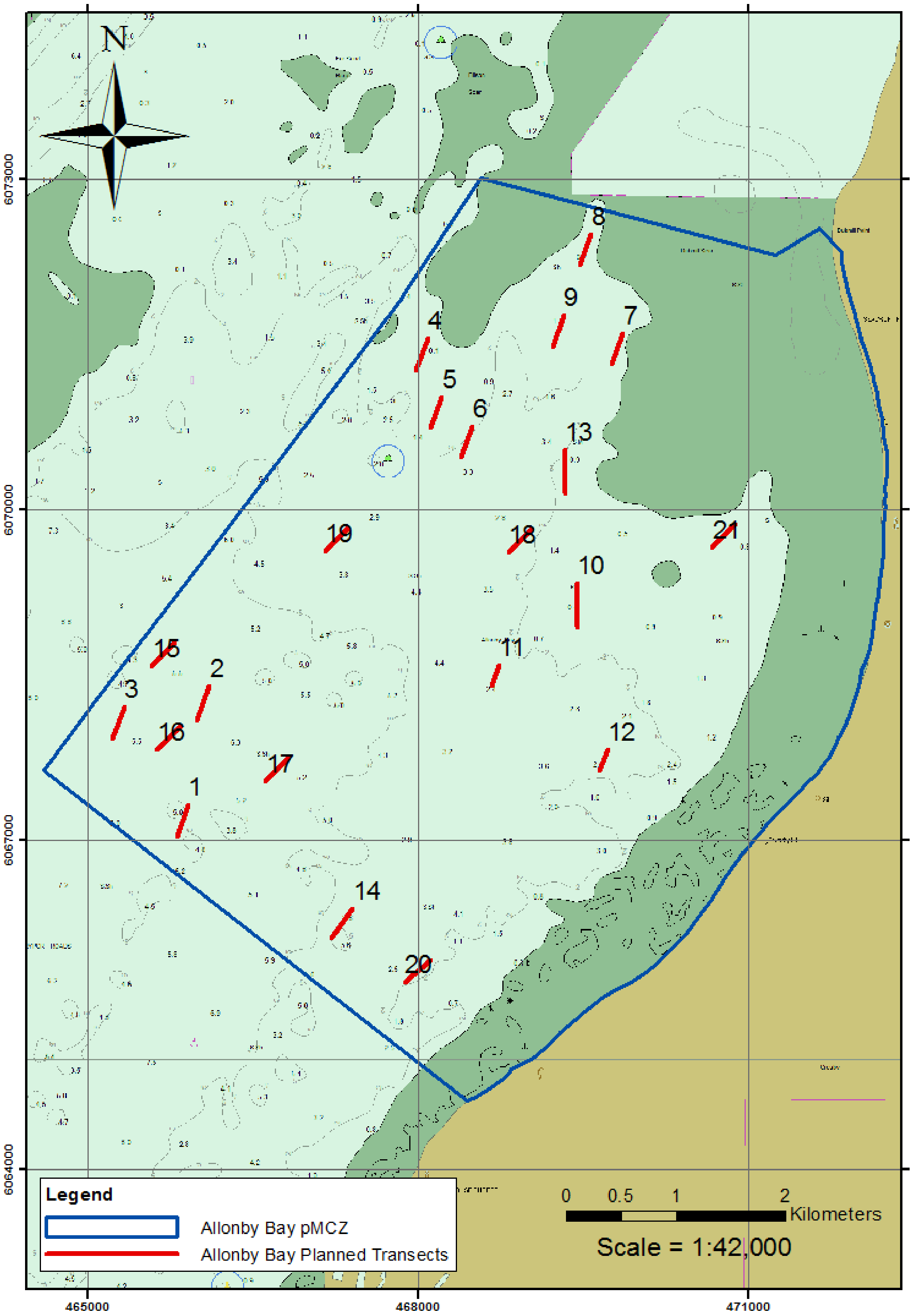


Figure 2.1: Planned video camera transect locations within Allonby Bay pMCZ

Camera stations for the Solway Firth SAC survey were planned using a systematic approach. As requested by the client, a triangular 750 m grid was created and sampling locations were planned at each grid node within the delineated survey area, resulting in a total of 47 sampling locations. As there were no repeat stations, only single locations rather than survey lines were planned, enabling the survey team to select the optimal line direction for each site when in the field, depending on prevailing conditions.

Six days were allocated for survey in the Solway Firth SAC, with high priority placed on the stations planned within areas thought to contain rocky scar grounds identified using data supplied to Seastar Survey by Natural England. The proposed sampling locations are shown in Figure 2.2. Full details of planned sampling locations are given in Appendix I.

2.2 Survey Methodology

2.2.1 Survey equipment

The equipment used during the Allonby Bay pMCZ and Solway Firth SAC rocky scar ground community DDV survey included:

- Hemisphere Crescent A100 DGPS
- Hypack 2011 survey management software
- Sony MiniDV recorder
- Seastar Survey Freshwater Camera System including:
    - Bowtech camera system (Phases I and II) comprising;
        - Bowtech Surveyor HD-Pro video camera
        - Bowtech Surface Control System
    - Kongsberg camera system (Phase III) comprising
        - Kongsberg OE14-502 HD video camera
        - Kongsberg Surface Control System
- Seatronics Ltd. SeaLED sub-sea lights
- 2 x 150 m soft umbilicals
- Simrad CA42 hull mounted echosounder
- Roberts Fluxgate Compass

2.2.2 Horizontal control

Positioning of the vessel was achieved using a Hemisphere Crescent A100 DGPS smart antenna. This system fed raw WGS84 positions into Hypack 2011 survey management software. The WGS84 positions were then converted by Hypack 2011 into Universal Transverse Mercator (WGS84 UTM North Zone 30 (6°W - 0°) grid coordinates. A navigation check was carried out at the beginning of the survey, where the vessel position was logged whilst alongside a known position, with all offsets measured.

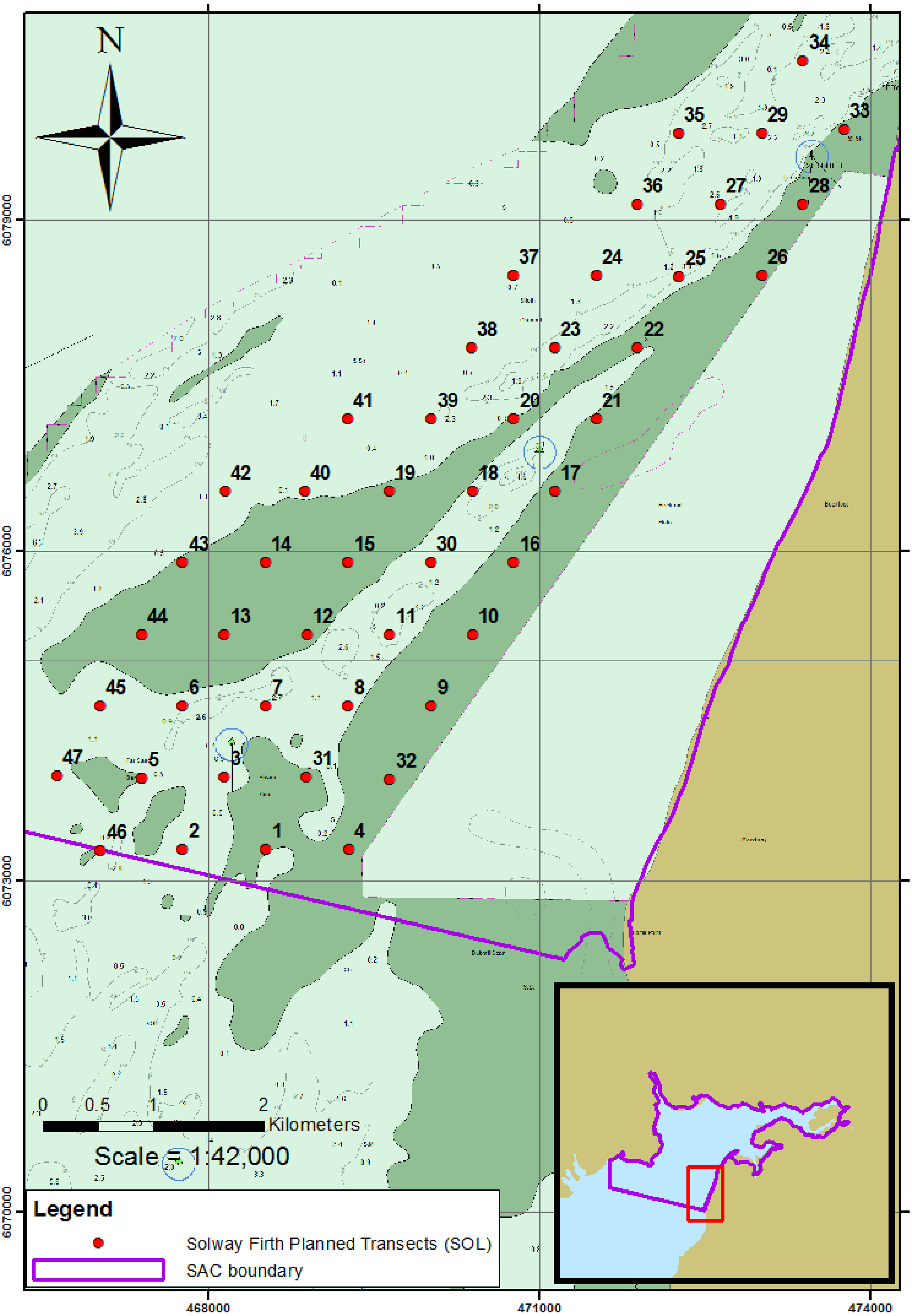


Figure 2.2: Planned video camera locations within the Solway Firth SAC.

2.2.3 Vertical control

SV *'Mariner'* was equipped with a Simrad NSS8 chart plotter and a CA42 hull mounted echosounder transducer. The raw depth under the keel was monitored and a correction added to account for the draught of the vessel. No tidal correction has been applied to the data.

2.2.4 Sampling methodology

2.2.4.1 Freshwater lens camera system

Due to the nature of the survey environment, the client specified that a freshwater lens system was to be used. The term 'freshwater lens' refers to a system comprising an underwater video camera housed within a sealed container filled with fresh or distilled water, mounted vertically over a clear lens at the base of the housing. This system enables useable seabed video data to be collected in highly turbid conditions by reducing the path length of light through the turbid water whilst still allowing the camera to be mounted far enough from the seabed to capture an appropriate field of view.

The Seastar Survey Freshwater Lens Camera System (FLCS) was designed in-house and custom-built to prioritise flexibility and reliability in challenging conditions. The system can house a variety of High Definition (1080p) subsea video cameras and allow these cameras to acquire a minimum seabed field of view of 40 x 29 cm in waters with a visibility of <10 cm.

The subsea video camera mounted within the FLCS for Phases I and II of the survey was a Bowtech Surveyor HD-Pro digital video camera, recording HD (1080p) video with a field of view of approximately 50 x 45 cm at a frame height of 10 cm. For Phase III a Kongsberg OE14-502 HD video camera was utilised, with a 40 x 30 cm field of view at a frame height of 10 cm. In both cases the camera was controlled using a surface command unit (SCU) enabling direct recording of HD video to either a 250 GB Hard Disk Drive (HDD) recorder or a professional disk recorder. Secondary recording was achieved using a high resolution Sony MiniDV digital tape recording system. The SCU enabled real time control of optical zoom, focal length and iris diameter. Four sub-sea LED lights were also mounted on the frame to illuminate the seabed and were controlled from the surface.

2.2.4.2 Deployment methodology

Due to the nature of the strong and very irregular tidal flows within the Solway Firth and surrounds, together with the poor underwater visibility experienced throughout the survey, it was determined that the established method of towing the camera frame just above the seabed would yield no usable data. Instead the camera frame had to be landed on the seabed in order to acquire usable footage. Seastar

Survey’s standard deployment methodology was therefore adapted to allow for approximately one seabed landing every 50 m.

The camera was deployed over the stern of the vessel using the vessel’s A-frame and winch. Two members of crew guided the frame over the stern of the vessel and the soft umbilical cable was taped to the winch wire at regular intervals in order to prevent excess drag and reduce the risk of entanglement. Once the camera system was in the water and approximately 1 m above the seabed the onboard surveyor began to log navigation data. The skipper then positioned the vessel with the bow facing into the tide and approached the first drop location. The vessel then came to a stop and the camera was slowly lowered to the seabed. On contact a manual fix was taken to record the time (UTC) and position of the frame on the seabed. The lack of vessel movement resulted in minimal horizontal layback of the frame from the vessel’s navigational reference point at the time of the fix. Once the camera was landed the umbilical and winch wire were paid out at an appropriate speed to compensate for vessel drift, allowing the camera to remain stationary on the seabed for sufficient time to allow for suspended sediment to clear and high quality video to be acquired.

The camera sent a continuous video feed to the surface, where the deployment was monitored and the camera was controlled by the camera operator using the surface control system. The HD recording system was used to record discrete seabed landings only, and each HD track was associated with a separate seabed landing. The entirety of each transect was recorded using MiniDV tapes.

Seven video clips, at approximately 50 m intervals along each transect, were planned. This number was increased in the field when rocky scar ground habitat was encountered. The distribution of seabed landings allowed for representative footage of the seabed habitats, dominant benthic fauna, seabed features and sediment types to be captured. Where visibility was very poor (<5 cm) the camera was still deployed in order to gain an indication of seabed type. On transects where there was no evidence of rocky scar grounds observed on the first two drops, or if visibility was insufficient to ascertain seabed type, the third planned drop was abandoned. If the fourth drop showed the same habitat type or conditions as the first two drops then the transect was cut short.

Raw navigation data were recorded throughout the drop-down camera deployment. All camera deployment logs were synchronised to the navigation data from the GPS system. The camera operator recorded the time in UTC from the GPS at the start and end of each deployment and the time of each landing. The position of each seabed landing was then extracted from the navigation data and backed up on a separate system.

The HDD tracks were backed up at the end of each day onto an external hard drive and stored in a separate location to the back-up MiniDV tapes. Upon completion of the survey the miniDV tapes from the video camera were uploaded to a computer, edited, titled and burnt to DVD at Seastar Survey's office in Southampton.

2.3 Video Analysis

2.3.1 Analysis of the HD video records

The nature of the highly turbid environment within the survey areas, and the resultant required deployment methodology, resulted in a dataset comprised of discrete seabed HD video 'clips.' These video clips record a static patch of the seabed of approximately 0.225 m^2 for a period of between 30 and 60 seconds. The camera system remained stationary during this time, however the entire video clip was analysed in each case in order to record any mobile fauna present.

Video clip analysis consisted of a description of the seabed and the identification of flora and fauna to the lowest practical taxonomic level. The abundance data were recorded using the semi-quantitative SACFOR scale, though counts or percentage cover of taxa were also recorded where it was deemed useful (e.g. reef forming species etc.). Sediment categories were assigned based on the Folk Trigon and Wentworth scale (see Leeder, 1982), with boulders and cobbles being described within 'gravel', and 'rock' referring to bedrock. A broadscale habitat (BSH) type was subsequently assigned to each video segment. If applicable a Habitat Features of Conservation Importance (FOCI) category was also assigned. The presence of any Annex I habitats and associated sub-features, including reef sub-features, were recorded. In addition, where potential stony or biogenic reef was recorded, an assessment of 'reefiness' was made based on elevation, coverage and, where possible, extent (Tables 2.1 and 2.2), as according to Irving (2009) and Gubbay (2007) respectively. However, without a grab survey, the fourth criterion of stony reefs could not be assessed. Any other features of interest, including anthropogenic impacts such as trawl marks or litter, were also noted. A list of the encountered fauna was produced for each site using species reference numbers as cited in the Marine Conservation Society Species Directory (Howson and Picton, 1997) with additional reference to the World Register of Marine Species (WoRMS Editorial Board, 2015) to avoid problems in species nomenclature. Video segments were assigned a biotope according to Connor *et al.* (2004) and a European Nature Information System (EUNIS) habitat classification code. The results were analysed using GIS which enabled a high level of processing, interpretation and display of substrata types, biotopes and HD video data.

The Quality Control (QC) process for the video analysis involved ongoing and post-analysis elements, as well as continuous collaboration with other Seastar Survey staff to check species identification, sediment classification and biotope classifications during the process of analysis. A senior member of staff also checked any uncertain identifications to ensure the highest possible level of data quality. The post-analysis QC process involved a re-assessment of 10 % of the data, checking the faunal / floral identification, habitat / biotope classification and data entry. Any discrepancies were discussed between analysts and agreed on prior to finalisation of the results.

Table 2.1: The main characterising features of a stony reef, *after* Irving (2009).

Characteristic	Not a reef	Resemblance to being a stony reef		
		Low	Medium	High
Composition	< 10 %	10 - 40 %	40 - 95 %	> 95 %
Elevation	Flat seabed	< 64 mm	64 mm - 5 m	> 5 m
Extent	< 25 m^2	> 25 m^2		
Biota	Dominated by infaunal species			> 80 % of species epifauna

Table 2.2: Threshold ranges proposed by workshop participants for reef characteristics which may be used in combination to determine whether an area of *Sabellaria* spp. aggregations might qualify as a biogenic reef. Note that the figures presented are not fully agreed or accepted thresholds for biogenic reef identification. From Gubbay (2007).

Characteristic	Not a reef	"Reefiness"		
		Low	Medium	High
Elevation (cm)	< 2	2 - 5	5 - 10	> 10
Extent (m^2)	< 25	25 - 10,000	10,000 - 1,000,000	> 1,000,000
Patchiness (% cover)	< 10	10 - 20	20 - 30	> 30

2.3.2 Habitat mapping

Ordinarily, the habitat mapping process would be achieved using ground-truthing data in conjunction with areas of consistent reflectivity identified from sidescan sonar acoustic data. Due to a lack of acoustic data and to the limited amount of ground-truthing the delineation of broad-scale habitats was deemed inappropriate at this stage. However, areas of rocky scar ground were delineated as far as possible on the basis of the video data alone. Three levels of confidence were assigned to the rocky scar ground polygons, so as to provide levels of accuracy in prediction of these habitats of interest.

The confidence in the level of certainty of the interpretation of the seabed environment at point source (i.e. a single video clip) is estimated at >90 % accurate (level 1). Level 2 rocky scar ground polygons (areas immediately surrounding point source data) have been assigned with 70 – 80 % confidence. These polygons were generated by extending a 50 m radius from any point source at which the seabed was shown to be composed of greater than 10 % cobbles, or from seabed contacts at which cobble coverage was recorded as <10 % but which were located within 50 m of a contact with >50 % recorded cobble coverage.

With acoustic data available, confidence level three would constitute areas with the same level of e.g. backscatter as point source data at distances greater than 50 m. For the purposes of this study, level three polygons have been delineated by extending areas of level two polygons by a further 250 m (i.e. 300 m from point source), however have been assigned a low level of confidence (<50 %). In addition to the lack of acoustic data, the reason for this relatively low confidence is the heterogeneity of the seabed observed in the survey areas; there was a high level of variability in the substrata within and between transects.

3 Results

3.1 Achieved survey locations

3.1.1 Allonby Bay pMCZ

A total of 12 transects were completed throughout the Allonby Bay pMCZ survey area. In addition, transect AL_13 was attempted but not completed due to equipment failure. The remaining eight transects were not attempted due to weather constraints experienced on the second day of survey (17th October). The location of the achieved camera transects are shown in Figure 3.1. A total of 89 discrete seabed video clips were recorded. Figure 3.2 shows the locations of all the achieved seabed landings. Full logs with details of achieved locations are given in Appendix II. Over 4.5 hours of seabed video footage were obtained.

Underwater visibility was very variable throughout the survey and ranged, depending on the state of the tide, between approximately 5 cm and > 20 cm. Given the poor underwater visibility conditions experienced throughout the survey area, the quality of the data acquired was very high overall.

3.1.2 Solway Firth SAC

A total of 51 transects were attempted in the Solway Firth SAC survey area. Of these, 47 were planned, 1 was a re-run of a previously attempted station, and 3 were added as extra stations in potential areas of interest. In addition, extra drops were carried out at stations where rocky scar ground was observed in order to better characterise the boundaries of these areas. Of the 51 attempted transects, 11 were completed in full, 31 were shortened due to poor visibility or to lack of features of interest and 9 were abandoned due to excessive current or lack of visibility. The locations of the achieved transects are shown in Figure 3.3. A total of 180 discrete seabed clips were recorded. Figure 3.4 shows the locations of each recorded clip. Full logs detailing their locations are supplied in Appendix II.

Underwater visibility was very variable throughout the survey and ranged, depending on the state of the tide, between approximately 2 cm and > 10 cm. The poorest visibility was experienced during Phase III, during which the majority of the data collection in the Solway Firth SAC survey area was carried out.

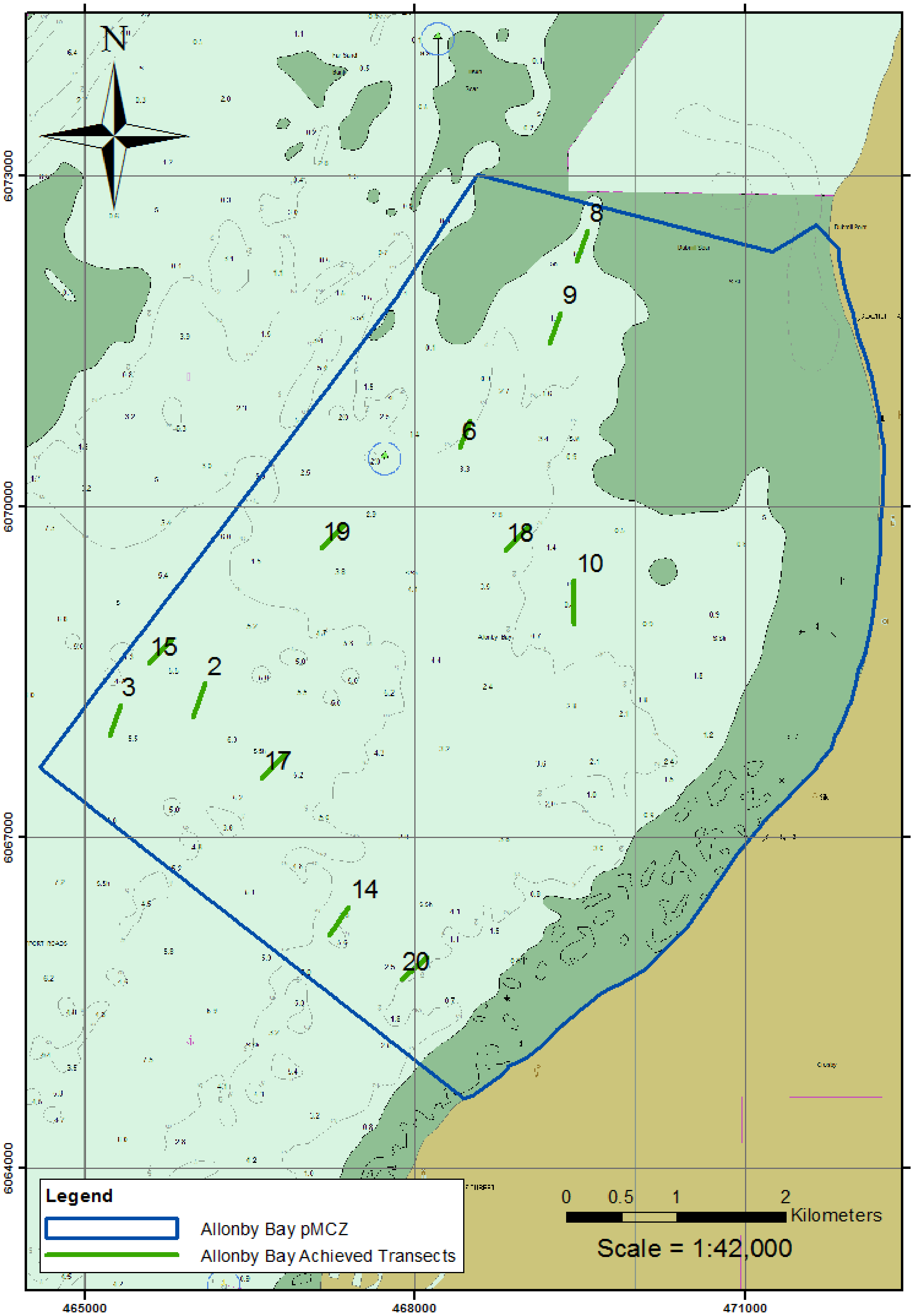


Figure 3.1: Achieved video camera transect locations within the Allonby Bay pMCZ

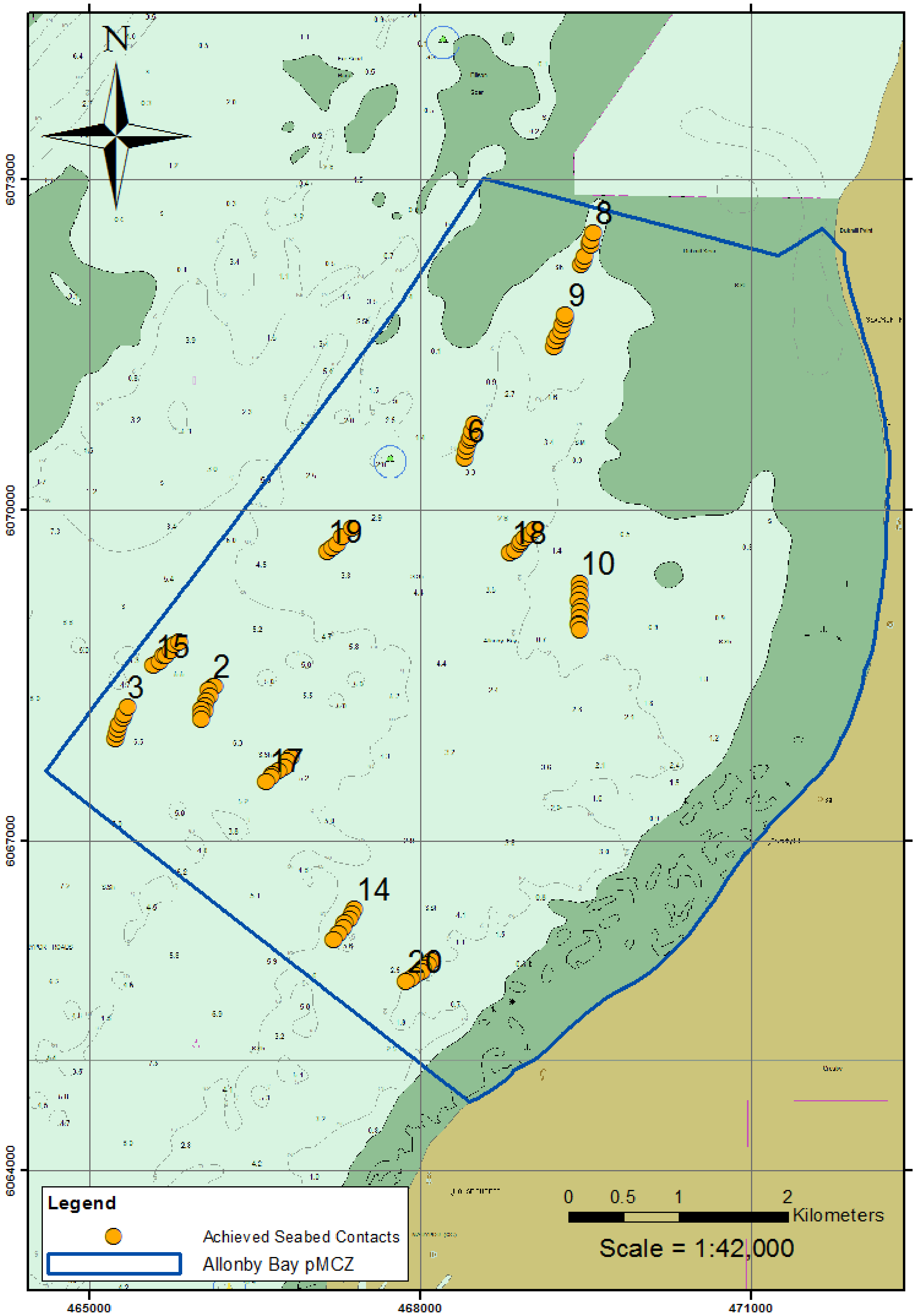


Figure 3.2: Achieved seabed landing locations within the Allonby Bay pMCZ

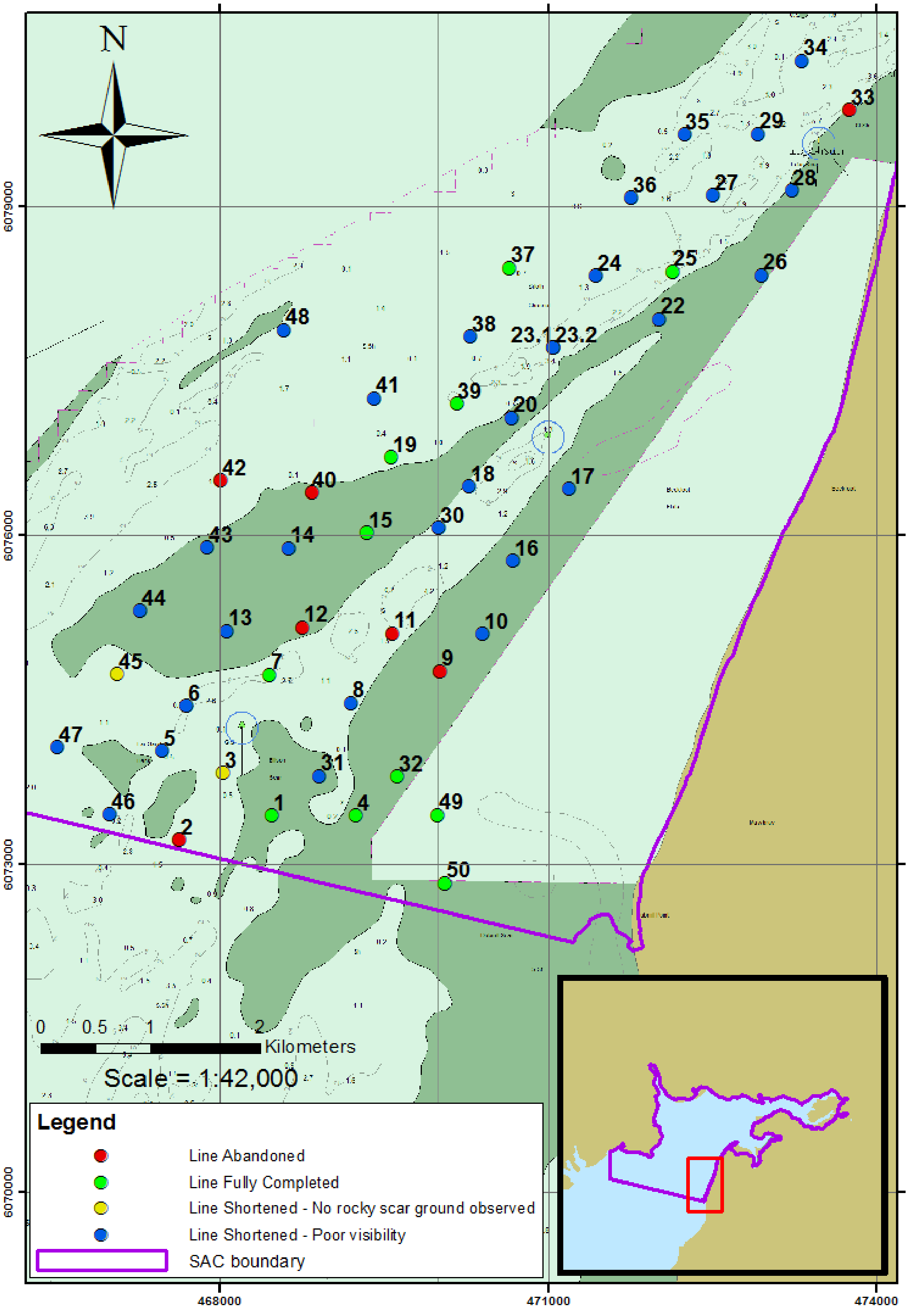


Figure 3.3: Results of attempted video transects during the Solway Firth SAC survey.

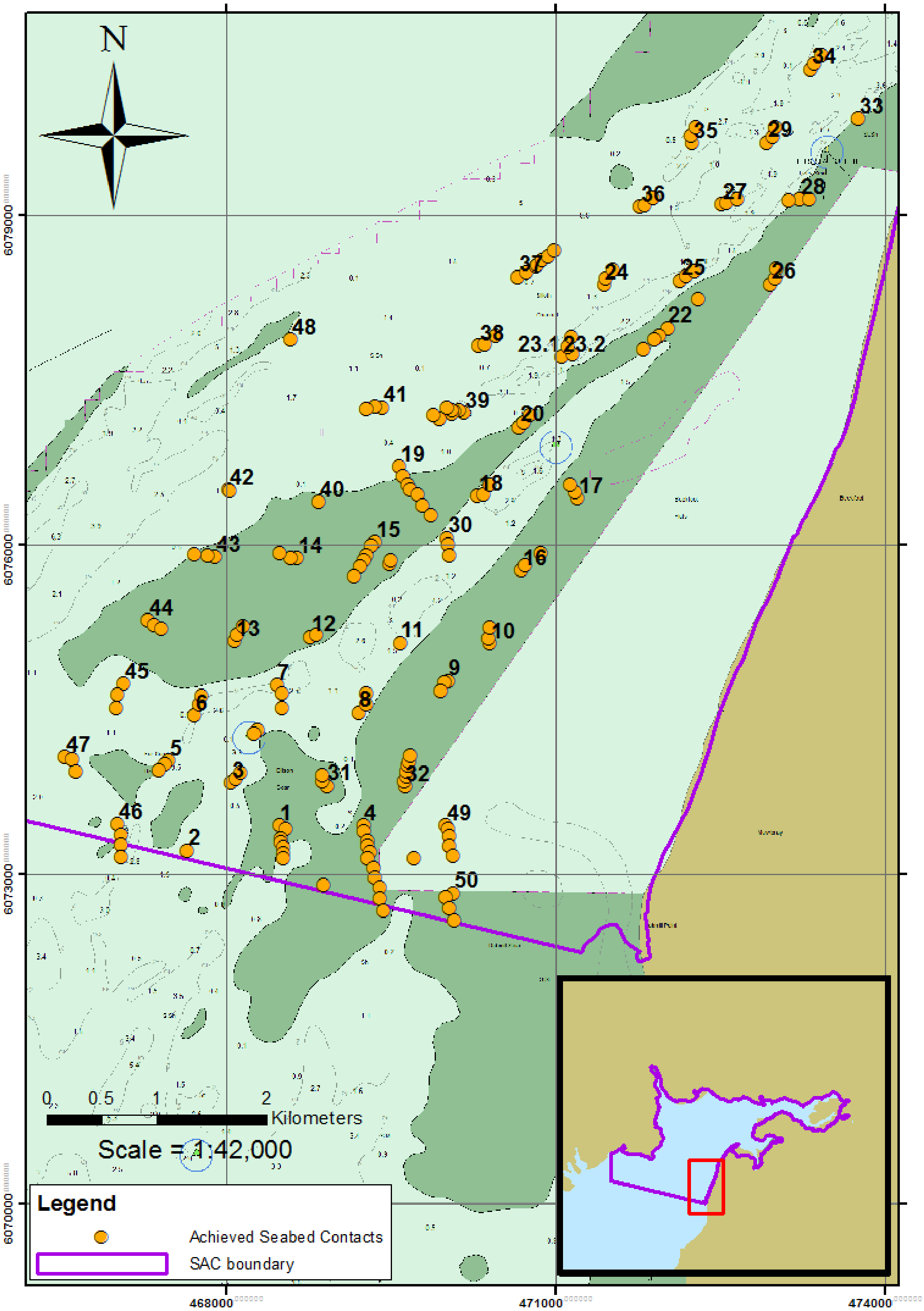


Figure 3.4: Achieved seabed landing locations with the Solway Firth SAC.

3.2 Example data

Example screenshots of video data from the Allonby Bay pMCZ survey are shown in Figure 3.5. In general the conditions experienced in this area during the survey allowed for very high quality video to be recorded.

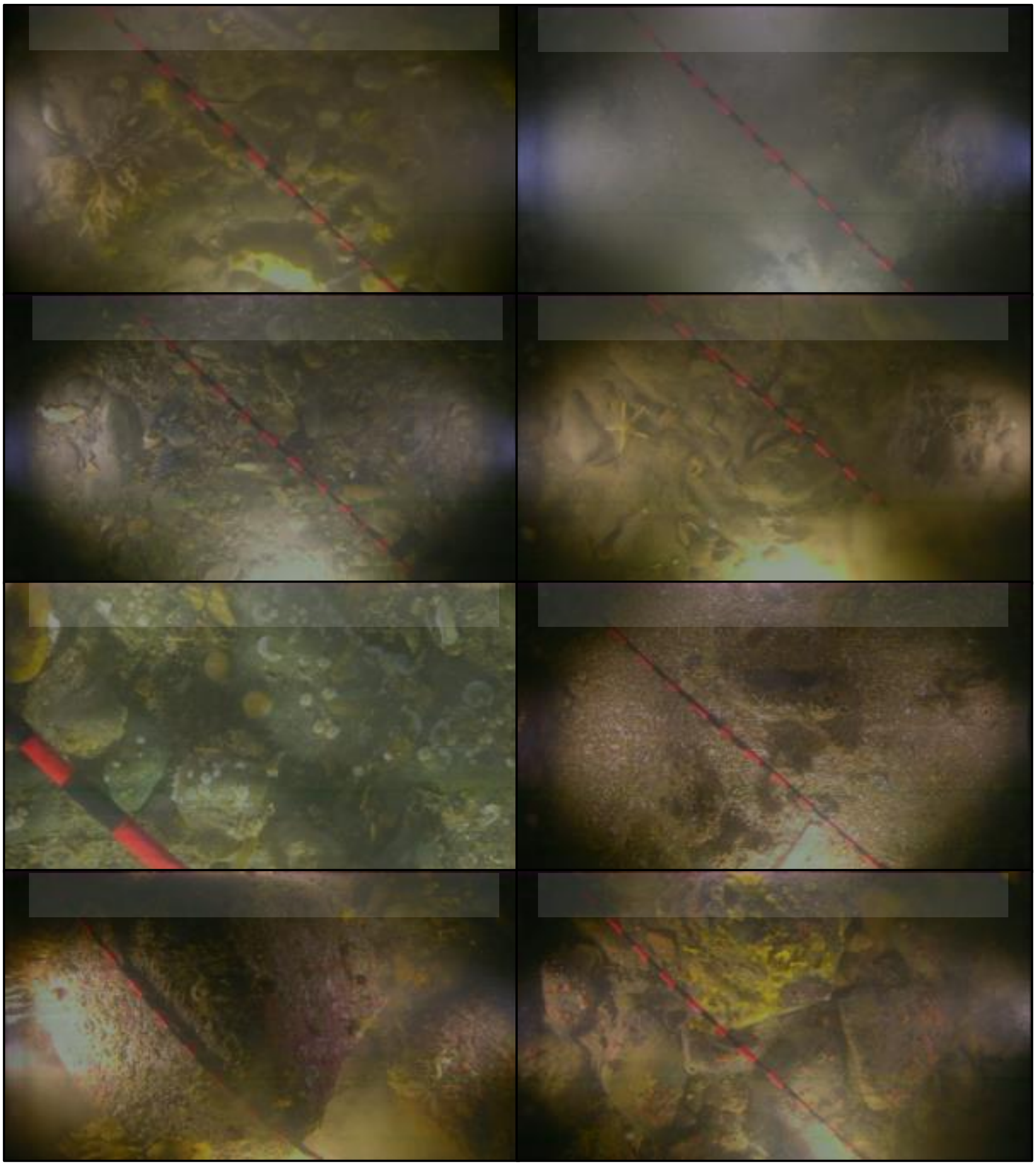


Figure 3.5: Example screenshots of video data collected in the Allonby Bay pMCZ

Example screenshots of video data collected during the Solway Firth SAC survey are shown in Figure 3.6. Conditions experienced during this survey, especially during the third phase of operations, were less good than those experienced during the Allonby Bay survey; as a result of there were a number of lines where no usable video footage was acquired.

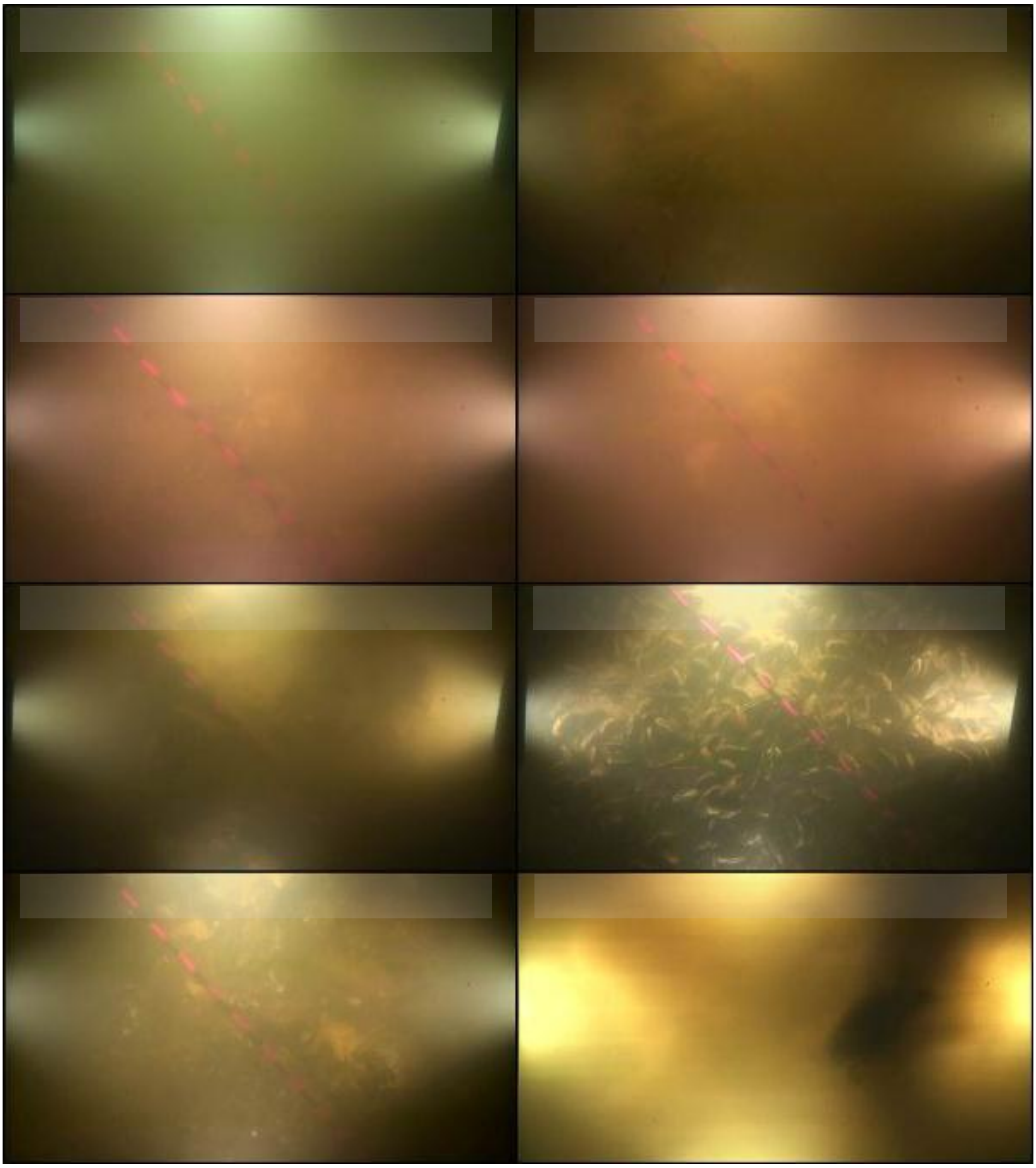


Figure 3.6: Example screenshots of video data collected in the Solway Firth SAC

3.3 General descriptions of the biological communities observed

3.3.1 Allonby Bay pMCZ

Allonby Bay pMCZ was found to be generally characterised by gravelly mixed sediments. A total of seven broad habitat types, biotope complexes and biotopes were identified. The details of the biotopes observed are given in Table 3.1 and Figure 3.7.

It should be noted that several biotope assignments have been left at the 'broad habitat type' level (level 2 in the MNCR classification). This is due primarily to a lack of information; soft sediment biotopes are primarily classified based on infaunal data rather than sediment characteristics alone. It is likely that, due to the shallow water depths in the survey area (generally < 5 m below chart datum), infralittoral biotopes (e.g. **SS.SMx.IMx**) are to be expected, however the highly turbid / low visibility conditions in the area suggest that 'classic' zonation patterns may be restricted to shallower depths than would otherwise be expected.

The assignment of mixed sediment and sandy or muddy biotopes was based on the assessment of the person undertaking the analysis. Without supporting data from sediment sample analysis there can be some uncertainty in the assessment of the quantities of sand and mud present. As a result some biotopes may be subject to change.

The survey area was found to be dominated by gravelly mixed sediments. The most commonly identified broad habitat type was **SS.SMx** (sublittoral mixed sediment), though coarse and sandy sediments (**SS.SCS**, sublittoral coarse sediment and **SS.SSa**, sublittoral sands and muddy sands, respectively) were also observed. Areas of sandy sediments were generally species poor, while coarse sediments – usually consisting of cobbles and pebbles – were generally characterised by encrusting sponges, encrusting bryozoans and serpulid worms (likely *Spirobranchus* sp.). Communities on mixed sediments were more species rich, being characterised by hydroids, the bryozoan *Alcyonidium diaphanum* and ascidians.

No bedrock was recorded during the survey, however areas of cobbles and boulders were observed on lines AL_10 and AL_20, characterised by encrusting sponges, barnacles and *Dendrodoa grossularia* in addition to sparse hydroid and bryozoan turf, though encrusting red algae was observed in one video clip. No exact biotope match was found for the communities observed; the broad habitat type **CR.MCR** (moderate energy circalittoral rock) was therefore recorded.

In addition to the areas of boulders, other areas of rocky (cobble) scar ground were observed on lines AL_08 and AL_18; these video clips were assigned the biotope

SS.SCS due to the paucity of fauna present. Areas of *Sabellaria* spp. were also observed. Potential Annex I features are described in more detail in section 3.4.

A total of 39 taxa were identified. The most common fauna identified included hydroids, such as *Hydrallmania falcata* and *Sertularia* sp. (*argentea* / *cupressina*), encrusting fauna including sponges, bryozoans and serpulid worms, the bryozoan *A. diaphanum*, the ascidian *D. grossularia*, the anemone *Urticina* sp. and the common starfish *Asterias rubens*.

Table 3.1: Summary of the observed broad habitat types, biotope complexes and biotopes observed during analysis of the Allonby Bay pMCZ video data.

Line	Line summary	Biotope(s) Observed	Assessment of 'Reefiness'
AL_02	Sublittoral mixed sediment (pebbles and shell on muddy sand) with sparse epifauna	**SS.SMx**	No potential reef features observed
AL_03	Sublittoral mixed sediment (pebbles and shell on muddy sand) with sparse hydroids	**SS.SMx**	No potential reef features observed
AL_06	Sublittoral mixed sediment and muddy sand	**SS.SSa.IMuSa** **SS.SMx**	No potential reef features observed
AL_08	Cobbles and pebbles on shelly sand with encrusting sponges	**SS.SCS**	Low resemblance to a stony reef
AL_09	Mosaic of cobbles and pebbles embedded / lying upon muddy sand with sparse faunal turf with small patches of *Sabellaria alveolata*	**SS.SMx** **SS.SBR.PoR.SalvMx**	Medium resemblance to a stony reef; single patch of potential biogenic reef observed
AL_10	Mosaic of cobbles and pebbles embedded / lying upon muddy sand with patchy aggregations of *Dendrodoa grossularia* and encrusting sponges	**CR.MCR** **SS.SSa.IMuSa** **SS.SMx**	Low - medium resemblance to a stony reef (final four clips only)
AL_14	Matrix of ?*Sabellaria* sp. tubes, sand and gravel with barnacles and *Dendrodoa grossularia*; with single patch of *Sabellaria alveolata*	**CR.MCR.CSab.Sspi.ByB** **SS.SMx** **SS.SBR.PoR.SalvMx**	Low resemblance to a stony reef; single patch of potential biogenic reef observed
AL_15	Sublittoral mixed sediment (pebbles and shell on muddy sand) with *Asterias rubens* and *Sertularia* sp.	**SS.SMx**	No potential reef features observed
AL_17	Sublittoral mixed sediment (pebbles and shell on muddy sand) with sparse fauna	**SS.SMx**	No potential reef features observed
AL_18	Rippled shelly sand and occasional cobbles with hydroids and *Alcyonidium diaphanum*	**SS.SCS** **SS.SSa**	Low resemblance to a stony reef (final three clips only)

AL_19	Rippled muddy sand and shell	**SS.SSa.IMuSa**	No potential reef features observed
AL_20	Mixed sediment and cobbles and boulders with *Dendrodoa grossularia* and encrusting sponges	**CR.MCR** **SS.SCS** **SS.SMx**	Medium to high resemblance to a stony reef

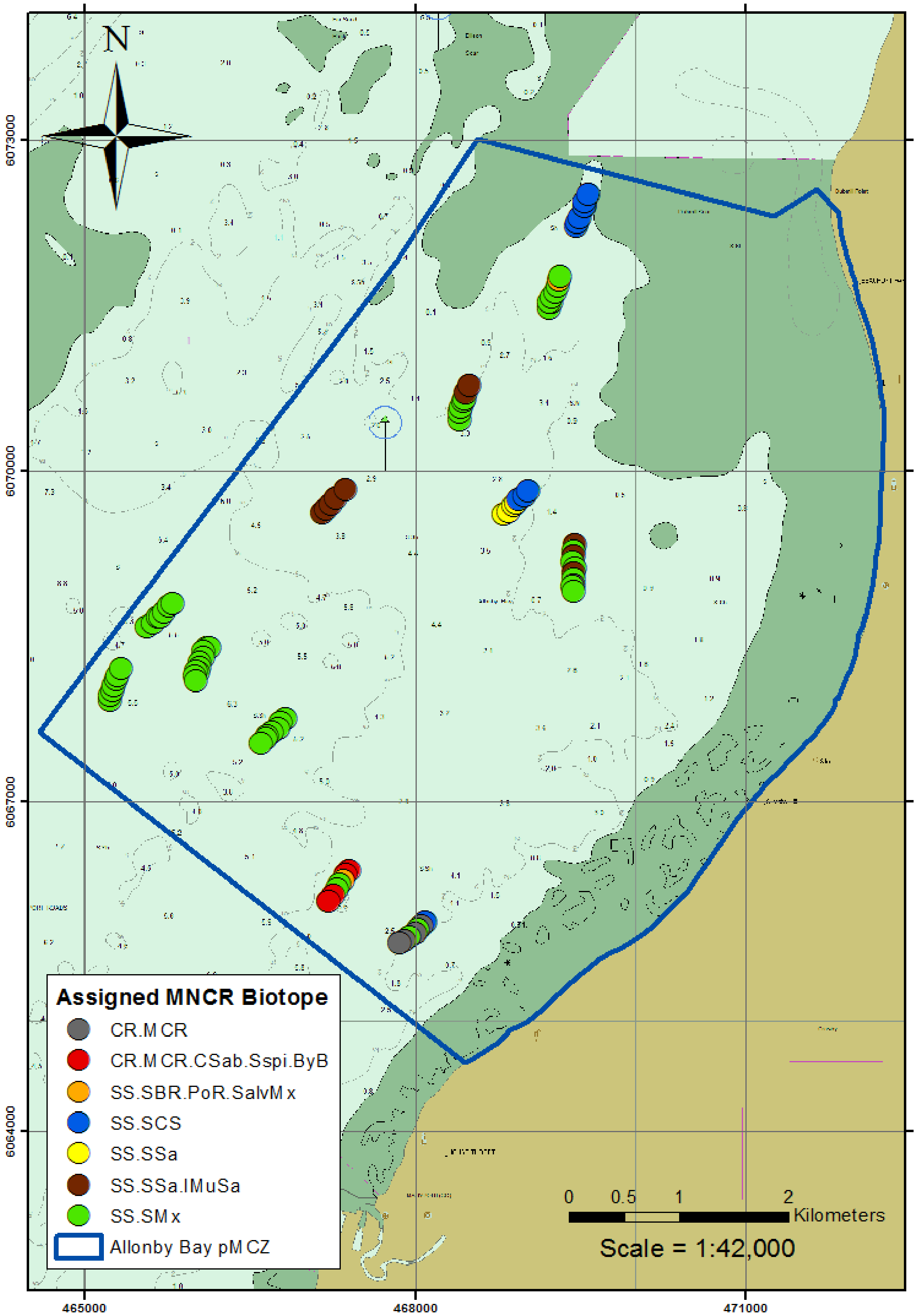


Figure 3.7: Distribution of observed MNCR biotopes (Connor *et al.*, 2004) in the Allonby Bay pMCZ. Each data point represents a single video clip.

3.3.2 Solway Firth SAC

The survey area within the Solway Firth SAC was found to be generally characterised by sands and muddy sands with a smaller fraction of coarse material, usually shell or pebbles. A total of eight broad habitat types, biotope complexes and biotopes were identified. The details of the biotopes and biotope complexes observed are given in Table 3.2 and Figure 3.8.

As with the Allonby Bay survey, several biotope assignments have been left at the 'broad habitat type' level, again due to a lack of infaunal information but often also due to the poor visibility experienced compared to Allonby Bay. This was particularly true for data collected in Phase III of the survey; only 10 of the 51 transects attempted yielded usable data. As underwater visibility during the survey was noticeably better over areas of cobbles and boulders, it may be possible to infer that where exceptionally poor visibility was experienced the substratum was likely to be mud or sand. With additional acoustic or ground-truthing data (e.g. sidescan sonar, grabs etc.), this assumption could be made with a reasonable level of confidence. However, as no such data were available at the time of writing, this inference was deemed inappropriate.

The assignment of mixed sediment and sandy or muddy biotopes was based on the assessment of the person undertaking the analysis. Without supporting data from sediment sample analysis there can be some uncertainty in the assessment of the quantities of sand and mud present. As a result some biotopes may be subject to change.

The survey area was found to be dominated by sands and muddy sands. The most commonly identified broad habitat type was **SS.SSa** (sublittoral sands and muddy sands) though coarse and mixed sediments (**SS.SCS**, sublittoral coarse sediment and **SS.SMx**, sublittoral mixed sediment respectively) were also observed. The soft sediments observed were generally species poor, with only mobile macrofauna such as swimming crabs (Portunoidea), shrimp (Caridea) and seastars such as *Asterias rubens* recorded.

No bedrock was recorded during the survey, however areas of cobbles were observed on three lines (STNs 01, 04 and 39). Fauna was very sparse even on hard substrata, with patchy faunal turf and sponges recorded. Due to the paucity of fauna, areas of cobbles were most frequently recorded either as **SS.SCS.CCS** or **SS.SMx.CMx** depending on the substrata present, although the biotope complex **CR.HCR.XFa** (mixed faunal turf communities) was identified on two lines; on line STN_39 the ascidian *Molgula* sp. was tentatively identified and the biotope **CR.HCR.XFa.Mol** (*Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock) was recorded. Another feature of interest recorded at STN_39 was a dense aggregation of the tube-forming amphipod

Ampelisca spp. in muddy sediment. The biotope **SS.SMu.ISaMu.AmpPlon** (*Ampelisca* spp., *Photis longicaudata* and other tube-building amphipods and polychaetes in infralittoral sandy mud) was recorded.

A total of 22 taxa were identified. The most common fauna identified included indeterminate hydroid turf, encrusting sponges and the common starfish *A. rubens*. On line STN_32 the mussel *Mytilus edulis* was recorded as abundant on every video clip. There was very little other epifauna observed on this line, limited to sparse indeterminate hydroids and barnacles. The biotope **SS.SBR.SMus.MytSS** (*Mytilus edulis* beds on sublittoral sediment) was therefore recorded.

Table 3.2: Summary of the observed broad habitat types, biotope complexes and biotopes observed during analysis of the Solway Firth SAC video data. Note that those transects which did not yield any usable data (41 stations / 139 seabed contacts total) are not detailed here.

Line	Line summary	Biotope(s) Observed	Assessment of 'Reefiness'
STN_01	Cobbles embedded in / lying on muddy sand	**SS.SCS SS.SSa SS.SMx.CMx**	Low resemblance to a stony reef
STN_03	Shelly sand	**SS.SSa**	No potential reef features observed
STN_04	Pebbles, gravel and shell on sand; *with* cobbles on sand with sparse fauna	**CR.HCR.XFa SS.SCS SS.SSa**	Medium to high resemblance to a stony reef in latter half of line
STN_05	Muddy shelly sand	**SS.SSa.IMuSa**	No potential reef features observed
STN_11	Muddy shelly sand	**SS.SSa.IMuSa**	No potential reef features observed
STN_15	Muddy shelly sand	**SS.SSa.IMuSa**	No potential reef features observed
STN_25	Muddy sand with sparse pebbles	**SS.SSa.IMuSa**	No potential reef features observed
STN_32	*Mytilus edulis* bed with sparse associated fauna	**SS.SBR.SMus.MytSS**	Potential biogenic reef
STN_39	Cobbles and pebbles on muddy sediment with patchy faunal turf; *with Ampelisca* tubes in muddy sediment	**CR.HCR.XFa.Mol SS.SCS SS.SMu.ISaMu.AmpPlon SS.SMx.CMx**	Low resemblance to a stony reef / not a reef (cobbles observed on two clips only) but potential scar ground
STN_45	Slightly rippled sand	**SS.SSa**	No potential reef features observed

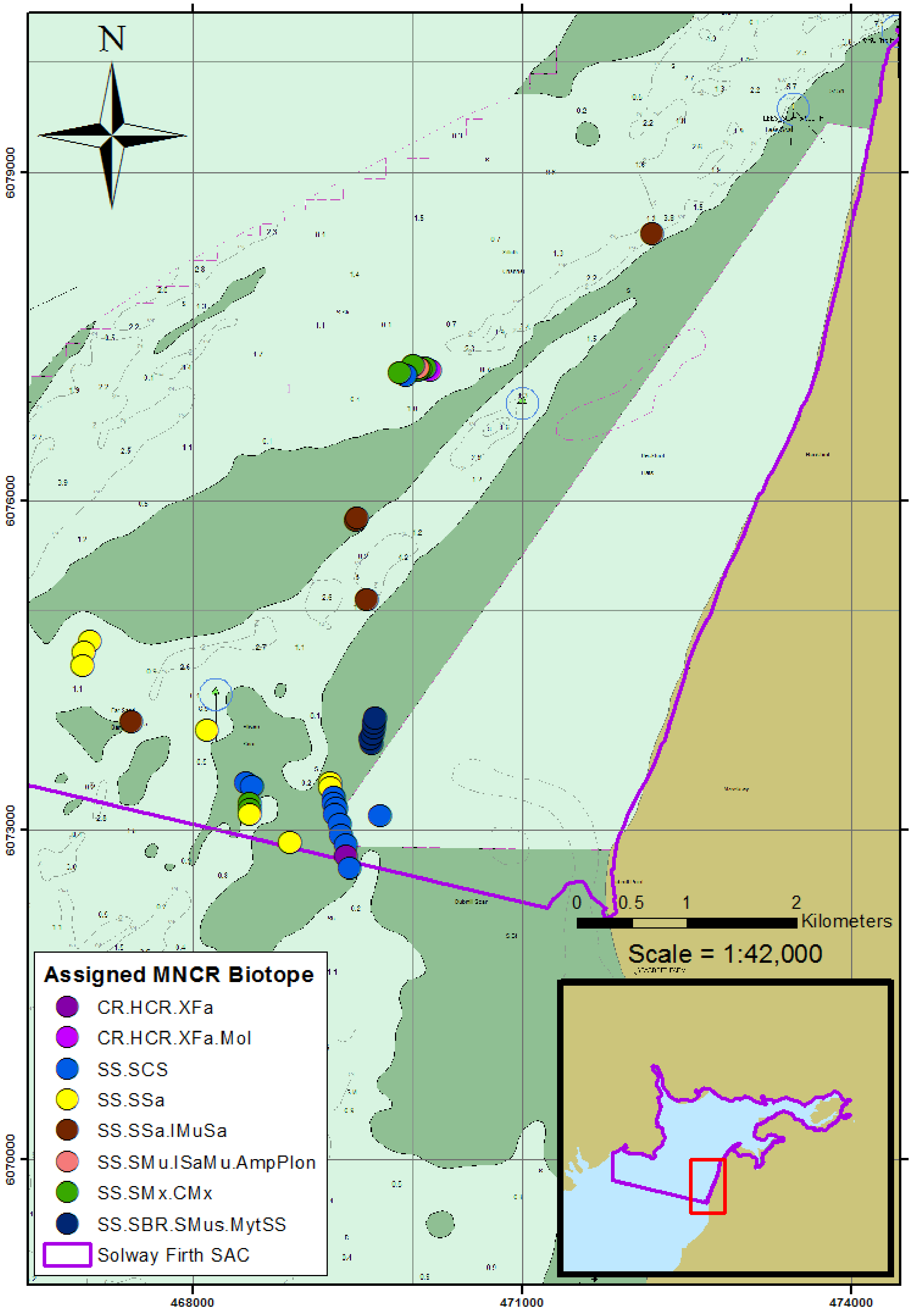


Figure 3.8: Distribution of observed MNCR biotopes (Connor *et al.*, 2004) in the Solway Firth SAC. Each data point represents a single viable video clip.

3.4 Annex I reef features

Figure 3.9 and Figure 3.10 illustrate the distribution of observed potential Annex I reef features in the Allonby Bay pMCZ and the Solway Firth SAC survey area respectively. All potential stony reef features observed consisted of areas of cobbles and boulders on otherwise soft sediment, i.e. rocky scar ground. Potential biogenic reef was observed in both survey areas, with *Sabellaria alveolata* observed in the Allonby Bay and *Mytilus edulis* observed just west of Beckfoot Flats, north of Dubmill Point.

3.4.1 Sabellaria spp. reefs

No *Sabellaria alveolata* or *S. spinulosa* were observed in the Solway Firth survey area, however, in the Allonby Bay pMCZ survey area *S. alveolata* was observed in a total of three video clips, all on different lines. On line AL_18 *S. alveolata* was recorded at very low abundances, however patches observed on lines AL_09 and AL_14 were much larger (Figure 3.11), and were deemed sufficient to assign the biotope **SS.SBR.PoR.SalvMx** (*Sabellaria alveolata* on variable salinity sublittoral mixed sediment) to the video clips.

Sabellaria spinulosa was observed on line AL_14. However, most of the records of this species from this line are due to the presence of high numbers of apparently broken tubes rather than crusts or aggregations of living animals; it is not certain whether these broken tubes are in fact *S. spinulosa*, and were recorded simply as *Sabellaria* sp.. Crusts of *S. spinulosa* were observed, however these were only recorded at very low abundances. The sediments on this line were predominantly a matrix of *Sabellaria* tubes, sand and gravel, with high abundances of *Austrominius modestus* and other barnacles, bryozoans and *Dendrodoa grossularia* (Figure 3.12). No exact biotope match could be found for the community and habitat described, however in order to flag the presence of *Sabellaria* spp. and due to the other species recorded, the biotope **CR.MCR.CSab.Sspi.ByB** (*Sabellaria spinulosa* with a bryozoan turf and barnacles on silty turbid circalittoral rock and mixed substrata) was tentatively assigned.

The simplest definition of *S. spinulosa* reef, as given by Gubbay (2007), is “an area of *S. spinulosa* which is elevated from the seabed and has a large spatial extent.” Using the criteria outlined in Table 2.2 the ‘reefiness’ of aggregations of *Sabellaria* spp. were assessed. It is unlikely that any of the *S. spinulosa* aggregations observed in this survey constitute a reef, primarily due to the apparent low extent, but also to the low percentage cover and low elevation. The patches of *S. alveolata* observed were significantly greater in terms of percentage cover (low – medium) and elevation (medium), however due to the nature of the sampling methodology employed, extent is difficult to estimate. As *S. alveolata* aggregations were only observed on one seabed contact per line, however, it can be assumed that extent is less than 10,000 m^2. It is therefore possible that the areas of *S. alveolata* recorded constitute a biogenic reefs of low 'reefiness.'

3.4.2 Mytilus edulis beds

The mussel *Mytilus edulis* was observed on only one line; STN_32 in the Solway Firth just west of Beckfoot Flats, north of Dubmill Point. The observed mussels were recorded as 'abundant' throughout the line and appeared in good condition (Figure 3.13).

3.4.3 Rocky scar ground communities

Rocky scar ground was observed on 7 of the 12 achieved transects in Allonby Bay, and 3 transects in the Solway Firth SAC survey area, though areas of sparse pebbles on soft sediment were more widespread.

On two lines in Allonby Bay (AL_17 and AL_14), cobbles were only observed on a single video clip. Boulders were observed predominantly on line AL_20, while lines AL_08, AL_09 and AL_10 were characterised by a mosaic of cobbles and pebbles lying on muddy sand. Line AL_18 was similar, but cobbles were less frequent. On line STN_39 in the Solway Firth survey area, cobbles were observed on just two video clips at low densities, though pebbles were common throughout the line. Lines STN_01 and STN_04 were found to be characterised by a higher percentage of cobbles, with the substrata at STN_04, west of Dubmill Scar, composed of up to 95 % cobble. Example images of observed rocky scar ground are given in Figure 3.14.

Fauna on areas of rocky scar ground was relatively sparse, generally featuring robust, scour-tolerant species such as hydroids and *Alcyonidium diaphanum*. Line AL_08 and STN_04 (which were both located relatively close together west of Dubmill Point), however, were characterised by high coverage by an unidentified sulphur-yellow encrusting sponge, while lines AL_20 and AL_10 were more species rich and featured aggregations of the ascidian *Dendrodoa grossularia*.

Video clips containing cobbles and boulders were analysed to ascertain whether these areas constituted potential rocky reefs, using the assessment criteria set out by Irving (2009) (see Table 2.1). Due to the nature of sampling, extent of each rocky scar ground was difficult to determine, however the characteristics of "composition" – i.e. percentage cover of cobbles and boulders – and "elevation" were used to assess 'reefiness.' Most areas of rocky scar ground were determined to be of low resemblance to a stony reef, with low (<40 %) coverage (Figure 3.15) and elevation however at some lines, notably STN_04, AL_09 and AL_20, large cobbles and boulders were more common, and clips were assigned medium 'reefiness' (Figure 3.16).

The areas of rocky scar ground delineated in the habitat mapping process are shown in Figure 3.17. Areas of rocky scar ground were concentrated primarily west of Dubmill Point and around Dubmill Scar (STN_01; STN_04; AL_08 and AL_09), with cobbles and boulders making up to 95 % of the observed substrata. Other areas of rocky scar ground were mapped in the centre of Allonby Bay (AL_18 and AL_10) and in the south of the bay (AL_20).

While cobbles were observed at STN_39, this area has not been designated as rocky scar ground. This is primarily due to the sparse / patchy nature of the hard substrata observed at this station, with cobbles observed on just two of the achieved video clips and at low densities (~15 % coverage). Similarly, while cobbles were observed in the area in the west of the Allonby Bay pMCZ at Maryport Roads (transects AL_02, AL_15 and AL_17), these were recorded at very low densities (generally < 15 % coverage) on just 3 of the 31 video clips achieved in this area.

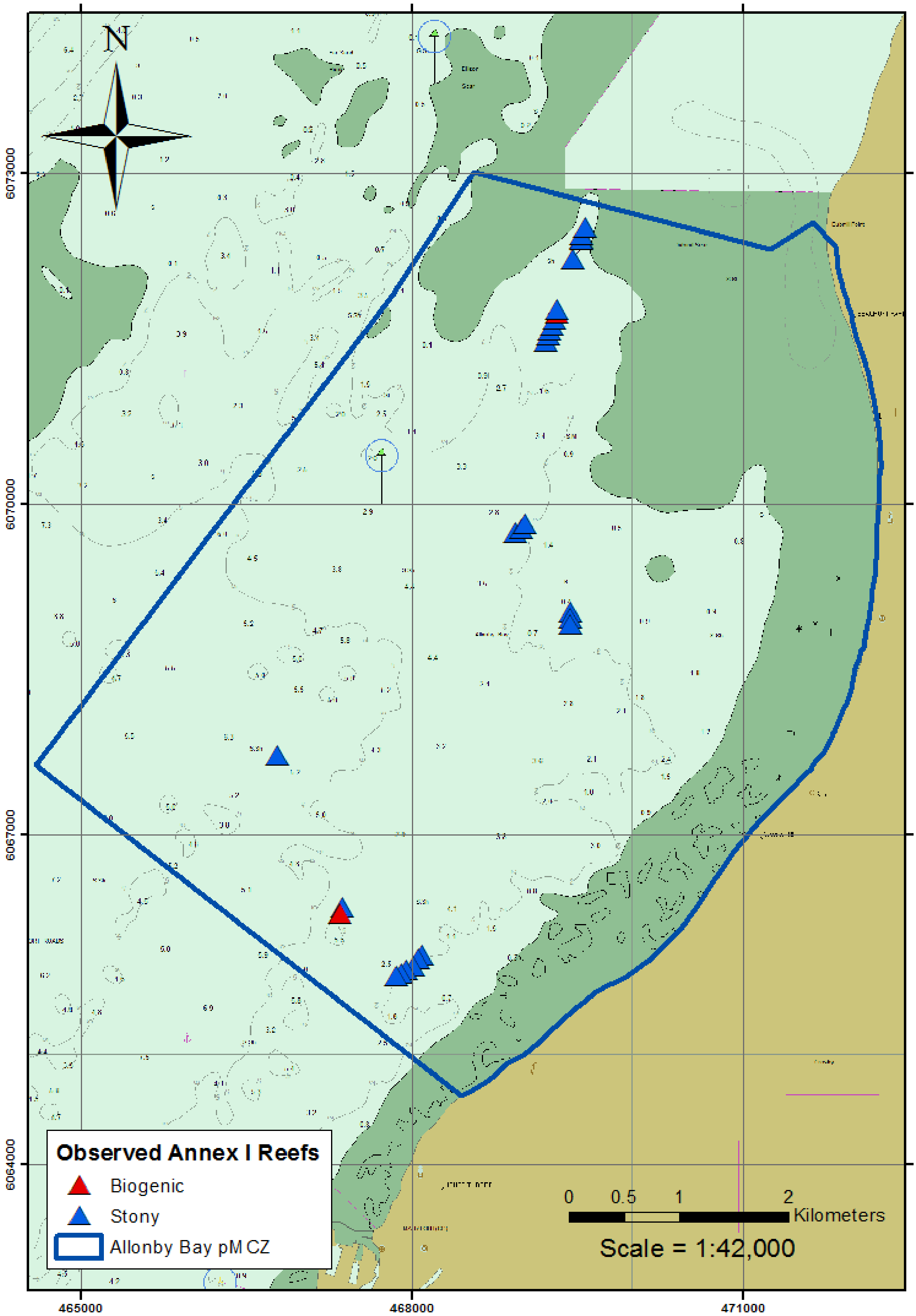


Figure 3.9: Distribution of observed potential Annex I reef features in the Allonby Bay pMCZ.

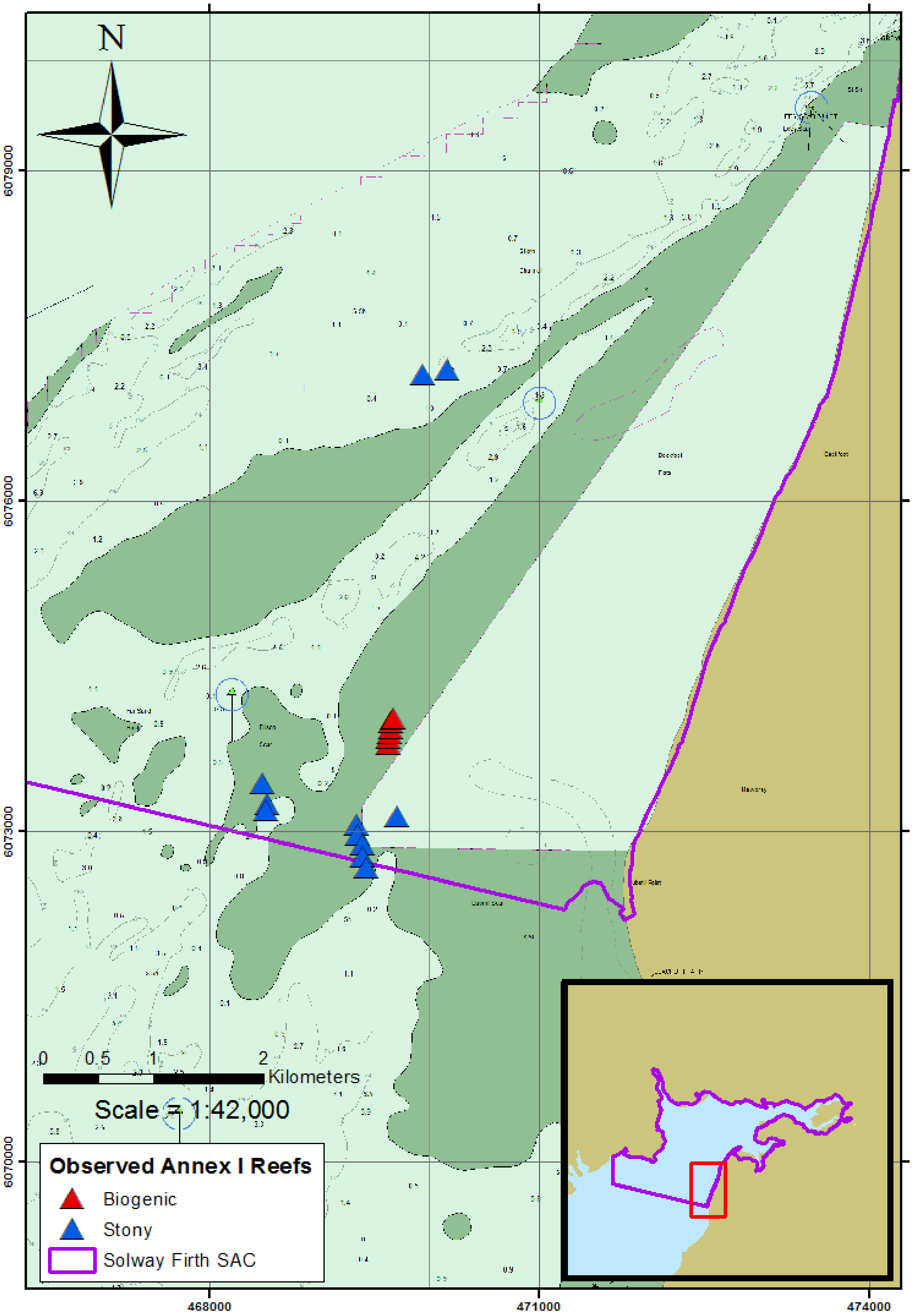


Figure 3.10: Distribution of observed potential Annex I reef features in the Solway Firth SAC survey area.

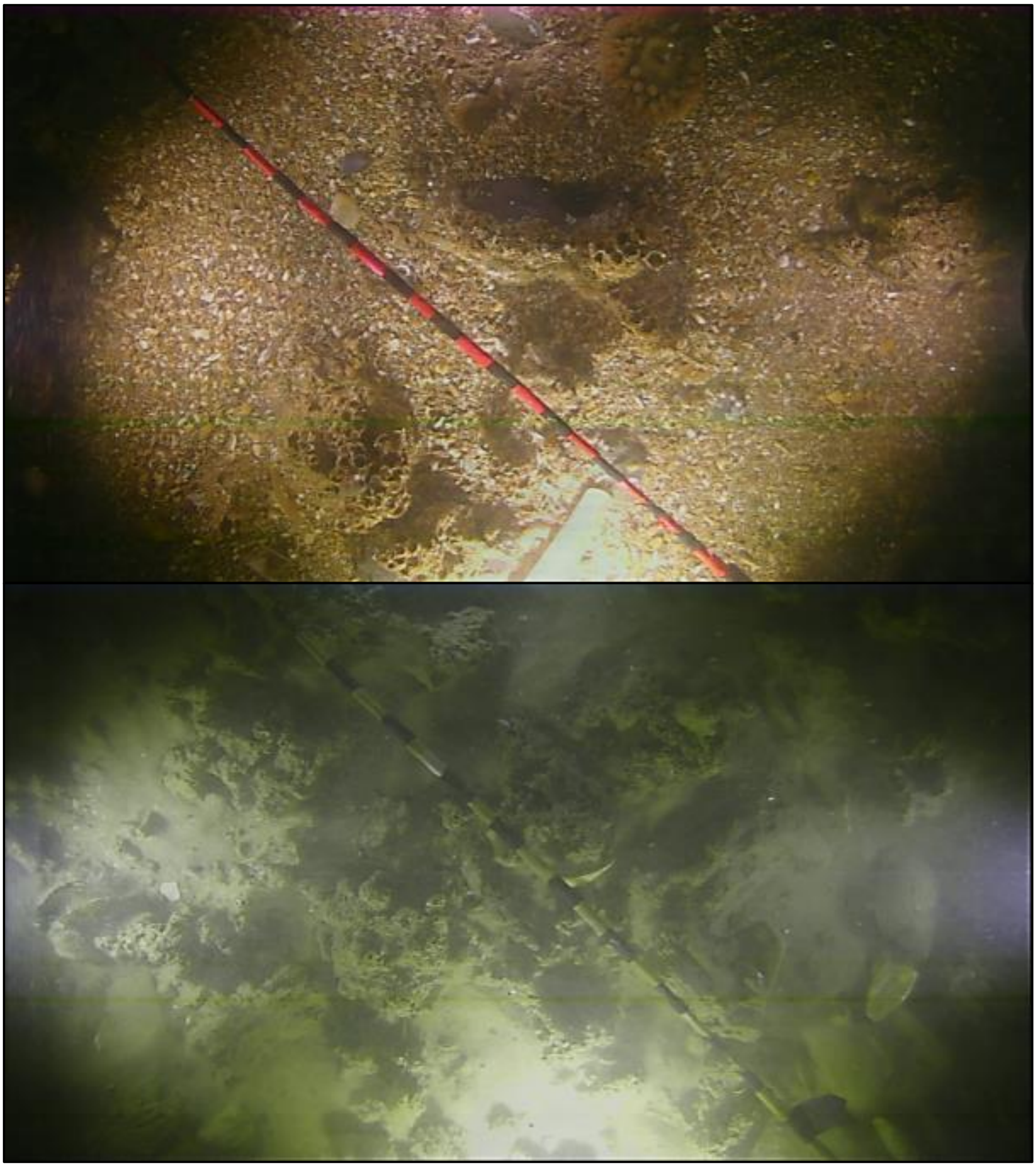


Figure 3.11: Screenshots of video footage captured at (a) line AL_14 (sample 412_009#01_03) and (b) AL_09 (sample 412_002#01_07) showing subtidal *Sabellaria alveolata* aggregations (scale bar in increments of 2 cm).

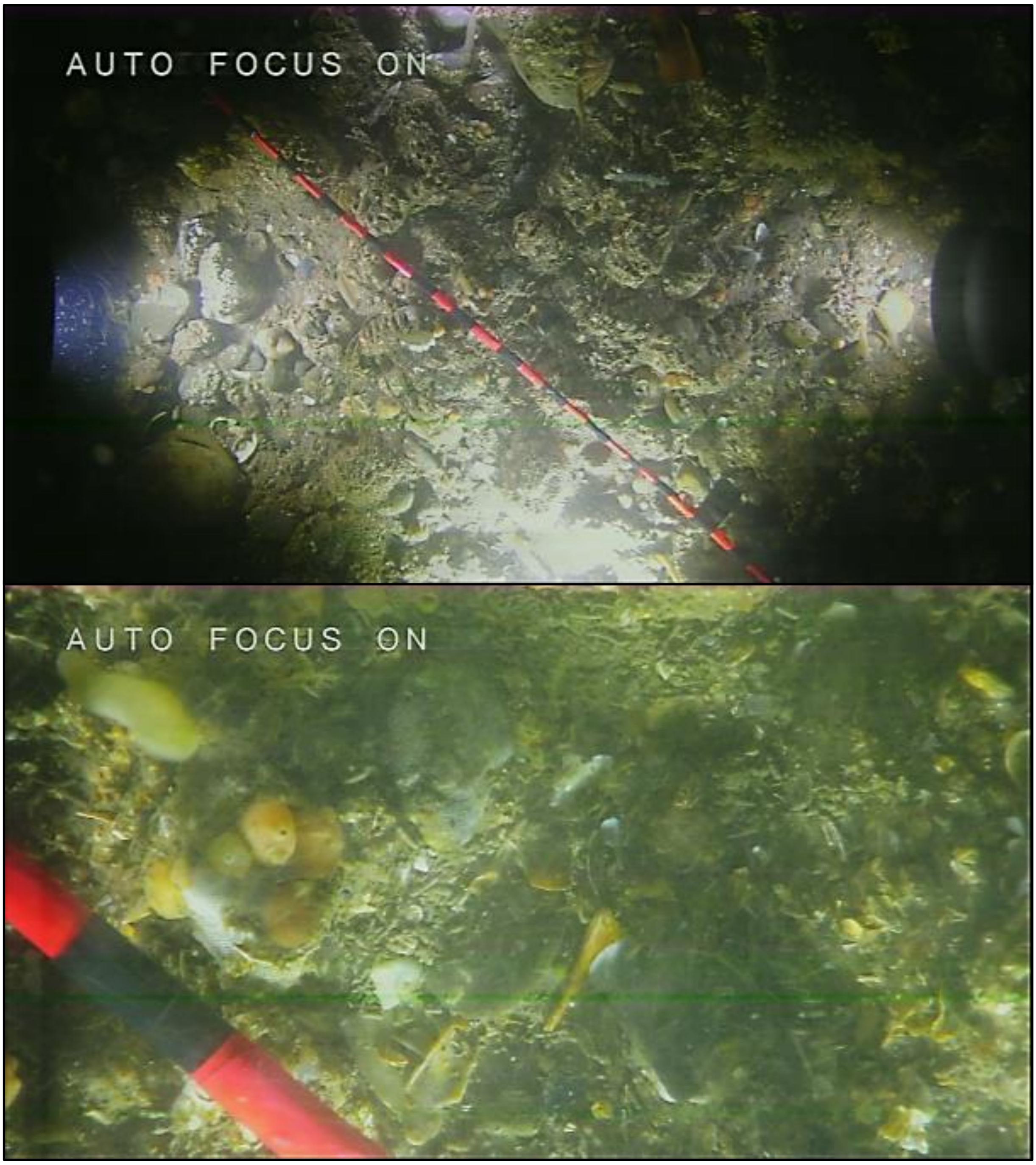


Figure 3.12: Screenshots of video footage captured at line AL_14 (sample 412_009#01_02) showing matrix of *Sabellaria* sp. tubes, shell, gravel and pebbles (top = full field of view; bottom = full zoom whilst camera landed. Scale bar in increments of 2 cm).

Figure 3.13: Screenshots of video footage captured at line STN_32 in the Solway Firth SAC survey area (sample 412_037#01_02) showing *Mytilus edulis* bed (top = full field of view; bottom = full zoom whilst camera landed. Scale bar in increments of 2 cm).

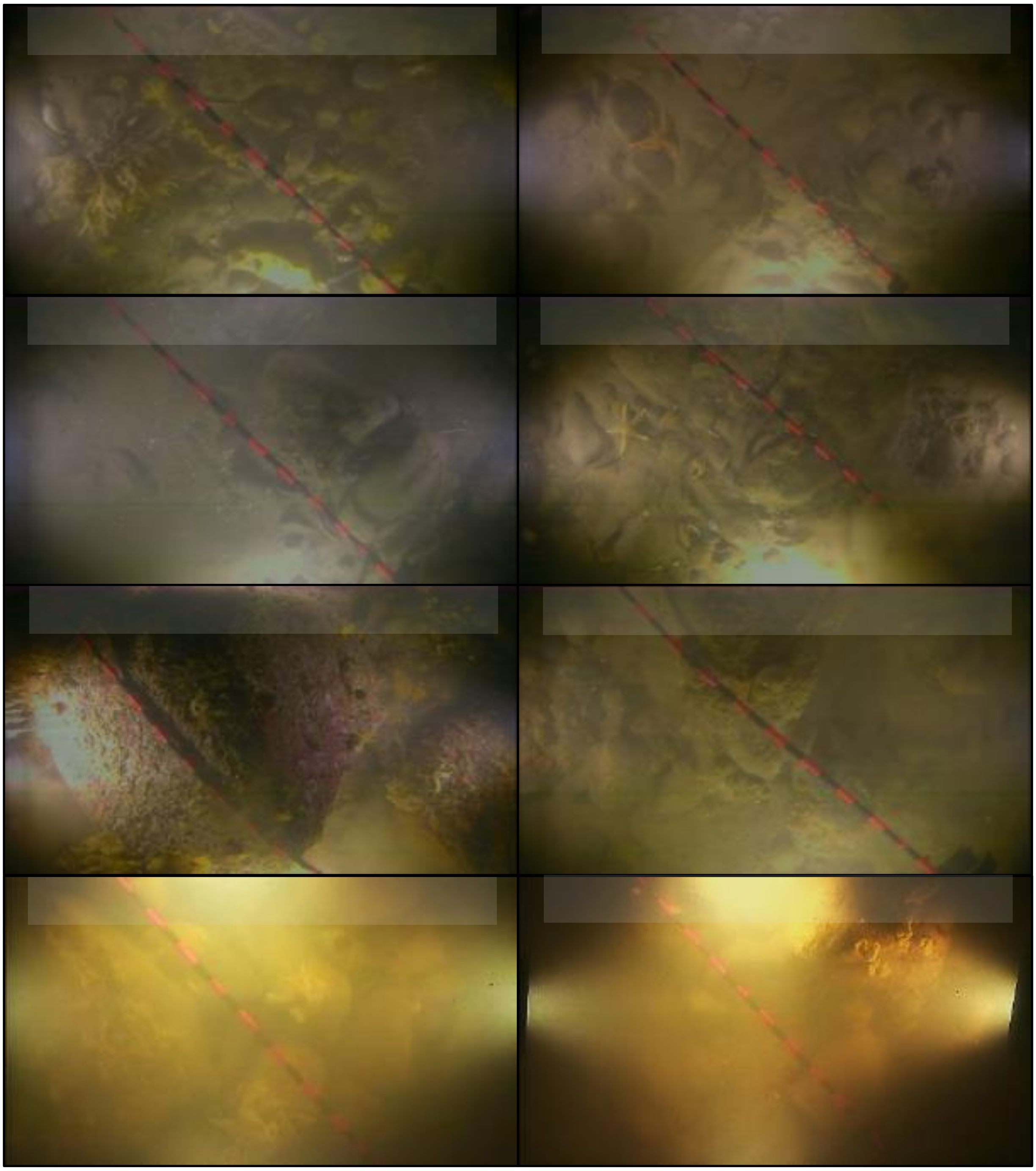


Figure 3.14: Example images of rocky scar ground observed in the Allonby Bay pMCZ and Solway Firth SAC survey areas; (a) *Flustra foliacea* and unidentified encrusting sponge on cobbles and pebbles; (b) cobbles and pebbles on muddy sand with sparse fauna; (c) cobbles on shelly sand with hydroids and *Alcyonidium diaphanum*; (d) cobbles and pebbles on muddy sand with sparse fauna; (e) *Flustra foliacea*, *Dendrodoa grossularia* and encrusting red algae on boulders; (f) cobbles on mixed sediment with *Alcyonidium diaphanum* and *Dendrodoa*

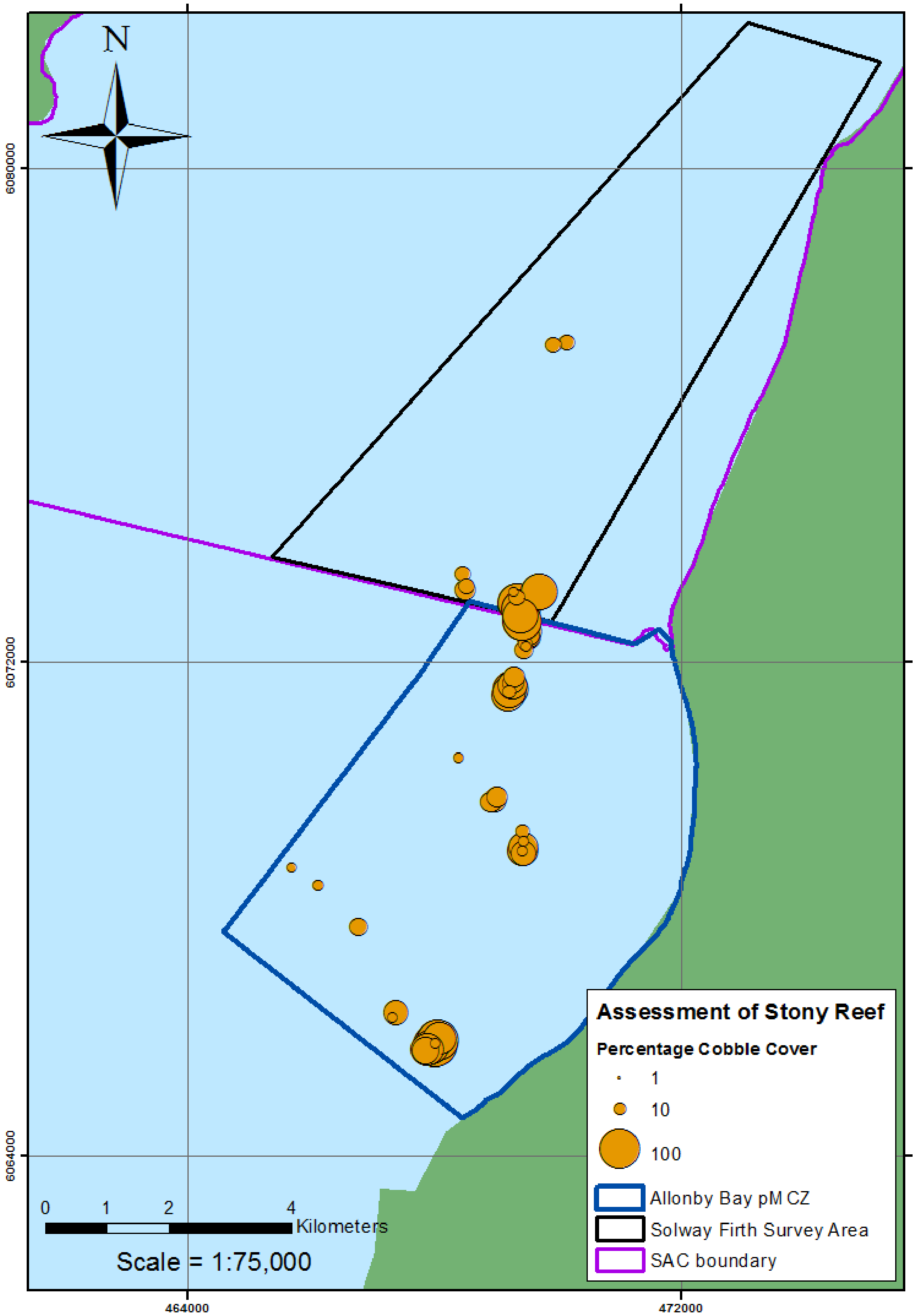


Figure 3.15: Percentage cover of cobbles and boulders observed in each video clip captured in the Allonby Bay pMCZ and Solway Firth SAC survey areas.

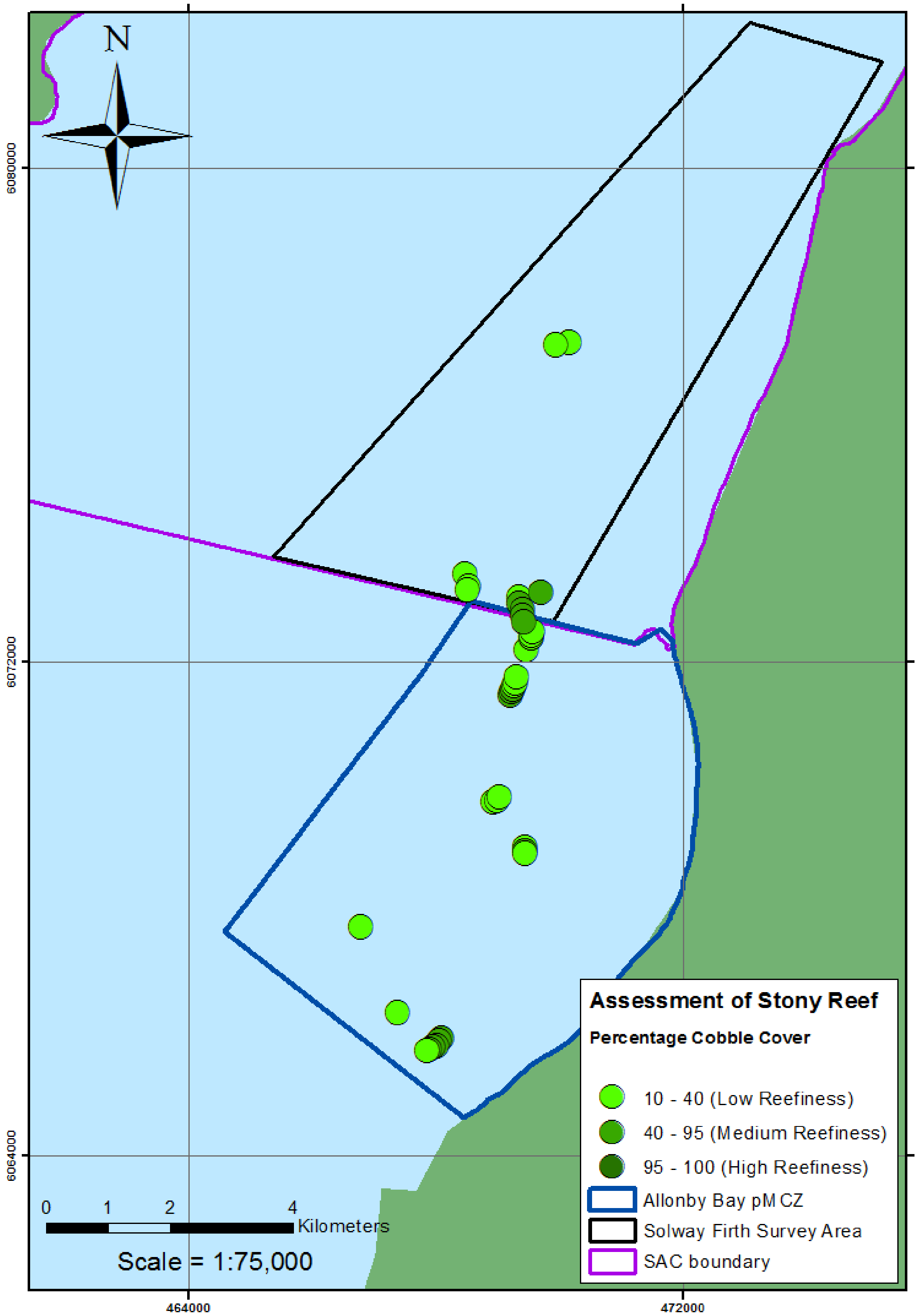


Figure 3.16: Assessment of rocky scar ground observed in the Allonby Bay pMCZ and Solway Firth SAC survey areas, showing resemblance to a potential stony reef as according to Irving (2009).

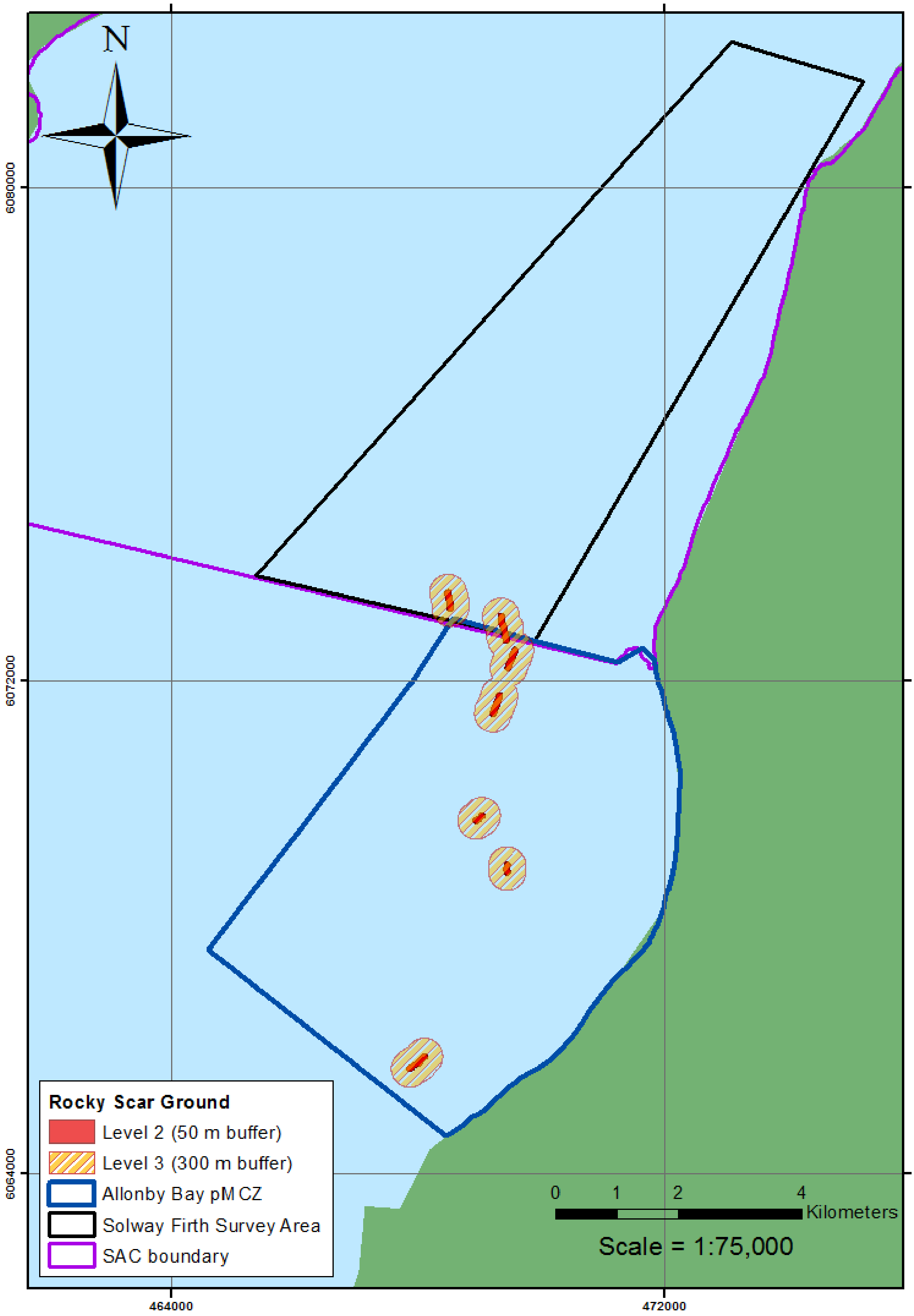


Figure 3.17: The distribution of confidence level 2 and 3 (50 m and 300 m radius ellipsoids) rocky scar ground habitats throughout the Allonby Bay pMCZ and Solway Firth SAC survey areas.

4 Discussion

4.1 Survey methodology

The use of an integrated approach to study an area of seabed has been shown to be successful in many studies (e.g. Bett and Masson, 1998; Axelsson, 2003; Masson *et al.*, 2003; Brown *et al.*, 2004; Axelsson *et al.*, 2006; O'Dell *et al.*, 2013). The use of underwater video data in surveys has been shown to be cost-effective with large areas being covered in a relatively short time (Brown *et al.*, 2004; Stevens and Connolly, 2005). A number of studies have concluded that video data are appropriate for the assessment of the presence and extent of biotopes (Service and Golding, 2001) as well as ground-truthing of acoustic images (Brown *et al.*, 2002; Brown *et al.*, 2004). There is, however, some loss in taxonomic resolution when using photography rather than biological sampling techniques (e.g. Stevens and Connolly, 2005) and some video records are not of a sufficient quality to allow biotope classifications to be carried out. Still photography and sediment sampling should be carried out simultaneously to supply meaningful data (Hiscock and Seeley, 2006) but in the current survey this was not possible due to the poor underwater visibility and to the focus of the survey being hard substrata, namely rocky scar ground and reef features.

Additional sampling effort is required in the survey areas in order to increase coverage, to improve understanding of the habitats and species and to improve the confidence in the maps illustrating the extent of the observed features. Ideally camera deployments and infaunal sampling should be carried out in conjunction with broad-scale acoustic techniques to allow very conspicuous changes in habitat distribution to become apparent. It is particularly recommended that sidescan sonar work be conducted in the survey areas in order to enable changes in sediment composition, including areas of rocky scar ground, to be readily identified. Any further camera work should be conducted during and following periods of calm weather conditions and during neap tides so that poor underwater visibility does not hamper survey effort.

4.2 Survey limitations

The survey methodology and equipment employed were selected specifically to allow for collection of high quality data in very strong tidal conditions and limited underwater visibility. Despite this, the poor visibility encountered hampered species identification.

The major limitation is the lack of continuous seabed footage over the proposed transects. Due to the very poor visibility in the Solway Firth survey area the camera had to be within a maximum of 10 cm of the seabed in order for seabed features to be visible. Flying the camera frame at this height above the seabed proved to be impossible. Furthermore, data acquired using such a method would be of little use. The decision was therefore taken to modify the methodology to focus on the landing of the camera frame on the seabed, allowing over a minute of seabed time to be recorded at a series of separate locations, approximately 50 m apart, along each transect. This was a time-consuming process and as such it was only feasible to have a maximum of 10 landings per transect in order to keep total transect time under 30 minutes in duration. In addition, this methodology has made estimates of extent of seabed features more problematic.

4.2.1 Weather conditions

Both survey areas are very susceptible to north-westerly, westerly and south-westerly winds and swells. The area was deemed unworkable in such winds of Force 4 or greater, or a significant wave height of greater than 0.5 m. The Met Office Inshore Waters Forecast was used to monitor weather forecasts and the decision to work was based on these forecasts. In addition, current speeds at times of peak tidal flow were found to disrupt vessel positioning to the point where it was deemed dangerous to deploy the freshwater camera system.

Bad weather experienced on the 17th October 2014 and prior to the second mobilisation likely affected the quality of data collected on those days (i.e. lines AL_10 and AL_06); visibility was notably worse on these lines than for data collected previously.

During Phase II, where survey operations were primarily targeted towards the Solway Firth SAC area, weather conditions were variable, with both the 22nd and 24th of November 2014 deemed unworkable due to weather. During Phase III only one weather day was taken as conditions were stable and suitable for work for the majority of the survey period.

4.2.2 Underwater visibility

Significant issues with visibility were experienced during the survey of the Solway Firth SAC. Despite the use of a specialised camera system visibility was frequently too poor (<5 cm) to capture clear imagery. Peak tidal flows in the area reached over 3.7 knots, entraining large quantities of fine sediment into the lower water column. The camera system was not deployed during peak flows for practical reasons, however the sediment remained suspended outside of peak flow times, significantly reducing underwater visibility.

Better underwater visibility was experienced under high water slack conditions and over areas of cobbles and pebbles. This is attributed to a number of factors including; the relatively clear water brought into the area by a flooding tide; low currents at slack water reducing entrainment of sediment into the water column; and the presence of less fine sediment to be disturbed when landing the camera frame.

As a result of this frequent poor visibility the decision was taken to apply the protocol requested by the client for skipping planned drops over areas without hard substrata to those transects where visibility was insufficient to gather suitable quality data.

Poor underwater visibility conditions were most prevalent during the third phase of the survey; poor weather in the week prior to Phase III (winds of up to 44 knots and large amounts of rainfall) and a spring tidal regime during the survey period created significantly reduced underwater visibility conditions compared to what had previously been experienced in the area. These conditions were, however, unavoidable due to time and weather constraints.

4.2.3 Survey extent and coverage

Not all planned transects were completed. In Allonby Bay, only 12 of the 21 proposed transects were completed. This was due to time constraints (only two days were available for the survey work in Allonby Bay) and to the poor weather experienced on 17th October 2014, which meant that few transects could be completed on that day, hampering attempts to obtain good coverage of the survey area. Despite this, the main areas of interest specified by the client prior to survey planning were covered, i.e. the northern part of the site including the expected scar grounds south of Dubmill Point; the southwest region of the site near Maryport Roads; and where rocky scar grounds had been previously identified in the middle of the pMCZ.

In the Solway Firth survey area, all 47 planned transects were attempted, with an additional 3 lines added in potential areas of interest. However the conditions experienced, particularly during Phase III, did not allow for full completion of a large number of these lines (see Figure 3.3 for details). Underwater visibility during the survey was noticeably better over areas of cobbles and boulders, than other potential substratum.

4.3 Confidence assessment

In this study, attempts have been made to minimise interpolation of the data as much as possible. However, as with many similar studies ground-truth coverage is not as extensive as might be desired. In order to illustrate the quality and interpretation of the data, confidence ratings have been assigned to the habitat maps.

The confidence in the level of certainty of the interpretation of the seabed environment at point source (i.e. a single video clip) is estimated at >90 % accurate (level 1). Confidence level 2 (areas immediately surrounding point source data) have been assigned with 70 – 80 % confidence. Level 2 rocky scar ground polygons were generated by extending a 50 m radius from any point source at which the seabed was shown to be composed of greater than 10 % cobbles, or from seabed contacts at which cobble coverage was recorded as <10 % but which were located within 50 m of a contact at which >50 % cobble coverage was recorded.

With acoustic data available, confidence level three would constitute areas with the same level of e.g. backscatter as point source data at distances greater than 50 m. For the purposes of this study, level three polygons have been delineated by extending areas of level two polygons by a further 250 m (i.e. 300 m from point source), however have been assigned a low level of confidence (<50 %). In addition to the lack of acoustic data, the reason for this relatively low confidence is the heterogeneity of the seabed observed in the survey areas; there was a high level of variability in the substrata within and between transects.

Underwater video photography has been demonstrated to be appropriate for the assessment of the presence and extent of marine biotopes, however the quality of the data and biotope recorded from video tapes relies heavily on the identification skills of the person scoring the tapes (Holt *et al.*, 2001). The classification of biotopes is also somewhat subjective and not all seabed environments 'fit' the biotope classification scheme resulting in some biotopes being classified to 'best fit' the communities present (Holt *et al.*, 2001). For example, no exact biotope match was found for the areas of cobbles and boulders observed on lines AL_10 and AL_20. The fauna present included sparse hydroid and bryozoan turf, encrusting sponges, barnacles and the ascidian *Dendrodoa grossularia*, however the broad habitat type **CR.MCR** (moderate energy circalittoral rock) was recorded. While this best describes the substratum present, it does not reflect the faunal community observed. Similarly, the matrix of tentatively identified *Sabellaria* sp. tubes, sand and gravel with barnacles and *D. grossularia* observed on line AL_14 was assigned the biotope **CR.MCR.CSab.Sspi.ByB** (*Sabellaria spinulosa* with a bryozoan turf and barnacles on silty turbid circalittoral rock), despite the lack of both rock and large quantities of *S. spinulosa*. This biotope was primarily selected in order to flag the presence of *Sabellaria* sp. and due to the presence of *Austrominius modestus*, other barnacles and bryozoans.

4.4 Comparisons with previous studies

The usefulness of comparisons with previous studies is limited by various factors. For example, the methods employed and the distributions of sampling points are not the same between surveys. Furthermore, the quality of the data obtained (e.g. quality of video recording) varies between studies, as does the compatibility of the biotopes listed in Connor *et al.* (2004). As such any findings or trends from comparisons with previous surveys must be treated with caution. Such comparisons may however be useful in attempting to assess feature condition.

4.4.1 Distribution of soft sediment habitats and biotopes

There is very little published information, particularly concerning epifaunal communities, with regards to the sublittoral regions of the Solway Firth. The subtidal area within the Solway Firth has been described as being dominated by mobile sandy sediments brought into the area from the Irish Sea (Cutts and Hemingway, 1996; Cutts, Hemingway and Thomson, 2011; Barne *et al.*, 1996). The sediments form constantly shifting sandbanks separated by a number of channels, the latter of which play an important role in maintaining a sediment balance within the estuary (Cutts and Hemingway, 1996; Covey, 1998; Axelsson *et al.*, 2006).

Abundance and species diversity have both been reported to be low within the Solway Firth (Cutts and Hemingway, 1996; SFP, 1996; Covey, 1998; Allen, 2006; Axelsson *et al.*, 2006) and there have been reports of an increase in diversity with distance from the head of the estuary (Perkins and Williams, 1966; Perkins, 1968; Cutts and Hemingway, 1996). Likewise, in the present study the Solway Firth SAC survey area was found to be dominated by sands and muddy sands and areas of soft sediment were species poor, with only mobile macrofauna recorded.

The biotopes assigned in the present study show general agreement with previous work; Allen (2006) reported that the majority of subtidal broad habitat types observed fell into either **SS.SCS**, **SS.SSa** or **SS.SMx**. Although direct comparisons with the present work cannot be made due to differences in sampling techniques and areas surveyed, studies focusing on the infauna of the Solway Firth also report that the majority of observed biotopes fall into the **SS.SSa** broad habitat (Covey, 1998; Axelsson *et al.*, 2006). Surveys conducted prior to the first biotope classification scheme (Connor *et al.*, 1997) being published (e.g. Perkins, 1968; Cutts and Hemingway, 1996) show very similar faunal communities to those observed in later studies (Axelsson *et al.*, 2006), suggesting that there has been very little change in the type and distribution of soft sediment biotopes in the Solway Firth.

4.4.2 Distribution and extent of rocky scar ground and Annex I features

Areas of Annex I habitat mapped in the current study appear relatively limited, with rocky scar ground restricted to the area around Dubmill Point and the centre and very south of Allonby Bay. These areas are broadly similar to Zone C reported by Allen (2006). ‘Zone C’ was located offshore from Dubmill Point in the vicinity of Ellison Scar. This area was characterised by cobbles and pebbles on sandy sediment with variable quantities of *Sabellaria alveolata* and limited epifauna. The distribution and extent of scar ground around Dubmill Point located in the present study is approximately similar to that described by Allen (2006), however the current data indicate that this scar ground in composed not only of cobbles and pebbles but also boulders, while fauna is dominated by *Flustra foliacea* and encrusting sponges.

The area of rocky scar ground in the centre of Allonby Bay (transects AL_18 and AL_10) has not been previously reported, however Allen (2006) described an area inshore from Dubmill Point ('Zone B'), northwest of the area identified in the current study. 'Zone B' was investigated with a single transect in the current survey, however no evidence of scar ground was observed.

In the Solway Firth SAC survey area, north of Dubmill Point, Allen (2006) identified several areas of scar ground ('Zone D'), described as areas of highly silted cobbles and pebbles on fine sand with very limited epifauna. Cutts and Hemingway (1996) also reported scar ground in the Silloth Channel. Although several transects were attempted in this area in the present survey, data acquisition was considerably hampered by poor underwater visibility conditions. Indeed, this area was far more turbid than the rest of the survey area, something also reported by Allen (2006). It is possible that scar ground is still present in this area, however further survey work is required in order to confirm this. The degree of siltation observed in both this study and previously indicates that any scar present in this area is highly sediment-influenced, and is perhaps a transient feature, subject to periodic inundation by sediment as described by Perkins (1981; 1986).

Perhaps the most drastic change indicated by the current study is the lack of scar ground in the west of the Allonby Bay pMCZ. Rocky scar ground in the vicinity of Maryport Roads has been reported in a number previous studies (Perkins, 1968; English Nature, 1997; Cutts and Hemingway, 1996; Allen, 2006). This area was thoroughly investigated in the present study, however cobbles were only observed on 3 of the 31 video clips achieved in this area, and at low densities (< 10 – 15 % coverage). This was not deemed sufficient to constitute rocky scar ground.

4.4.2.1 Characteristic biotopes of rocky scar ground

Very few studies have examined the biotopes of rocky scar ground in the Solway Firth. The type and distribution of biotopes in this study largely coincide with those recorded by Allen (2006), with the broad habitats **SS.SCS**, **SS.SSa** and **SS.SMx** used to describe substrata characterised by a lack of obvious epifauna. The areas of rocky scar ground observed by Allen (2006) were generally identified as highly impoverished versions of the biotopes **SS.SCS.CCS.PomB** (*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles), **SS.SMx.CMx.FluHyd** (*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment), **CR.HCR.XFa.SpNemAdia** (sparse sponges, *Nemertesia* spp. and *Alcyonidium diaphanum* on circalittoral mixed substrata) and **SS.SBR.SMus.MytSS** (*Mytilus edulis* beds on sublittoral sediment). This is generally consistent with the present study; faunal communities were both variable and considerably impoverished, although some biotopes not previously cited have been identified. For example, the *Molgula manhatensis* dominated **CR.HCR.XFa.Mol** and the *Ampelisca* spp. biotope **SS.SMu.ISaMu.AmpPlon** were both identified in the Solway Firth survey area.

The biogenic reef biotopes **SS.SBR.PoR.SalvMx** and **SS.SBR.SMus.MytSS** identified in the current study have been recorded in few previous surveys (Allen, 2006; Axelsson *et al.*, 2006). Direct comparisons between surveys are problematic, however both *Sabellaria alveolata* and *Mytilus edulis* have been identified in a large number of studies (Perkins, 1968; Perkins, 1986; English Nature, 1997; Cutts and Hemingway, 1996; Allen *et al.*, 1999; Allen *et al.*, 2002; Lancaster, 2009; Cutts, Hemingway and Thompson, 2011).

4.4.2.2 Characteristic fauna of rocky scar ground habitats

While fauna was generally sparse throughout the survey areas, areas of rocky scar ground were found to be more species rich than other substrata. Species identified in the present study are broadly similar to species recorded in previous surveys. As with the present survey, Allen (2006) reported that fauna were both sparse and difficult to identify due to the poor underwater visibility encountered. Species observed were generally akin to those recorded in the current study, however, with fauna being dominated by mobile epifauna such as the common starfish *Asterias rubens* and the swimming crab *Liocarcinus* sp., encrusting sponges, ‘low grade’ faunal turf and anemones, including tentatively identified *Sagartia* sp..

Intertidal surveys of the Solway Firth SAC also report similar species to those identified in the current study. Lancaster (2009) reported that reduced siltation on scar ground on the lower shore at Dubmill Point had resulted in increased diversity of fauna compared with previous years. This area, which may be considered the shallow sublittoral rather than truly intertidal (Lancaster, 2009), was characterised by the ascidians *Dendrodoa grossularia* and *Molgula manhatensis*, both of which were observed in the current study, and by the breadcrumb sponge *Halichondria panacea*. While this species was not identified in the current study, large amounts of an unidentified yellow sponge were recorded on transects in the vicinity of Dubmill Point. Without direct sampling, however, the identity of this species cannot be confirmed.

The area of rocky scar ground at Maryport Roads reported in previous studies (Perkins, 1968; English Nature, 1997; Cutts and Hemingway, 1996; Allen, 2006) but which was not observed in the present study (see above) has been recorded as being characterised by rich faunal communities featuring *Sabellaria alveolata*, soft corals, *Flustra foliacea*, *D. grossularia*, a variety of sponges and the horse mussel *Modiolus modiolus* (English Nature, 1997). Contrastingly, Cutts and Hemingway (1996) record the fauna in this area as “variable” while Allen (2006) describes the scar grounds as having a sparse, scoured appearance. Given that scar grounds were not observed in this area in the current study, it is likely that this is an area which is subject to periodic inundation by sand as described by Perkins (1981; 1986) and which, as a result, displays temporal variation in faunal community.

Extensive areas of the tube-dwelling polychaete *S. alveolata* have been recorded on the Cumbrian coast of the Solway Firth, including the rocky scar grounds off Dubmill Point (Allen *et al.*, 1999; Allen *et al.*, 2002), though subtidal examples have also been identified (Allen, 2006; Axelsson *et al.*, 2006). Reef composed of *S. alveolata* is particularly abundant in this region as the species favours fairly exposed conditions with relatively high water current velocities where the water holds a high load of sand and food particles in suspension (Natural England and SNH, 2010). No *S. alveolata* was observed in the Solway Firth survey area in the current study, however aggregations were recorded in the Allonby Bay pMCZ, associated with areas of hard substrata. As these examples were only recorded on isolated video clips, it is unlikely that the aggregations observed constitute biogenic reef features.

The mussel *Mytilus edulis* was observed at a single site in the current survey, located west of Beckfoot Flats and north of Dubmill Point. Previous studies have recorded *M. edulis* beds throughout the Solway Firth and Allonby Bay areas, and although reports are primarily limited to the intertidal (Perkins, 1968; Cutts and Hemingway, 1996; Allen *et al.*, 1999; Allen *et al.*, 2002; Lancaster, 2009; Cutts, Hemingway and Thompson, 2011) there are records from the subtidal (English Nature, 1997; Allen, 2006; Axelsson *et al.*, 2006). Discrepancies in the distribution and extent of mussel beds between surveys is most likely due to differences in sampling techniques and areas surveyed, however recruitment, and therefore distribution of adult beds, is likely to be heavily influenced by stochastic recruitment events (Perkins, 1986).

4.5 Recommendations for future monitoring

The conservation objectives for reefs and subtidal scar ground (intertidal scar ground targets are listed separately) as outlined by Natural England and SNH (2010) are as follows;

i. there is no decrease in extent of rocky scar ground from an established baseline (subject to natural change)
ii. there is no change in the extent of characteristic biotopes from an established baseline (allowing for natural succession / known cyclical change)
iii. maintain the variety of biotopes identified for the site (allowing for natural succession / known cyclical change)
iv. maintain the distribution / spatial arrangement of biotopes (allowing for natural succession / known cyclical change)
v. maintain the age / size class structure of *Mytilus edulis* and *Sabellaria alveolata*

The 2014-15 survey of the Solway Firth SAC collected data for the re-establishment of a baseline of the extent of Annex I reef habitat, including the rocky scar ground sub-feature, for condition monitoring. In addition, the data enabled an assessment of change against previously collected datasets and thereby an initial assessment of feature condition. The results and achievements of the survey are given in Table 4.1 together with recommendations for future monitoring.

Table 4.1: Favourable condition assessment table with recommended measures and attributes post-2014-15 survey (from Natural England and SNH, 2010).

Sub-feature	Attribute	Measure	Target	Comments	2014-15 survey results / achievements	Recommendations (2015)
Scar ground	Extent	Area of scar ground measured	No decrease in extent from established baseline, subject to natural change	Based on Allen (2006)	- 22 transects were successfully surveyed (62 attempted) within the Allonby Bay pMCZ and the Solway Firth SAC with a large geographic spread - Scar ground observed at a number of sites and areas tentatively delineated	- Additional FWLS DDV work to be conducted - Acoustic surveys to be conducted to enable changes in sediment composition, including areas of rocky scar ground, to be more readily identified - Establishment of permanent transects to examine temporal variability in scar ground

	Characteristic biotope – extent of mussel beds	Area measured in summer months	No decrease in extent from established baseline, subject to natural change	The extent of mussel beds is a key structural component of the estuary… (Holt et al. 1998).	- 22 transects were successfully surveyed (62 attempted) within the Allonby Bay pMCZ and the Solway Firth SAC with a large geographic spread - Mussel bed observed on single transect	- In conjunction with further acoustic data acquisition, historic sites should be revisited using a FWLS and the SAC investigated for instances of this attribute.
	Characteristic biotope – extent of *Sabellaria spinulosa* reefs	Area of *Sabellaria spinulosa* reefs on sublittoral scar ground, measured during September	No decrease in extent from established baseline, subject to natural change	The extent of *S. spinulosa* reefs on sublittoral scar ground is a key structural component of the subtidal hard substrata present in the estuary. It is a fragile biotope thus a good indicator of physical disturbance.	- 22 transects were successfully surveyed (62 attempted) within the Allonby Bay pMCZ and the Solway Firth SAC with a large geographic spread - No instances of *S. spinulosa* reef observed	- In conjunction with further acoustic data acquisition, historic sites should be revisited using a FWLS and the SAC investigated for instances of this attribute.

Reefs	Extent	Extent should be assessed periodically against a baseline map/aerial image or through the review of any known activities that may have caused an alteration in extent.	No change in the extent of the biotopes, allowing for natural succession / known cyclical change.	Changes in extent would be considered unfavourable if attributable to activities which interrupt natural coastal processes such as coastal protection schemes or coastal development.	- 22 transects were successfully surveyed (62 attempted) within the Allonby Bay pMCZ and the Solway Firth SAC with a large geographic spread - Scar ground observed at a number of sites and areas tentatively delineated - Areas of biogenic reef (*S. alveolata* and *M. edulis*) observed	- Additional FWLS DDV work to be conducted - Acoustic surveys to be conducted to enable changes in sediment composition, including areas of reef, to be more readily identified - Establishment of permanent transects to examine temporal variability in reef features
	Biotope composition of biogenic reef	Repeated assessment of overall biotope composition.	Maintain the variety of biotopes identified for the site, allowing for natural succession or known cyclical change.	Where there is a change in biotope composition outside the expected variation or a loss of the conservation interest of the site, then	- 22 transects were successfully surveyed (62 attempted) within the Allonby Bay pMCZ and the Solway Firth SAC with a large geographic spread	- Acoustic surveys to be conducted to enable changes in sediment composition, including areas of biogenic reef, to be more readily identified

				condition should be considered unfavourable.	- Where biogenic reef observed, the biotopes **SS.SBR.PoR.SalvMx** and **SS.SBR.SMus.MytSS** assigned	
	Distribution / spatial arrangement of biotopes	Assess the geographic distribution of specified biotopes identified for the site. Assess the zonation pattern or the juxtaposition of specified biotopes.	Maintain the distribution / spatial arrangement of biotopes, allowing for natural succession / known cyclical change	Where there is a change in distribution / spatial pattern outside the expected variation or a loss of the conservation interest of the site, then condition should be considered unfavourable.	- 22 transects were successfully surveyed (62 attempted) within the Allonby Bay pMCZ and the Solway Firth SAC with a large geographic spread - Biotopes assigned to point source data and used in the construction of reef maps	- Acoustic surveys to be conducted to enable changes in sediment composition, including areas of biogenic reef, to be more readily identified - Acoustic data acquisition will also aid the construction of biotope maps

Age structure	Repeated assessment of overall biotope composition	Maintain age / size class structure *Mytilus edulis* and *Sabellaria alveolata*	Where there is a change in age structure outside the expected variation or a loss of the conservation interest of the site, then condition should be considered unfavourable	- Attribute not assessed as a part of this study	- Intertidal and / or grab sampling to take place to assess age / size structure of *M. edulis* and *S. alveolata* aggregations. - Establishment of permanent transects to examine temporal variability in reef features

Some disparities between this survey and previous studies of the area have been identified. The broadscale spatial extent of rocky scar ground appears to have decreased when compared with the work of Allen (2006), particularly around the Maryport Roads area in Allonby Bay and inshore from Dubmill Point, in the centre of the pMCZ. However, there appear to be increased areas of rocky scar ground south of Dubmill Point (around transects AL_08 and AL_09) and in the inshore part of Allonby Bay (around transects AL18 and AL_10).

The Solway Firth is a naturally dynamic site, and the distribution of rocky scar grounds – and associated biogenic reef – has been reported to exhibit a degree of temporal variability in the SAC (Perkins, 1986; Allen, 2006). The changes in distribution of observed rocky scar ground in the vicinity of Maryport Roads could reflect this, however these differences may also arise due to variations in the survey methods used, the areas surveyed and the time of year at which the surveys were conducted.

The type and variety of biotopes observed in the present study are generally similar to those assigned in previous work. However, as no survey has adequately mapped the subtidal biotopes of the Solway Firth area determining change in extent and spatial arrangement of characteristic biotopes is problematic.

4.5.1 Recommendations for immediate additional survey effort

There are several habitats and species within the Allonby Bay pMCZ and the Solway Firth SAC requiring future monitoring measures. The current survey collected considerable amounts of baseline data but additional baseline data are required in order to enable future monitoring of all the habitats and species present in the survey areas.

It is recommended that additional ground-truthing survey work using a freshwater lens camera system is completed to acquire more data and achieve an increased coverage of the seabed environment, therefore allowing a higher confidence in the detail of the habitat maps. Immediate survey work using the same methodology undertaken in this survey is required in order to ground-truth areas such as the mid to north of the Solway Firth survey area where poor visibility prevented usable video data being collected from several sampling locations, or those planned transects in the Allonby Bay survey area which were not surveyed due to time constraints. Ideally survey work would be conducted during and following periods of calm weather conditions and during neap tides so that poor underwater visibility does not hamper survey effort.

Further survey work should also be conducted in the more shallow areas of the SAC, with particular focus on areas of intertidal scar ground and biogenic reef, which were not investigated in the current study.

4.5.2 Future monitoring

Camera deployments and infaunal sampling using a 0.1 m^2 sediment grab sampler should be carried out in conjunction with broad-scale acoustic techniques to allow very conspicuous changes in habitat distribution to become apparent. It is particularly recommended that sidescan sonar survey work be conducted. This would enable changes in sediment composition, including areas of rocky scar ground, to be readily identified. Future subtidal surveys of the Allonby Bay pMCZ and the Solway Firth SAC should see ‘permanent’ transects established in order to enable repeat monitoring to take place.

4.6 Conclusions

The drop-down video survey of the Allonby Bay pMCZ and Solway Firth SAC survey areas aimed to assess the extent and distribution of subtidal rocky scar ground communities and Annex I reef features and was successfully completed in three phases in 2014-15. A total of 62 transects were attempted throughout the survey areas sing Seastar Survey’s own HD Freshwater Lens Camera System (FLCS), with a total of 269 discrete video clips achieved. While the data quality achieved in the Allonby Bay pMCZ was very high overall, underwater visibility was very poor in the Solway Firth survey area (frequently < 5 cm). As a result much of the data acquired in the Solway Firth was of poor quality.

In the Allonby Bay pMCZ the seabed was found to be dominated by gravelly mixed sediments. The most commonly identified broad habitat type was **SS.SMx** (sublittoral mixed sediment), though coarse and sandy sediments (**SS.SCS**, sublittoral coarse sediment and **SS.SSa**, sublittoral sands and muddy sands, respectively) were also observed. Areas of sandy sediments were generally species poor, while coarse sediments – usually consisting of cobbles and pebbles – were generally characterised by encrusting sponges, encrusting bryozoans and serpulid worms. Communities on mixed sediments were more species rich, being characterised by hydroids, the bryozoan *Alcyonidium diaphanum* and ascidians.

The Solway Firth SAC survey area was found to be dominated by sands and muddy sands. The most commonly identified broad habitat type was **SS.SSa** (sublittoral sands and muddy sands) though coarse and mixed sediments (**SS.SCS**, sublittoral coarse sediment and **SS.SMx**, sublittoral mixed sediment respectively) were also observed. The soft sediments observed were generally species poor, with only mobile macrofauna such as swimming crabs, shrimp and seastars such as *Asterias rubens* recorded.

Rocky scar ground was observed on 7 of the 12 achieved transects in Allonby Bay, and 3 transects in the Solway Firth SAC survey area, though areas of sparse pebbles on soft sediment were more widespread. Due to a lack of available acoustic data, rocky scar ground polygons have been generated by extending a 300 m radius from any point source at which the seabed was shown to be composed of greater than 10 % cobbles.

Areas of rocky scar ground were concentrated primarily west of Dubmill Point and around Dubmill Scar (STN_01; STN_04; AL_08 and AL_09), with cobbles and boulders making up to 95 % of the observed substrata. Other areas of rocky scar ground were mapped in the centre of Allonby Bay (AL_18 and AL_10) and in the south of the bay (AL_20). In contrast to previous surveys, no rocky scar ground was observed in the west of the Allonby Bay pMCZ in the vicinity of Maryport Roads.

Fauna on areas of rocky scar ground was relatively sparse, generally featuring robust, scour-tolerant species such as hydroids and *A. diaphanum*. Line AL_08 and STN_04 (which were both located relatively close together west of Dubmill Point), however, were characterised by high coverage by an unidentified sulphur-yellow encrusting sponge, while lines AL_20 and AL_10 were more species rich and featured aggregations of the ascidian *Dendrodoa grossularia*.

Areas of the reef forming polychaete *Sabellaria alveolata* were observed in Allonby Bay, whilst a single transect in the inshore of the Solway Firth SAC was found to be dominated by the mussel *Mytilus edulis*.

It is recommended that future monitoring incorporate camera deployments and infaunal sampling with broad-scale acoustic techniques to allow very conspicuous changes in habitat distribution to become apparent. This would enable changes in sediment composition, including areas of rocky scar ground, to be readily identified.

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6 Appendices

Appendix I. Planned drop-down camera locations for the Allonby Bay pMCZ and Solway Firth SAC survey areas

Planned drop-down camera transect locations in the Allonby Bay pMCZ survey area (all positions WGS84; SOL = start of line; EOL= end of line).

Station No.	SOL Latitude	SOL Longitude	EOL Latitude	EOL Longitude
AL_01	54.75192	-3.52973	54.74938	-3.53129
AL_02	54.76163	-3.52684	54.75888	-3.52853
AL_03	54.75986	-3.53884	54.75732	-3.54041
AL_04	54.79014	-3.49638	54.78760	-3.49795
AL_05	54.78539	-3.49429	54.78285	-3.49586
AL_06	54.78301	-3.48994	54.78047	-3.49151
AL_07	54.79069	-3.46878	54.78815	-3.47035
AL_08	54.79876	-3.47339	54.79622	-3.47495
AL_09	54.79209	-3.47715	54.78955	-3.47872
AL_10	54.77025	-3.47497	54.76666	-3.47492
AL_11	54.76355	-3.48598	54.76186	-3.48702
AL_12	54.75666	-3.47059	54.75497	-3.47163
AL_13	54.78119	-3.47690	54.77759	-3.47686
AL_14	54.74352	-3.50640	54.74116	-3.50926
AL_15	54.75646	-3.53416	54.75838	-3.53089
AL_16	54.75394	-3.51879	54.75586	-3.51552
AL_17	54.77268	-3.48471	54.77460	-3.48144
AL_18	54.77269	-3.51063	54.77461	-3.50736
AL_19	54.73763	-3.49901	54.73946	-3.49530
AL_20	54.77323	-3.45595	54.77515	-3.45268
AL_21	54.76320	-3.53495	54.51877	-3.53168

Planned transect locations for the Solway Firth SAC survey. All positions WGS84.

Station No.	Start of Line Latitude	Start of Line Longitude
1	54.80583	-3.48977
2	54.80575	-3.50146
3	54.81165	-3.49571
4	54.80587	-3.47808
5	54.81159	-3.50735
6	54.81747	-3.50160
7	54.81753	-3.48993

Station No.	Start of Line Latitude	Start of Line Longitude
8	54.81754	-3.47824
9	54.81759	-3.46657
10	54.82345	-3.46079
11	54.82342	-3.47246
12	54.82337	-3.48418
13	54.82332	-3.49583
14	54.82921	-3.49008
15	54.82925	-3.47838
16	54.82933	-3.45501
17	54.83520	-3.44923
18	54.83515	-3.46093
19	54.83511	-3.47262
20	54.84100	-3.45514
21	54.84106	-3.44347
22	54.84693	-3.43768
23	54.84687	-3.44936
24	54.85274	-3.44359
25	54.85277	-3.43189
26	54.85282	-3.42021
27	54.85865	-3.42610
28	54.85866	-3.41444
29	54.86450	-3.42033
30	54.82931	-3.46671
31	54.81171	-3.48406
32	54.81162	-3.47229
33	54.86480	-3.40865
34	54.87039	-3.41454
35	54.86440	-3.43212
36	54.85865	-3.43793
37	54.85275	-3.45538
38	54.84682	-3.46119
39	54.84096	-3.46679
40	54.83505	-3.48463
41	54.84097	-3.47863
42	54.83500	-3.49587
43	54.82914	-3.50177
44	54.82321	-3.50746
45	54.81740	-3.51336
46	54.80566	-3.51311
47	54.81165	-3.51935

Appendix II. Drop-down video survey logs detailing achieved 'seabed contacts' in the Allonby Bay pMCZ and the Solway Firth SAC survey areas

Seastar Survey Ltd			
Solway Firth SAC and Allonby Bay pMCZ DDV Survey			
Log of seabed contacts / video clips			
WGS 1984 UTM Zone 30N (6°W - 0°)			
Client	Natural England	**Job No.**	J/14/412
Location	Solway Firth SAC	**Vessel**	SV Mariner

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
20/11/2014	14:12:22	2	412_012#01#01	467640.6	6073214.3	54.80505	-3.50343	3.9	1	7
20/11/2014	15:35:06	11	412_013#01#01	469586.4	6075099.8	54.82212	-3.47336	3.8	2	7
21/11/2014	09:53:47	9	412_015#01#01	470017.7	6074754.0	54.81904	-3.46661	6.0	10	8
21/11/2014	09:56:04	9	412_015#01#02	469990.2	6074748.0	54.81898	-3.46704	6.3	11	8
21/11/2014	10:00:57	9	412_015#01#03	469954.0	6074668.2	54.81826	-3.46759	6.5	12	8
21/11/2014	10:33:47	45	412_016#01#01	467067.3	6074726.1	54.81860	-3.51252	9.0	13	8
21/11/2014	10:36:13	45	412_016#01#02	467010.7	6074630.3	54.81774	-3.51339	9.3	14	8
21/11/2014	10:39:06	45	412_016#01#03	466994.3	6074504.5	54.81660	-3.51363	9.3	15	8
23/11/2014	11:05:53	22	412_018#01#01	472016.4	6077970.5	54.84806	-3.43581	9.3	3	9
23/11/2014	11:09:34	22	412_018#01#02	471947.4	6077901.4	54.84743	-3.43688	9.4	4	9
23/11/2014	11:12:39	22	412_018#01#03	471902.1	6077868.4	54.84713	-3.43759	9.4	5	9
23/11/2014	11:15:53	22	412_018#01#04	471802.8	6077778.4	54.84632	-3.43912	10.2	6	9
23/11/2014	11:47:00	39	412_019#01#01	470167.3	6077195.1	54.84098	-3.46453	16.4	7	9
23/11/2014	11:50:05	39	412_019#01#02	470116.7	6077219.6	54.84120	-3.46532	16.9	8	9
23/11/2014	12:01:16	39	412_019#01#03	470078.2	6077211.0	54.84112	-3.46592	16.7	9	9
23/11/2014	12:08:35	39	412_019#01#04	470057.8	6077190.7	54.84094	-3.46624	16.4	10	9
23/11/2014	12:15:45	39	412_019#01#05	470052.6	6077216.3	54.84117	-3.46632	16.7	11	9

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
23/11/2014	12:21:41	39	412_019#01#06	470006.6	6077244.0	54.84141	-3.46704	14.7	12	9
23/11/2014	12:32:14	39	412_019#01#07	469942.0	6077146.7	54.84053	-3.46804	15.2	13	10
23/11/2014	12:40:25	39	412_019#01#08	469884.9	6077174.4	54.84078	-3.46893	15.4	14	10
23/11/2014	13:03:22	40	412_020#01#01	468844.7	6076385.2	54.83362	-3.48504	11.9	15	10
19/01/2015	10:24:48	1	412_021#01#01	468482.9	6073437.0	54.80711	-3.49035	7.4	3	11
19/01/2015	10:28:31	1	412_021#01#02	468537.9	6073406.0	54.80683	-3.48949	7.4	4	11
19/01/2015	10:32:39	1	412_021#01#03	468492.3	6073321.7	54.80607	-3.49019	7.9	5	11
19/01/2015	10:36:49	1	412_021#01#04	468497.6	6073292.1	54.80581	-3.49010	7.9	6	11
19/01/2015	10:39:41	1	412_021#01#05	468524.5	6073245.6	54.80539	-3.48968	8.3	7	11
19/01/2015	10:44:20	1	412_021#01#06	468520.2	6073188.9	54.80498	-3.48974	8.3	8	11
19/01/2015	10:46:33	1	412_021#01#07	468519.3	6073143.7	54.80447	-3.48975	8.2	9	11
19/01/2015	11:40:16	25	412_022#01#01	472134.6	6078402.0	54.85194	-3.43402	10.7	10	11
19/01/2015	11:42:52	25	412_022#01#02	472184.1	6078439.7	54.85228	-3.43325	10.7	11	11
19/01/2015	11:49:22	25	412_022#01#03	472260.9	6078484.7	54.85269	-3.43206	10.1	12	11
19/01/2015	11:54:30	25	412_022#01#04	472303.8	6078227.6	54.85038	-3.43136	8.7	13	11
19/01/2015	12:19:45	23	412_023#01#01	471054.1	6077708.8	54.84565	-3.45078	13.3	14	11
19/01/2015	13:13:28	42	412_025#01#01	468019.1	6076495.1	54.83456	-3.49790	9.4	16	11
19/01/2015	13:17:08	42	412_025#01#02	468027.7	6076483.8	54.83446	-3.49777	9.5	17	11
19/01/2015	13:58:29	3	412_026#01#01	468041.9	6073829.3	54.81060	-3.49725	5.0	18	11
19/01/2015	14:00:59	3	412_026#01#02	468088.4	6073868.6	54.81096	-3.49653	5.0	19	11
19/01/2015	14:08:39	3	412_026#01#03	468130.9	6073921.0	54.81143	-3.49588	4.5	20	11
19/01/2015	14:24:07	31	412_027#01#01	468914.6	6073801.7	54.81041	-3.48367	2.6	21	11
19/01/2015	14:26:46	31	412_027#01#02	468880.7	6073846.4	54.81081	-3.48420	2.7	22	11
19/01/2015	14:30:29	31	412_027#01#03	468876.5	6073894.9	54.81125	-3.48427	2.6	23	11
19/01/2015	14:45:41	8	412_028#01#01	469204.1	6074466.8	54.81641	-3.47924	3.5	24	12
19/01/2015	14:49:34	8	412_028#01#02	469276.7	6074542.2	54.81709	-3.47812	3.5	25	12
19/01/2015	14:52:58	8	412_028#01#03	469272.0	6074638.6	54.81795	-3.47820	3.5	26	12

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
19/01/2015	15:38:48	18	412_029#01#01	470285.4	6076438.9	54.83419	-3.46262	7.7	27	12
19/01/2015	15:41:22	18	412_029#01#02	470341.9	6076459.9	54.83439	-3.46174	6.1	28	12
19/01/2015	15:44:14	18	412_029#01#03	470394.2	6076544.9	54.83515	-3.46093	6.4	29	12
19/01/2015	16:17:01	20	412_030#01#01	470670.2	6077067.7	54.83987	-3.45669	9.2	30	12
19/01/2015	16:20:03	20	412_030#01#02	470707.5	6077107.2	54.84022	-3.45611	10.0	31	12
19/01/2015	16:26:38	20	412_030#01#03	470767.2	6077176.2	54.84085	-3.45519	7.2	32	12
19/01/2015	16:56:47	36	412_031#01#01	471763.6	6079074.7	54.85796	-3.43986	5.5	33	12
19/01/2015	16:59:14	36	412_031#01#02	471813.9	6079089.4	54.85810	-3.43908	5.7	34	12
19/01/2015	17:02:09	36	412_031#01#03	471882.6	6079157.7	54.85872	-3.43801	5.9	35	12
19/01/2015	17:28:36	24	412_032#01#01	471438.1	6078365.3	54.85157	-3.44486	11.0	36	12
19/01/2015	17:31:31	24	412_032#01#02	471454.8	6078424.3	54.85210	-3.44461	10.5	37	12
19/01/2015	17:39:01	24	412_032#01#03	471517.9	6078502.9	54.85281	-3.44363	9.5	38	12
19/01/2015	17:52:08	37	412_033#01#01	470651.2	6078434.8	54.85215	-3.45712	1.7	39	12
19/01/2015	17:54:40	37	412_033#01#02	470727.3	6078481.7	54.85258	-3.45594	1.8	40	12
19/01/2015	17:56:44	37	412_033#01#03	470821.2	6078537.7	54.85309	-3.45449	2.0	41	12
19/01/2015	17:57:21	37	412_033#01#04	470826.9	6078545.3	54.85315	-3.45440	2.0	No HD	12
19/01/2015	18:00:00	37	412_033#01#05	470873.2	6078584.9	54.85351	-3.45368	2.0	42	12
19/01/2015	18:01:30	37	412_033#01#06	470927.4	6078625.5	54.85388	-3.45284	2.3	43	12
19/01/2015	18:03:16	37	412_033#01#07	470984.4	6078679.4	54.85437	-3.45196	2.3	44	12
19/01/2015	18:14:22	38	412_034#01#01	470295.4	6077808.3	54.84650	-3.46260	5.3	45	13
19/01/2015	18:17:09	38	412_034#01#02	470353.4	6077820.0	54.84661	-3.46170	5.3	46	13
19/01/2015	18:22:12	38	412_034#01#03	470452.1	6077904.6	54.84737	-3.46017	6.0	47	13
19/01/2015	18:53:32	41	412_035#01#01	469418.7	6077245.3	54.84139	-3.47619	4.0	49	13
19/01/2015	18:56:25	41	412_035#01#02	469358.0	6077252.3	54.84145	-3.47714	4.0	50	13
19/01/2015	19:00:17	41	412_035#01#03	469279.5	6077231.7	54.84126	-3.47836	4.1	51	13
20/01/2015	10:52:17	4	412_036#01#01	469248.4	6073437.9	54.80716	-3.47844	7.7	52	13
20/01/2015	10:54:57	4	412_036#01#02	469251.1	6073391.3	54.80674	-3.47839	7.5	53	13
20/01/2015	10:57:45	4	412_036#01#03	469284.6	6073300.6	54.80593	-3.47786	7.5	54	13

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
20/01/2015	11:00:42	4	412_036#01#04	469289.4	6073250.2	54.80548	-3.47778	7.5	55	13
20/01/2015	11:02:47	4	412_036#01#05	469309.3	6073200.4	54.80503	-3.47747	7.0	56	13
20/01/2015	11:04:57	4	412_036#01#06	469291.7	6073144.7	54.80453	-3.47774	7.2	57	13
20/01/2015	11:07:26	4	412_036#01#07	469342.2	6073055.4	54.80373	-3.47694	7.0	58	13
20/01/2015	11:10:21	4	412_036#01#08	469352.5	6072964.7	54.80292	-3.47677	7.7	59	13
20/01/2015	11:13:15	4	412_036#01#09	469399.0	6072872.8	54.80209	-3.47604	7.5	60	13
20/01/2015	11:15:42	4	412_036#01#10	469399.8	6072771.5	54.80118	-3.47601	8.3	61	13
20/01/2015	11:18:30	4	412_036#01#11	469427.7	6072663.9	54.80022	-3.47557	8.0	62	13
20/01/2015	11:24:20	4	412_036#01#12	469707.3	6073137.3	54.80449	-3.47127	7.4	63	13
20/01/2015	11:33:11	4	412_036#01#13	468890.9	6072894.4	54.80226	-3.48394	7.6	1	13
20/01/2015	11:47:20	32	412_037#01#01	469626.2	6073792.4	54.81037	-3.47260	7.1	2	14
20/01/2015	11:50:12	32	412_037#01#02	469622.9	6073840.3	54.81080	-3.47266	7.0	3	14
20/01/2015	11:53:24	32	412_037#01#03	469644.5	6073886.7	54.81122	-3.47233	7.0	4	14
20/01/2015	11:56:54	32	412_037#01#04	469647.7	6073936.0	54.81166	-3.47228	7.0	5	14
20/01/2015	12:00:33	32	412_037#01#05	469655.4	6073986.3	54.81211	-3.47217	7.3	6	14
20/01/2015	12:02:31	32	412_037#01#06	469667.8	6074025.3	54.81247	-3.47198	7.4	7	14
20/01/2015	12:04:45	32	412_037#01#07	469677.1	6074080.1	54.81296	-3.47184	7.6	8	14
20/01/2015	12:22:54	10	412_038#01#01	470402.6	6075095.0	54.82212	-3.46065	5.5	9	14
20/01/2015	12:25:25	10	412_038#01#02	470383.7	6075143.6	54.82256	-3.46095	5.3	10	14
20/01/2015	12:28:51	10	412_038#01#03	470403.7	6075239.2	54.82342	-3.46065	5.4	11	14
20/01/2015	12:48:16	16	412_039#01#01	470688.8	6075762.5	54.82814	-3.45627	5.5	12	14
20/01/2015	12:50:47	16	412_039#01#02	470721.9	6075810.6	54.82857	-3.45576	5.0	13	14
20/01/2015	12:54:29	16	412_039#01#03	470865.0	6075917.4	54.82954	-3.45354	4.5	14	14
20/01/2015	13:07:37	17	412_040#01#01	471200.5	6076416.0	54.83404	-3.44837	4.6	15	14
20/01/2015	13:09:24	17	412_040#01#02	471175.5	6076471.4	54.83454	-3.44876	4.7	16	14
20/01/2015	13:12:26	17	412_040#01#03	471128.7	6076540.5	54.83516	-3.44950	5.5	17	14
20/01/2015	13:47:51	26	412_041#01#01	472954.2	6078367.1	54.85167	-3.42125	2.4	18	14
20/01/2015	13:49:53	26	412_041#01#02	473000.1	6078426.3	54.85221	-3.42054	2.2	19	14

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
20/01/2015	13:52:08	26	412_041#01#03	473008.7	6078515.3	54.85301	-3.42041	2.0	20	14
20/01/2015	14:01:42	28	412_042#01#01	473224.6	6079141.5	54.85865	-3.41711	3.5	21	14
20/01/2015	14:03:46	28	412_042#01#02	473310.3	6079141.7	54.85865	-3.41577	2.2	22	14
20/01/2015	14:09:16	28	412_042#01#03	473117.4	6079135.7	54.85859	-3.41878	2.3	23	14
20/01/2015	14:27:00	33	412_043#01#01	473751.5	6079876.2	54.86528	-3.40897	4.5	24	15
20/01/2015	16:43:57	29	412_044#01#01	472922.8	6079656.4	54.86326	-3.42186	4.0	25	15
20/01/2015	16:46:41	29	412_044#01#02	472974.8	6079706.6	54.86371	-3.42105	3.9	26	15
20/01/2015	16:49:18	29	412_044#01#03	472997.3	6079804.7	54.86459	-3.42071	4.1	27	15
20/01/2015	17:00:23	34	412_045#01#01	473317.9	6080325.5	54.86929	-3.41576	4.2	28	15
20/01/2015	17:01:49	34	412_045#01#02	473353.1	6080377.7	54.86976	-3.41522	4.2	29	15
20/01/2015	17:04:10	34	412_045#01#03	473416.9	6080456.1	54.87047	-3.41423	3.8	30	15
20/01/2015	17:44:56	35	412_046#01#01	472246.3	6079652.2	54.86318	-3.43240	5.7	31	15
20/01/2015	17:46:54	35	412_046#01#02	472234.1	6079720.4	54.86379	-3.43259	4.6	32	15
20/01/2015	17:49:23	35	412_046#01#03	472271.5	6079801.0	54.86452	-3.43202	5.6	33	15
20/01/2015	18:01:16	27	412_047#01#01	472509.4	6079097.3	54.85821	-3.42824	5.2	34	15
20/01/2015	18:03:07	27	412_047#01#02	472556.8	6079108.9	54.85832	-3.42751	4.8	35	15
20/01/2015	18:05:19	27	412_047#01#03	472657.2	6079144.6	54.85864	-3.42595	3.7	36	15
20/01/2015	18:23:33	23	412_048#01#01	471155.3	6077731.7	54.84586	-3.44920	6.0	37	15
20/01/2015	18:27:37	23	412_048#01#02	471111.0	6077802.4	54.84649	-3.44990	6.7	38	15
20/01/2015	18:30:08	23	412_048#01#03	471144.1	6077893.1	54.84731	-3.44939	6.9	39	15
20/01/2015	18:54:32	19	412_049#01#01	469573.1	6076706.0	54.83655	-3.47373	7.7	40	15
20/01/2015	18:58:17	19	412_049#01#02	469607.9	6076624.2	54.83582	-3.47318	7.9	41	15
20/01/2015	19:01:14	19	412_049#01#03	469650.8	6076542.6	54.83509	-3.47251	5.7	42	15
20/01/2015	19:05:14	19	412_049#01#04	469671.6	6076495.5	54.83466	-3.47218	5.0	43	15
20/01/2015	19:08:11	19	412_049#01#05	469740.7	6076450.6	54.83427	-3.47110	4.6	44	15
20/01/2015	19:10:59	19	412_049#01#06	469782.9	6076349.8	54.83336	-3.47043	3.7	45	15
20/01/2015	19:14:09	19	412_049#01#07	469869.7	6076270.8	54.83266	-3.46907	5.2	46	15

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
20/01/2015	19:22:22	30	412_050#01#01	470008.2	6076059.6	54.83077	-3.46689	4.2	47	16
20/01/2015	19:24:58	30	412_050#01#02	470019.6	6075994.6	54.83018	-3.46671	4.0	48	16
20/01/2015	19:27:23	30	412_050#01#03	470028.4	6075893.9	54.82928	-3.46656	3.7	49	16
21/01/2015	11:34:01	15	412_051#01#01	469351.2	6076019.7	54.83037	-3.47711	11.9	50	16
21/01/2015	11:36:34	15	412_051#01#02	469316.0	6075984.1	54.83005	-3.47766	11.3	51	16
21/01/2015	11:40:09	15	412_051#01#03	469274.4	6075897.3	54.82927	-3.47830	11.4	52	16
21/01/2015	11:43:34	15	412_051#01#04	469256.8	6075853.4	54.82887	-3.47857	11.6	53	16
21/01/2015	11:46:19	15	412_051#01#05	469217.7	6075797.2	54.82836	-3.47917	11.6	54	16
21/01/2015	11:49:38	15	412_051#01#06	469159.6	6075704.5	54.82753	-3.48006	11.9	55	16
21/01/2015	11:55:03	15	412_051#01#07	469489.2	6075824.7	54.82863	-3.47495	12.5	56	16
21/01/2015	11:56:33	15	412_051#01#08	469498.7	6075851.0	54.82886	-3.47480	11.9	No HD	16
21/01/2015	12:06:06	14	412_052#01#01	468639.9	6075876.3	54.82904	-3.48817	14.0	57	16
21/01/2015	12:07:59	14	412_052#01#02	468582.1	6075875.4	54.82903	-3.48907	12.9	58	16
21/01/2015	12:10:02	14	412_052#01#03	468485.2	6075921.0	54.82943	-3.49058	11.9	59	16
21/01/2015	12:20:05	43	412_053#01#01	467893.0	6075882.2	54.82904	-3.49980	14.9	60	16
21/01/2015	12:22:41	43	412_053#01#02	467835.1	6075903.8	54.82923	-3.50070	15.5	61	16
21/01/2015	12:25:19	43	412_053#01#03	467708.2	6075910.8	54.82929	-3.50268	15.2	62	16
21/01/2015	12:33:23	44	412_054#01#01	467286.5	6075308.4	54.82385	-3.50917	8.6	63	16
21/01/2015	12:37:59	44	412_054#01#02	467337.9	6075262.1	54.82343	-3.50837	9.0	64	16
21/01/2015	12:41:52	44	412_054#01#03	467409.9	6075226.4	54.82312	-3.50724	9.4	65	16
21/01/2015	13:01:43	13	412_055#01#01	468072.9	6075120.3	54.82221	-3.49691	7.7	66	17
21/01/2015	13:04:59	13	412_055#01#02	468098.1	6075173.6	54.82269	-3.49653	7.9	67	17
21/01/2015	13:07:36	13	412_055#01#03	468148.4	6075255.0	54.82342	-3.49575	8.5	68	17
21/01/2015	13:20:13	12	412_056#01#01	468766.1	6075154.5	54.82256	-3.48613	10.0	3	17
21/01/2015	13:25:44	12	412_056#01#02	468815.9	6075180.1	54.82279	-3.48536	10.0	4	17
21/01/2015	17:03:36	48	412_057#01#01	468591.1	6077865.5	54.84691	-3.48915	1.1	No HD	17
22/01/2015	11:24:24	49	412_058#01#01	469998.6	6073441.3	54.80724	-3.46677	6.5	7	17
22/01/2015	11:26:48	49	412_058#01#02	470015.2	6073405.6	54.80692	-3.46651	6.5	8	17

Date	Time (UTC)	Station	Sample #	Easting	Northing	Lat_WGS84	Lon_WGS84	Depth	HDD / XCAM Track	Tape #
22/01/2015	11:29:41	49	412_058#01#03	470036.6	6073344.5	54.80637	-3.46617	6.3	9	17
22/01/2015	11:32:10	49	412_058#01#04	470028.4	6073250.4	54.80552	-3.46629	6.5	10	17
22/01/2015	11:34:21	49	412_058#01#05	470067.7	6073162.7	54.80474	-3.46567	6.8	11	17
22/01/2015	11:41:39	50	412_059#01#01	470065.0	6072823.6	54.80169	-3.46567	6.9	12	17
22/01/2015	11:45:33	50	412_059#01#02	469996.2	6072791.3	54.80140	-3.46674	6.9	13	17
22/01/2015	11:49:42	50	412_059#01#03	470034.7	6072683.8	54.80043	-3.46613	6.7	14	17
22/01/2015	11:52:38	50	412_059#01#04	470070.5	6072572.4	54.79943	-3.46556	7.4	15	17
22/01/2015	12:14:30	46	412_060#01#01	467005.7	6073449.3	54.80712	-3.51333	9.1	16	17
22/01/2015	12:17:38	46	412_060#01#02	467045.8	6073357.2	54.80630	-3.51270	9.3	17	17
22/01/2015	12:21:38	46	412_060#01#03	467039.4	6073263.4	54.80545	-3.51279	9.7	18	17
22/01/2015	12:24:17	46	412_060#01#04	467043.4	6073155.7	54.80449	-3.51271	10.6	19	17
22/01/2015	12:40:04	47	412_061#01#01	466531.9	6074060.3	54.81258	-3.52077	12.4	20	18
22/01/2015	12:42:54	47	412_061#01#02	466598.5	6074039.1	54.81240	-3.51974	12.7	21	18
22/01/2015	12:45:36	47	412_061#01#03	466627.3	6073927.8	54.81140	-3.51927	12.5	22	18
22/01/2015	12:59:03	6	412_062#01#01	467710.2	6074437.4	54.81605	-3.50248	11.8	23	18
22/01/2015	13:01:42	6	412_062#01#02	467752.1	6074542.2	54.81699	-3.50184	11.9	24	18
22/01/2015	13:04:32	6	412_062#01#03	467779.3	6074621.6	54.81771	-3.50143	11.8	25	18
22/01/2015	13:12:08	7	412_063#01#01	468459.1	6074720.1	54.81864	-3.49086	10.9	26	18
22/01/2015	13:15:05	7	412_063#01#02	468509.4	6074640.4	54.81792	-3.49007	10.4	27	18
22/01/2015	13:17:31	7	412_063#01#03	468511.9	6074514.2	54.81679	-3.49002	10.4	28	18
22/01/2015	13:20:52	7	412_063#01#04	468286.8	6074313.9	54.81497	-3.49350	9.0	29	18
22/01/2015	13:22:07	7	412_063#01#05	468248.8	6074277.1	54.81464	-3.49408	9.0	30	18
22/01/2015	13:29:09	5	412_064#01#01	467480.4	6074027.6	54.81235	-3.50601	10.8	31	18
22/01/2015	13:31:52	5	412_064#01#02	467445.4	6073998.1	54.81208	-3.50655	10.4	32	18
22/01/2015	13:35:52	5	412_064#01#03	467387.9	6073940.3	54.81156	-3.50744	9.4	33	18

Appendix III: Full list of taxa identified in the video data collected from the Allonby Bay pMCZ and Solway Firth SAC survey areas.

MCS alpha	MCS num	Taxon	Qualifier
C	1	Porifera	encrusting
C	1	Porifera	massive
C	1	Porifera	yellow indet.
C	632	*Halichondria*	sp
D	58	Hydrozoa	turf
D	58	Hydrozoa	
D	163	*Tubularia*	sp
D	166	*Tubularia indivisa*	
D	424	*Hydrallmania falcata*	
D	433	*Sertularia*	argentea/cupressina
D	433	*Sertularia*	sp
D	462	*Nemertesia*	sp
D	597	*Alcyonium digitatum*	
D	662	Actiniaria	
D	682	*Urticina*	sp
D	684	*Urticina felina*	
D	711	Sagartiidae	
P	2	Polychaeta	tube
P	1115	*Sabellaria*	sp; tube
P	1116	*Sabellaria alveolata*	
P	1117	*Sabellaria spinulosa*	
P	1195	*Lanice conchilega*	
P	1324	Serpulidae	
P	1339	*Spirobranchus*	sp; tube
R	15	Thoracica	
R	68	*Austrominius modestus*	
S	422	Ampeliscidae	sp; tube
S	1293	Caridea	
S	1445	Paguridae	
S	1568	Portunoidea	
S	1577	*Liocarcinus*	sp
S	1580	*Liocarcinus depurator*	
W	162	*Gibbula*	sp
W	1695	*Mytilus edulis*	
Y	1	Bryozoa	encrusting
Y	1	Bryozoa	turf
Y	76	*Alcyonidium diaphanum*	
Y	187	*Flustra foliacea*	
ZB	18	Asteroidea	
ZB	75	*Crossaster papposus*	
ZB	100	*Asterias rubens*	
ZD	2	ASCIDIACEA	small solitary
ZD	120	*Dendrodoa grossularia*	

MCS alpha	MCS num	Taxon	Qualifier
ZD	151	*Molgula manhattensis*	colonial
ZG	441	Ammodytidae	
ZG	545	Pleuronectiformes	
ZM	1	Rhodophyta	encrusting
ZM	1	Rhodophyta	foliose

Appendix IV: Broad habitat types, biotopes complexes and biotopes identified using video data collected from the Allonby Bay pMCZ and Solway Firth SAC survey areas.

CR.HCR.XFa	Mixed faunal turf communities
CR.HCR.XFa.Mol	*Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock
CR.MCR	Moderate energy circalittoral rock
CR.MCR.CSab.Sspi.ByB	*Sabellaria spinulosa* with a bryozoan turf and barnacles on silty turbid circalittoral rock
SS.SCS	Sublittoral coarse sediment
SS.SSa	Sublittoral sands and muddy sands
SS.SSa.IMuSa	Infralittoral muddy sand
SS.SMu.ISaMu.AmpPlon	*Ampelisca* spp., *Photis longicaudata* and other tube-building amphipods and polychaetes in infralittoral sandy mud
SS.SMx	Sublittoral mixed sediment
SS.SMx.CMx	Circalittoral mixed sediment
SS.SBR.PoR.SalvMx	*Sabellaria alveolata* on variable salinity sublittoral mixed sediment
SS.SBR.SMus.MytSS	*Mytilus edulis* beds on sublittoral sediment

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