JOINT NATURE CONSERVATION COMMITTEE

JNCC Report
No. 424

Broadscale Subtidal Biotope Mapping to the West of the Outer Hebrides, Scotland, UK

A. Mitchell

January 2009

ISSN 0963 8091

defra Department for Environment Food and Rural Affairs

Scottish Natural Heritage All of nature for all of Scotland

afbi Agri-Food and Biosciences Institute

For further information please contact:

Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough
Cambridgeshire
PE1 1JY

Email: offshoresurvey@jncc.gov.uk
Tel: +44 (0)1733 866840
Fax: +44 (0)1733 555948
Website: www.jncc.gov.uk/marineprotectedsites

This report should be cited as:
Mitchell A. 2009. Broadscale subtidal biotope mapping to the west of the Outer Hebrides, Scotland, UK. *JNCC Report* No. 424.

Contents

Summary

Acoustic remote sensing, video ground-truthing and grab sampling were integrated within a Geographical Information System (GIS) to derive benthic habitat maps for five survey sites off the western Outer Hebrides (west and southwest of the island of Barra). The surveys targeted potential bedrock reef areas, which are a habitat listed under the EC Habitats Directive, at the inshore-offshore waters boundary (12nm from the coast). Background data was limited for these sites due to their distance offshore, and therefore acoustic remotely sensed data were gathered in order to generate bathymetries for each site for use in stratifying the video surveys and to ensure bedrock reef was targeted. Multibeam echosounders were used to generate complete-coverage bathymetric maps (minimum resolution of 5m) and stratify the video surveys for bedrock habitats. Bathymetric data was post-processed to derive hillshaded images, slope angles, rugosity levels and contour lines, which revealed complex topographies at each survey site, with depth ranges of up to 115m. The acoustic backscatter data collected by the multibeam echosounders was analysed to produce backscatter mosaics, which indicate differing acoustic ground-types over each survey area. In addition and where possible, single-beam acoustic ground discrimination system data was gathered to complement the multibeam echosounder data, which enhanced ground-type discrimination.

Video tows were completed at each site using either a towed sledge or drop-frame, the latter on bedrock reef areas, although total effort was limited due to time and weather constraints. Where coverage was adequate, habitat maps were produced surrounding the ground-truthed area within each survey site. Video images were semi-quantitatively analysed to give SACFOR epifaunal species abundances and detailed sediment descriptions made to permit biotope or biotope complex classification. This data was spatially linked to the acoustic datasets, guiding the interpretation of areas surrounding the video tows into habitats. Grab samples were used to describe the sedimentary basins surrounding the bedrock outcrops.

The bedrock reefs at each survey site showed habitats typical of deep, high energy, exposed environments, with sponges (encrusting and erect) dominating the epifauna. Encrusting and erect bryozoans, cup corals and keel worms were also common members of the reef epifauna. A total of seven habitats were identified from the reef sites: CR.HCR.DpSp, CR.HCR.DpSp.PhaAxi, CR.HCR.XFa, CR.HCR.XFa.ByErSp, CR.MCR.EcCr.CarSp.Bri, CR.MCR.EcCr.CarSp.PenPor and CR.MCR.EcCr.CarSwi. The bedrock was generally highly fissured. In all sites, except Barra 5, deep gullies separated the bedrock topographic highs, which were often infilled by coarse sands, gravels, cobbles and boulders. The sloping edges of the reefs typically showed the highest species richness, particularly further from the surrounding sediment where sand scour may have constrained species richness. The surrounding sedimentary areas were composed of fine to coarse sands, often with a gravel component, which were frequently rippled or megarippled. Boulder fields and extensive areas of coarse sands with cobbles fringed the base of each reef, characterised by the habitat SS.SCS.CCS.PomB, and in the SW Barra site by the habitat CR.MCR.EcCr.CarSwi, with the sea fan *Swiftia pallida* common.

In order to produce complete-coverage habitat maps for all the bedrock reefs within each survey site further ground-truthing is required. This is necessary to ensure that all habitats have been encountered, adequately described, and their full conservation importance determined.

This project represents one of only a few attempts at using multibeam echosounder data in association with other datasets to map seabed habitats within the UK, and as such raised a number of methodological issues. These were addressed in a project workshop (22 March 2005) and the resulting discussions are reported in Appendix 1 of the report. Overall, it was agreed that the project achieved the aims of integrating various datasets to produce broad scale habitat maps of bedrock reefs within each survey site. Furthermore, it was found that the acoustic datasets were invaluable in stratifying the video surveys and may be used in the future to design additional habitat investigations. Data generated from the video surveys may aid future habitat classification work, as currently few records exist for deeper circalittoral rock environments within the UK.

1. Introduction

Knowledge of benthic habitats and associated marine life (biotopes) is fundamental to marine resource management, and an integrated approach to marine stewardship. In 1998, the Oslo and Paris Commission (OSPAR) recognised the need to assess which marine habitats required protection, through the production of an inventory of habitats. This added to those habitats specified for protection and sensitive management under the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora). Further drivers for such habitat studies have come from the move towards ecosystem-based fisheries management. Other drivers will include the increased likelihood of offshore developments such as wind farms and their associated seabed cabling.

Modern acoustic remote sensing technologies such as RoxAnn™ (Stenmar Sonavision Ltd.), sidescan sonar and multibeam echosounders (MBES), along with GIS (Geographical Information Systems) allow the production of broad scale habitat maps at an improved spatial coverage compared with traditional survey techniques involving direct point sampling, such as grabs, used in isolation. When such acoustic techniques are coupled with adequate ground-truthing, a wide variety of habitats/biotopes may be resolved and mapped with a moderate to high degree of spatial accuracy. Many such habitats have been rarely encountered previously, particularly in deeper (deeper than 40m) waters that are not accessible to SCUBA divers; such areas represent a sizeable area of the UK continental shelf. Remotely operated camera systems coupled with accurate positioning and the invaluable information derived from acoustic ground discrimination surveys facilitates the mapping and investigation of such areas.

The surveys addressed in this report have focused on a number of sites to the west of the Outer Hebrides, Scotland, on the UK continental shelf (Figure 1). The sites were selected based upon their distance offshore (around 12nm, which represents the extent of national territorial waters and the official boundary between 'inshore' waters and 'offshore' waters) and existing broadscale bathymetric and sediment information from the British Geological Survey (Graham *et al*, 2001), which indicated areas of bedrock reef. Bedrock reef habitat is specified under the EC Habitats Directive (Council Directive 92/43/EEC) and although many examples of such habitat have been examined within UK inshore waters, there are far fewer studies of deeper regions offshore.

This project aims to map the broadscale biotopes and habitats of the rocky reef sites west of the Outer Hebrides through integrating multibeam echosounder data, acoustic ground discrimination system (AGDS) data, underwater video/camera surveys and grab data, facilitated through the use of GIS. Where possible, biotopes have been resolved and classified using the National Marine Habitat Classification for Britain and Ireland (Connor *et al*, 2004), and suggestions are made as to their conservation value at a regional, UK and European level. Recommendations have been made for further survey work where appropriate.

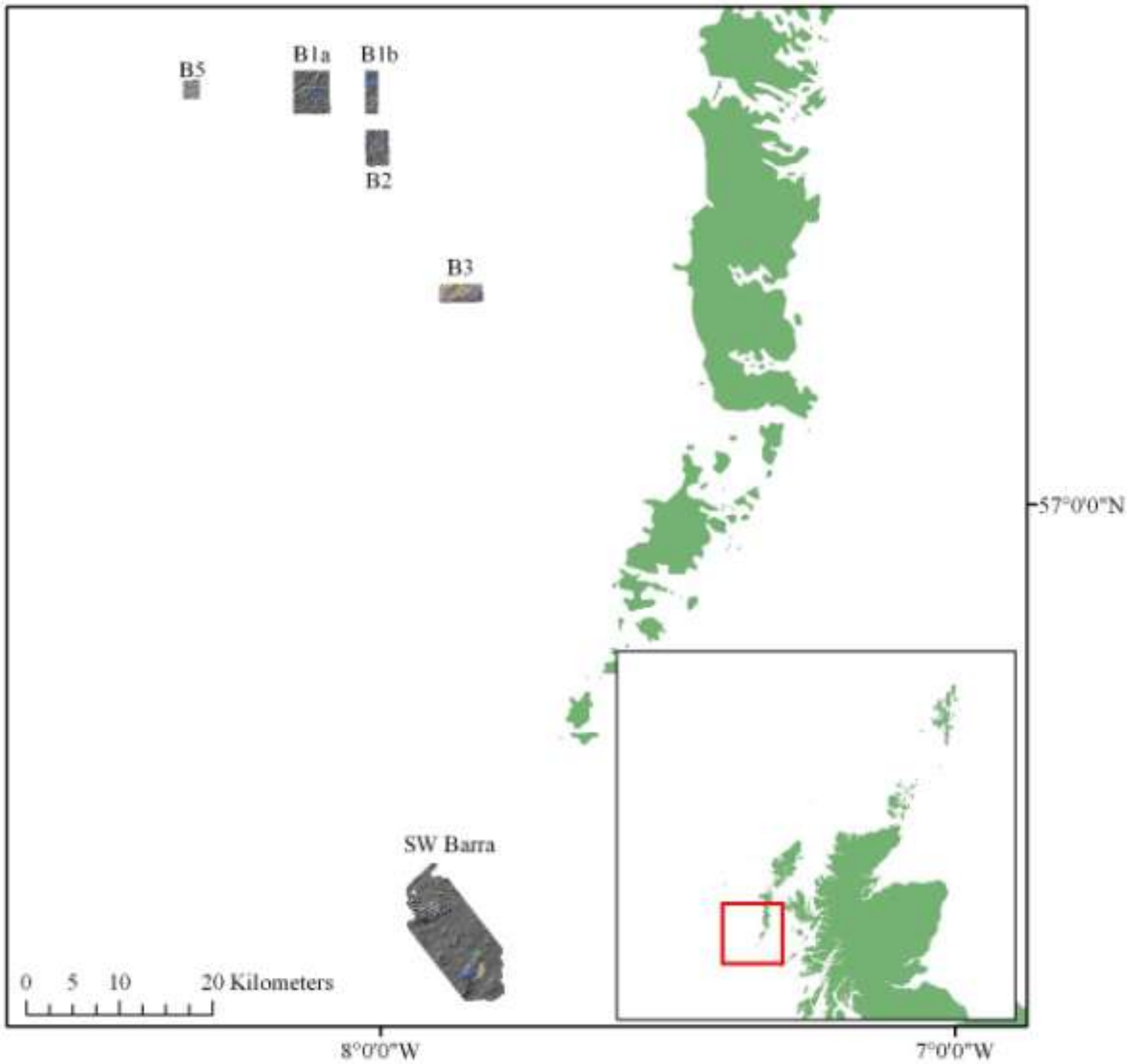

Figure 1. Overview of survey sites, with hillshaded bathymetries and habitat maps overlaid.

2. Materials and Methods

In total, three separate research cruises were undertaken for this project, covering a total of five sites. Four sites, to the northwest of Barra, were surveyed from the *RV Lough Foyle* between 26 July 2004 and 29 July 2004. These sites were named Barra 1, Barra 2, Barra 3 and Barra 5 (Figure 1). A further site to the southwest of Barra was surveyed over two research cruises aboard the *RV Aora*, with the acoustic survey work completed 9 September 2004 – 12 September 2004, and the ground-truthing survey undertaken between 1 November 2004 and 4 November 2004. This site was named SW Barra (Figure 1).

2.1 Acoustic surveys

Multibeam echosounder (MBES) datasets were collected for Barra 1, Barra 2, Barra 3 and Barra 5 using a Reson SeaBat 8101 multibeam system (operated by Chris Harper, of Fathoms Ltd. (subcontracted)) operated from *RV Lough Foyle*. During the collection of the MBES data where possible RoxAnn AGDS data was also collected using a 38kHz transducer. However, on some occasions it appeared that the 38kHz sound interfered with the operation of the MBES and was therefore switched off. The multibeam echosounder had a frequency of 240kHz, 101 beams of 1.5° x 1.5° beam size, and an update rate of up to 30 swaths per second. In addition to bathymetric coverage, the system had an integrated seabed imaging capability through a combination of phase and amplitude detection (referred to here as 'backscatter').

The Reson 8101 was deployed with the following ancillary parts:

- TSS MAHRS motion sensor and gyro to measure vessel movement
- Navitronics SVP 15 sound velocity probe to measure speed of sound through water
- Trimble AG 132 differential GPS (dGPS) system, with the differential corrections obtained from the IALA Beason system, for horizontal position control
- QPS QINSy Version 7.3 Integrated Navigation and Surveying software

A number of software suites were used during the acquisition and subsequent data reduction. During the survey QPS QINSy Version 7.3 software was used for acquisition and quality assurance/quality control. This recorded all the acquisition data and also applied sound velocity at the sonar head and through the water column. roll, pitch, timing, and heading calibrations were undertaken with this software.

Tidal corrections were applied to the multibeam data from 10 minute tidal curves modelled using information from the Admiralty Tide Tables and the UK Hydrographic Office (TotalTide software). The tidal models were entered directly into the navigation computer and to the multibeam acquisition software for online quality control during acquisition so that real-time corrections could be made and reapplied in post-processing.

Post-processing of bathymetric and backscatter data was carried out by Chris Harper of Fathoms Ltd. This involved using CARIS HIPS version 5.4 software to produce cleaned XYZ data at 5m resolution (eastings, northings, depth below lowest astronomical tide). Variable track spacing ensured adequate coverage of data such that data interpolation was not required.

Backscatter data were processed using CARIS SIPS for production of the UTM (Universal Transverse Mercator)–projected data mosaic images at 1m resolution.

The SW Barra site was also surveyed using a Reson SeaBat 8101 multibeam system (operated by Tim Le Bas and colleagues, Southampton Oceanography Centre (subcontracted)) operated from *RV Aora*. Where possible, QTC-view AGDS data was collected using a 38kHz transducer during the multibeam survey. However, an hour of QTC data was lost due to a software problem. For this survey, the Reson 8101 was deployed with the following ancillary parts:

- 81-P sonar processor for Reson 8101 sonar head and SVP near head. Tidal corrections were applied using this processing software, with corrections taken from the tide tables for Castlebay;
- POS MV position and attitude processor (with attached dGPS receivers and Inertial Motion Unit (IMU) 200);
- 6042 computer for running of data logging software and preliminary bathymetric grid creation; and
- CTD SBE 19plus for measuring speed of sound through water.

Multibeam bathymetric data was processed by Tim Le Bas using CARIS HIPS software to produce cleaned XYZ data. The processing was completed on a 4m resolution grid and depths are given in metres below lowest astronomical tide. Where there were minor gaps in the data due to the fixed line spacing of 360m, interpolation was used to give continuous coverage (time constraints due to weather prevented completion of narrower track spacing over shallow (less than 60m) areas). PRISM software was used to process the backscatter amplitudes stored in snippets by the Reson 8101 system. These amplitudes were corrected using basic radiometric and geometric techniques on a 0.5m resolution grid and UTM-projected data mosaic images produced.

RoxAnn AGDS datasets were collected by Matthew Service (DARDNI) during the multibeam sonar survey aboard *RV Lough Foyle*. RoxAnn datasets were obtained using a hull-mounted 38kHz transducer, a GroundMaster RoxAnn signal processor combined with RoxMap software, saving at a rate of 1s intervals. An Atlas differential Geographical Positioning Systems (dGPS), providing positional information, was integrated via the RoxMap laptop. Track spacing followed that of the multibeam survey. For the purpose of this report work, RoxAnn data was only used in its raw format. Post survey, erroneous data point removal was completed by Annika Mitchell.

QTC-View AGDS datasets were collected and processed by Tom Stevenson (UMBS, University of Glasgow) during the multibeam survey aboard *RV Aora*. QTC-View datasets were obtained using a hull-mounted 38kHz transducer connected to a computer integrated with dGPS. Track spacing followed that of the multibeam survey. The data was analysed using QTC-Impact software, which undertakes Principal Components Analysis (PCA) to pick the three features that best account for the variation between each captured echo. These become q1, q2 and q3. The cluster analysis section groups the captured pings on the basis of these three values. This is done by taking each existing class in turn (initially there is only one) splitting it along each of its three axes, and seeing which one gives the most statistically significant split. For the SW Barra data, the initial class 1 was split into 1 and 2, then class 1 was split into 1 and 3, then class 3 was split into 3 and 4, and finally class 2 was split into class 2 and 5.

2.2 Ground-truthing surveys

Ground-truthing information was gathered at Barra Sites 1, 2, 3 and 5 by Matthew Service (DARDNI), James Strong (QUB) and Caroline Turnbull (JNCC) during the July 2004 *RV Lough Foyle* cruise. In total, 16 video tows were completed for multibeam survey areas. Five video tows were on Barra Site 1, one video tow was on Barra Sites 2, six video tows were on Barra Site 3 and four video tows were on Barra Site 5. In addition, two sites within Barra Site 1 were sampled using a Day grab and Hamon grab in order to examine the sedimentary habitats surrounding the rocky outcrops. One site was similarly sampled using the Hamon grab at Barra Site 3. Due to time and weather constraints, no further grab samples were taken at the other sites.

Ground-truthing data was collected for the SW Barra site by Adam Mellor (QUB) during the November 2004 *RV Aora* cruise. In total, 10 video drops were completed from 30 sites selected based upon the multibeam bathymetric and backscatter information, which had been analysed prior to the cruise. The 10 video drops targeted the rocky outcrop areas throughout the site. However due to poor winter weather conditions further video drops or grab sampling could not be completed.

The video tows (Barra Sites 1, 2, 3, 5) were undertaken from a towed sledge that was deployed over the stern of the ship. The amount of cable deployed and depth of water were noted during these surveys such that sledge layback could be calculated/estimated and the sledge position corrected.

The video drops (SW Barra) were undertaken from a drop frame deployed over the stern of the ship such that the cameras were dropped vertically to the seafloor with minimal layback. The video system used was a Kongsberg Simrad Osprey underwater video camera operated using a Simrad video control deck unit. Footage was recorded to VHS tapes via a Panasonic video recorder for the July 2004 cruise, and directly to DVD using a Sony DVD recorder during the November 2004 cruise. Positional information was overlaid on the video records using a dGPS linked to TrakView overlay system. Videotapes were later copied to DVD in the case of the July 2004 cruise. A stills camera system (Photosea 1000A 35mm camera and Photosea 1500S strobe) was also fitted to the sledge or drop frame, and operated through the Simrad video control unit. Slide film (Kodak or Fuji 200 ASA) was used, with the resulting stills scanned onto computer using a Nikon CoolScan IV slide scanner. These images were enhanced using Adobe Photoshop (brightness, contrast and colour adjusted), and catalogued with positional information, which was determined as far as possible using the associated video footage and field log notes.

The video footage from Barra Sites 1, 2, 3 and 5 was of moderate to good quality (occasionally the auto focus focussed too close to the video camera causing some blurring of the seafloor in the field of view). The video footage from SW Barra was of excellent quality, albeit difficult to maintain a constant height above the seafloor due to the swell. However, field of view was adequate to permit identification of biotopes. The stills images from both cruises were of excellent quality, their high resolution facilitated identification of many epifaunal species that were too blurred on the video footage (due in part to the movement of the video camera). One hundred and eighty stills images in total were taken for ground-truthing. The analysis of the still images complements the video footage analysis and permits a more accurate identification/classification of biotopes. Underwater visibility at all sites was typically very good.

2.3 RoxAnn data analysis

The datasets were exported from RoxMap and imported into MS Access, which could then be viewed in a GIS using a non-earth plot (depth as Y axis, data point ID (sequential) as X axis) to examine and remove erroneous depth values. In addition, the datasets were clipped such that only data over each site as covered by the multibeam survey were retained. The datasets were split where necessary so that each site had a separate dataset in MS Access. Upon examination in an Earth plot/projection in GIS, no positional jumps/errors were apparent in the data. The RoxAnn data was overlain on the multibeam datasets and classed according to roughness or hardness. This later facilitated the spatial discrimination of habitats.

2.4 QTC-View data presentation

The processed QTC-View data (see above) was imported into MS Access for viewing in the GIS. The data was presented in a number of ways, showing the different cluster group memberships depending upon the number of clusters split during the various stages of the classification (eg five or three clusters in total). The changes in cluster membership along the tracks are examined with respect to bathymetric changes revealed from the multibeam data and substrate changes shown in the backscatter analysis. The QTC-View data, similarly to the RoxAnn data, aids interpretation of the multibeam data with respect to the spatial discrimination of habitats.

2.5 Multibeam data analysis

Multibeam data for all sites was provided as XYZ files and as backscatter mosaics (in .tiff format). The XYZ files contained positions given in Universal Transverse Mercator (Zone 29N) projection, based on 5x5m grid spacing for Barra Sites 1, 2, 3 and 5, and a 4x4m grid spacing for the SW Barra site. The XYZ files were imported into MS Access, where the depth values were converted into negative numbers such that they were comparable with the RoxAnn data format and would enable production of digital elevation models. The data was loaded into ArcMap 9, and TIN (triangulated irregular networks) and grid files created from the data using the 3D Analyst and Spatial Analyst extensions, which use depth as the elevation field (where appropriate, interpolation method details are stored in grid metadata). The TIN files were then converted into Raster grids. These elevation / bathymetric data layers were then presented in ArcScene 9, where they are viewed in three dimensions. From the raster grids, contour lines, slope angles, complexity/rugosity and hillshaded images highlighting topographic features are generated using Spatial Analyst and the Surface Area and Ratios extension for ArcView 3.x (Jenness, 2003). The accompanying datasets (AGDS track data, ground-truthing data) were overlaid on these bathymetric layers to improve habitat interpretation. The georeferenced multibeam backscatter images were presented in ArcMap and also added into ArcScene in 3D. Where necessary, image greyscales were manipulated to accentuate features.

2.6 Ground-truthing data analysis

The video data was reviewed. Where footage was of adequate quality, notes were made of substrate type and characterising species. Substrate type was defined as being the substrate that covers, on average, greater than 70% of the seabed over an area of approximately $5m^2$ or greater (which may be assessed by considering that the image width is approximately 1m across). In addition, notes were made of the topography of the area. Where possible, species were identified to species or genus level, depending upon video resolution and visibility. The relative abundance of species in each habitat section was also noted using the SACFOR scale. Habitat sections were determined by using change in substrate type to indicate a new habitat (see above explanation of how substrate is defined), or where the species assemblage appeared to change notably over a scale of greater than or equal to $5m^2$ (which may or may not occur with a change in substrate). The positions of the video at boundaries between habitat sections were noted from the video overlay. Positional data, taken from navigational track recordings or from video, was used to track the position of the video over the seafloor, and was added to an MS Access database along with associated substrate and species information. The stills images showed more detail than the video footage and added to the habitat descriptions by facilitating species identification. Once all footage had been examined, final habitat categories were assigned to each area based upon the species and substrate descriptions. Habitat classification, to biotope level where possible, adheres closely to the National Marine Habitat Classification for Britain and Ireland (Connor *et al*, 2004). The video track represented in the MS Access database was coded according to habitat or biotope. The video data has been visually presented within the GIS according to the habitat/biotope codes (as provided in Connor *et al,* 2004), and has been overlain on the acoustic datasets.

All photographic ground-truthing data (video footage and stills) was subsequently imported into a customised Access database developed by JNCC for storing such data for their future use and distribution to national marine recording initiatives.

A separate study is planned to carry out multivariate cluster analysis on the SACFOR species abundance data, in order to assess natural groupings in the data and examine how well these correspond to the biotope classification, which is derived primarily from a qualitative interpretation of the data. This will enable examination of interpretive consistency and also facilitate identification of biotopes that are currently not well known/characterised (due to lack of existing data in such regions). It is also hoped that using such methods in combination with acoustic classification techniques will enable an understanding of whether such biotopes have distinct acoustic properties.

The habitat categories identified from the video data are provided in Table 1 below in the Results section.

2.7 Data integration and habitat map production

All acoustic and ground-truthing data has been presented in a GIS, incorporating database tables (ground-truthing data, RoxAnn and QTC-View data, and video track and stills positional data), bathymetric grids (including derived grids such as hillshaded grids, slope, rugosity etc.), and backscatter mosaics. The associated legends for the presentation of these data are saved as layer files only where necessary. Where possible, GIS file metadata has been populated, and can be accessed readily through ArcCatalog.

The final habitat maps (shapefiles) were developed by combining the interpretation of each of the different datasets listed in the previous paragraph. Throughout this process, the following assumption was made. Where a habitat or biotope identified from ground-truthing occurs consistently upon similar topographic regions (eg depth, slope, rugosity), and upon a similar substrate (as shown from the topographic images combined with backscatter information and AGDS data), an area surrounding the ground-truthing site with similar properties can be considered to be the same habitat or biotope. However, extrapolation of such interpretations to areas far from any ground-truthing was not undertaken due to lack of knowledge of habitat heterogeneity and distinctiveness of each acoustic 'signature' (topography and substrate) for the habitat/biotopes. Habitat areas were delineated by hand within the GIS environment to create a series of non-overlapping polygons, each of which was given the relevant biotope/habitat code and description. Interpreted habitat maps do not cover the entire multibeam survey area. In light of this fact, recommendations have been made for additional groundtruthing to be completed in these areas, to allow complete coverage habitat maps to be compiled in future.

Within the GIS, the positions and biotope categories of ground-truthing stills photographs have been hyperlinked to the photographic images, aiding interpretation of the maps and biotope coding.

Finally, summary statistics can be generated for each study site from the final habitat map, including areas of each habitat or biotope, typical depth ranges, slope angles and rugosity values. These may be used to compare with other areas containing the same habitats/biotopes in an attempt to build a catalogue of topographic signatures for the biotopes. This falls under future Mapping European Seabed Habitats (MESH) project work.

3. Results and discussion

3.1 Habitats identified from ground-truthing photographic footage

Table 1 describes each biotope/biotope complex identified from the ground-truthing video, in conjunction with analysis of the stills photographs. The biotopes were determined qualitatively by using the substrate information combined with species abundance data (Section 2.6). In many cases the data did not appear to fit comfortably into one particular biotope. However, by looking at the entire dataset and attempting to ensure internal consistency in habitat designations, final classification was possible. In addition, biotopes on the bedrock outcrops appeared to merge into one another making it difficult to assign boundaries between them. In total, 11 biotopes/biotope complexes were recorded throughout the five survey sites. The attached appendix (on CD) provides an Excel spreadsheet of the video data, giving position, depth, tow identifier, substrate description, species SACFOR abundances and biotope designation. It is recommended that the reader refer to this for detailed lists of species in each habitat section. The deeper water biotopes described in the National Marine Habitat Classification for Britain and Ireland (Connor *et al*, 2004) are based on comparatively few datasets and it is acknowledged that biotopes in such areas require further work to confirm and elaborate the classifications.

Table 2 below summarises the biotopes/biotope complexes found at each site for reference, and Table 3 below provides the average number of conspicuous epifaunal species per habitat, using data from all the survey sites. The distribution and extent of these habitats is addressed by the resulting habitat maps (Section 3.5).

Greatest species richness appears to be found in the CR.MCR.EcCr.CarSp.PenPor biotope in the SW Barra site, while lowest species richness appears to be found in the megarippled SS.SCS.OCS biotope complexes (Table 3).

Table 1: Habitat Descriptions for Barra Sites

Habitat code	Sites present	Substrate description	Characterising fauna/flora	Energy environment and depth range	Official description
SS.SCS.OCS	Barra Site 1, Barra Site 3, Barra Site 5 and SW Barra	Megarippled or rippled coarse sand with occasional gravel/pebbles in troughs. Shell debris common. Occasional dead *Porella compressa* fragments.	Fauna rare and sparse due to mobility of substrate. Rare occurrence of: *Luidia ciliaris*, *Ophiura albida*, *Pagurus* spp, *Porania pulvillus*, *Pomatoceros* spp.	Moderate energy, deep wave-exposed or tide-swept environment. 63 – 130m depth range.	Offshore coarse sediment
SS.SSA.OSa	Barra Site 5 and SW Barra	Fine to medium sand with occasional comminuted shell, *Dentalium* spp shells and depressions. Usually level but occasional irregular ripples.	Fauna rare and sparse. Rare occurrence of *Asterias rubens*, *Porania pulvillus*, *Luidia ciliaris*, *Ophiura albida*, *Arachnanthus sarsi*, *Holothuria forskali*(?) and *Pagurus* spp.	Moderate energy, possibly tide-swept environment. 117 – 138m depth range.	Offshore circalittoral sand
SS.SMX.CMx	SW Barra	Coarse sand and gravel with frequent pebbles, whole bivalve shells and *Porella compressa* fragments. Level with occasional ripples.	Virtually no fauna. *Pomatoceros* spp occasional on pebbles.	Moderate energy, tide-swept environment. 99 –104m depth range.	Circalittoral mixed sediment with poorly sorted mosaics of shell, cobbles and pebbles embedded or lying on sand or gravel

SS.SCS.CCS.PomB	Barra Site 2, Barra Site 3 Barra Site 5 and SW Barra.	Cobbles/small boulders on gravel/coarse sand, often with shell debris and *Porella compressa* fragments. Occasional megaripples.	*Pomatoceros triqueter*, encrusting bryozoans, *Caryophyllia smithii*, *Filograna implexa*, *Parazoanthus anguicomus*, starfish, *Phakellia ventilabrum* and Axinellid sponges.	Moderate to high energy, deep wave-exposed and tide swept environment. 63 – 140m depth range.	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles
CR.HCR.DpSp.PhaAxi	Barra Site 1, Barra Site 2, Barra Site 3, Barra Site 5, SW Barra	Bedrock outcrop or dense boulders on coarse sand. Bedrock often covered with fine layer of silt, and is fissured. Large fissures contain boulders, cobbles and coarse sand. Includes vertical rock walls.	Diverse and abundant erect and branching sponges (*Axinella infundibuliformis*, *Polymastia* spp, *Phakellia ventilabrum*, *Raspailia* spp). Encrusting bryozoans and occasional encrusting sponges, starfish, coralline algae where <60m deep	High energy – wave and tidal current exposure. 53 –140m depth range.	*Phakellia ventilabrum* and Axinellid sponges on deep wave-exposed circalittoral rock
CR.HCR.DpSp	Barra Site 1, Barra Site 2, Barra Site 3, Barra Site 5.	Bedrock (often silted), cobbles/boulders in bedrock fissures or boulders/cobbles at foot of outcrop	Erect and encrusting sponges common, *Phakellia ventilabrum* and Axinellid sponges frequent. Encrusting bryozoans frequent, starfish, *Diazona violacea*, *Caryophyllia smithii* and *Pomatoceros triqueter* occasional to common.	High energy – wave and tidal current exposure. 54 – 138m depth range.	Deep sponge communities

CR.HCR.XF	Barra Site 1	Dense boulders and cobbles on coarse sand (near edge of bedrock outcrop)	Generally sparse fauna. Occasional erect and encrusting sponges (Axinellid sponges and *Phakellia ventilabrum*), and encrusting bryozoans, more rarely *Pomatoceros triqueter*, *Parazoanthus anguicomus* and starfish	High energy; tide-swept environment. ~122m depth.	Mixed faunal turf communities on tide-swept circalittoral rock
CR.HCR.XFa. ByErSp	Barra Site 1, Barra Site 2, Barra Site 3, Barra Site 5, SW Barra	Bedrock, frequently silted, or boulders on coarse sand near/at edge of bedrock outcrop. Occasional bare patches of rock.	Encrusting bryozoans (including *Parasmittina trispinosa*) common, *Porella compressa*, *Bugula* spp, *Securiflustra securifrons* common at SW Barra sites, *Pomatoceros triqueter* and *Caryophyllia smithii* occasional-frequent, erect sponges frequent (including *Phakellia ventilabrum* and Axinellid sponges). Encrusting sponges rare to occasional.	High energy, both tide-swept and wave-exposed. 45m –135m depth range.	Bryozoan turf and erect sponges on tide-swept circalittoral rock

CR.MCR.EcCr.CarSp.PenPor	SW Barra	Bedrock, or at edge of bedrock outcrop. Common on vertical rock walls.	*Porella compressa* common, *Caryophyllia smithii* occasional-common, encrusting bryozoans common, encrusting corallines at top of bedrock (<65m), erect sponges frequent (Axinellids and *Phakellia ventilabrum*). *Swiftia pallida* and *Filograna implexa* occasional. Starfish occasional.	Moderate energy, potentially tide and wave exposed. 53m – 107m depth range.	*Caryophyllia smithii* and sponges with *Porella compressa* and crustose communities on wave-exposed circalittoral rock
CR.MCR.EcCr.CarSp.Bri	Barra Site 1	Silted bedrock	*Ophiocomina nigra* frequent-common, encrusting corallines (<63m) and encrusting bryozoans (including *Parasmittina trispinosa*) frequent, *Pomatoceros triqueter* and *Caryophyllia smithii* occasional, erect sponges frequent (Axinellids and *Phakellia ventilabrum*)	Moderate energy, potentially tide and wave exposed. 56m – 62m depth range.	Brittlestar bed overlying coralline crusts, *Parasmittina trispinosa* and *Caryophyllia smithii* on wave-exposed circalittoral rock

CR.MCR.EcCr.CarSwi	SW Barra	Dense boulders on coarse sand near edge of bedrock outcrop	*Swiftia pallida* occasional to frequent, *Caryophyllia smithii* common, encrusting bryozoans and erect sponges frequent (inc. Axinellids, *Phakellia ventilabrum*), *Munida rugosa* occasional, *Filograna implexa* and *Pomatoceros triqueter* rare to occasional.	Moderate energy, tide-swept environment. 107m –114m depth range.	*Caryophyllia smithii* and *Swiftia pallida* on circalittoral rock

Table 2: Summary of biotopes/biotope complexes found at each survey site.

Site name	Biotope/biotope complex	Average number of species per biotope per site	Total number of biotopes/ biotope complexes	Number of video tows/drops
Barra Site 1	SS.SCS.OCS CR.HCR.DpSp.PhaAxi CR.HCR.DpSp CR.HCR.XFa CR.HCR.Xfa.ByErSp CR.MCR.EcCr.CarSp.Bri	1.3 16.2 14.2 12.0 9.0 15.4	6	6
Barra Site 2	CR.HCR.DpSp.PhaAxi CR.HCR.DpSp CR.HCR.Xfa.ByErSp SS.SCS.CCS.PomB	22.0 20.0 8.0 5.0	4	1
Barra Site 3	SS.SCS.OCS SS.SCS.CCS.PomB CR.HCR.DpSp.PhaAxi CR.HCR.DpSp CR.HCR.Xfa.ByErSp	0.7 3.8 19.1 13.2 16.6	5	6
Barra Site 5	SS.SSA.OSa SS.SCS.OCS SS.SCS.CCS.PomB CR.HCR.DpSp.PhaAxi CR.HCR.DpSp CR.HCR.Xfa.ByErSp	2.3 0 7.8 21.5 13.8 13.0	6	4
SW Barra	SS.SCS.OCS SS.SSA.OSa SS.SMX.CMx SS.SCS.CCS.PomB CR.HCR.DpSp.PhaAxi CR.HCR.Xfa.ByErSp CR.MCR.EcCr.CarSp.PenPor CR.MCR.EcCr.CarSwi	0.6 0.2 1.0 10.5 19.6 19.4 22.0 13.7	8	10

Table 3. Average numbers of conspicuous epifaunal species per biotope/biotope complex throughout all survey sites.

Biotope	Average number of conspicuous epifaunal species per habitat
SS.SCS.OCS	0.7
SS.OSA.OSa	1.3
SS.SMX.CMX	1.0
SS.SCS.CCS.PomB	6.8
CR.HCR.DpSp	14.2
CR.HCR.DpSp.PhaAxi	19.7
CR.HCR.XFa	12.0
CR.HCR.XFa.ByErSp	13.2
CR.MCR.EcCr.CarSp.Bri	15.4
CR.MCR.EcCr.CarSp.PenPor	22.0

3.2 Overview of each survey site

3.2.1 Barra 1

Sub-site Barra 1a

Figure 2a shows the multibeam bathymetry for Barra 1a, along with ground-truthing stations. This exposed site was characterised by extensive deep bedrock outcrops (reefs), which were heavily fractured with a number of deep gullies, of up to a few tens of metres across, running between the topographic highs. These gullies had been infilled by sediments that, from the limited ground-truthing, appeared to consist mainly of coarse, mobile sands. To the north of the site the bedrock appeared separated by larger deep basins. These were not ground-truthed, but from the acoustic signature, it is likely that these were filled by fine sand or sandy mud, as indicated by the RoxAnn data and multibeam backscatter. The water depth ranged over this area from 85m to 140m, with slope angles of up to 46° at the edges of the bedrock outcrops. The topographic deeps in this area were only ground-truthed by grab sampling rather than with video, and appeared to consist of coarse to medium sand with frequent *Dentalium* shells. The rock habitats were ground-truthed with two video tows, from which two habitats were identified: CR.HCR.DpSp.PhaAxi and CR.HCR.XFa, with highest numbers of species encountered on the bedrock outcrop edges/slopes. This extensive survey sub-site would require further video ground-truthing effort to determine its habitat richness and uniqueness.

Sub-site Barra 1b

Figure 2a shows the multibeam bathymetry for Barra 1b, along with ground-truthing stations. This exposed site encompassed an extensive area of bedrock reef, with numerous gullies (up to 80m across) containing coarse sand. One reef area in particular was prominent (north west corner of site) with a topographic high of 52m, which was the shallowest water depth within both sub-sites. Maximum depth was 115m, with slope angles up to 54°. The area was ground-truthed with four video tows, which indicated a range of sedimentary environments ranging from highly fractured bedrock reefs with steep slopes, through boulder and cobble fields on coarse sand to pure coarse sand (showing current ripples). From the video footage, four habitats were identified: CR.HCR.DpSp, CR.HCR.DpSp.PhaAxi, CR.HCR.XFa.ByErSp and SS.SCS.OCS, with the highest species richness occurring on the CR.HCR.DpSp.PhaAxi mainly along steeper slopes of the bedrock outcrops.

3.2.2 Barra 2

Figure 2b shows the multibeam bathymetry for Barra 2, along with ground-truthing stations. Extensive fractured bedrock reefs characterise this site, which appeared to be highly exposed. The fractures/gullies were up to 100m across and infilled by coarse sand and cobbles/boulders. Separating the areas of bedrock reef were extensive sedimentary basins up to 110m in water depth. The bedrock reef formed topographic highs, in some areas as shallow as 77m water depth, with slope angles of up to 57°. Due to time constraints, only one video tow was undertaken in this site, which indicated a fairly diverse assemblage of biotopes over the fractured bedrock reefs and the coarse sand/cobbles of the rock gullies. Acoustic data (RoxAnn and multibeam backscatter) indicated that the basins between the bedrock reefs contained fine sands or sandy mud (that is possibly bioturbated by megafauna). CR.HCR.DpSp, CR.HCR.DpSp.PhaAxi, CR.HCR.XFa.ByErSp and SS.SCS.CCS.PomB biotopes were identified from the video footage with the deep sponge communities showing the highest species richness, particularly on the more sheltered sloping edges of the outcrops. This extensive survey site would require substantial further video ground-truthing effort to determine its habitat richness and uniqueness.

3.2.3 Barra 3

Figure 2c shows the multibeam bathymetry for Barra 3, along with ground-truthing stations. This site was dominated by extensive areas of highly fractured bedrock, characterised by fauna typical of a high energy, deep-water environment. The fractures formed a regular network of gullies, some as wide as 130m with sides up to 30m in height. Although not extensively ground-truthed, the gullies appeared to be infilled by coarse sands. The bedrock arose from the seabed in some areas as shallow as 39m, with the gullies as deep as 96m. The bedrock showed a range of slope angles, up to 46°. The biotopes CR.HCR.DpSp.PhaAxi, CR.HCR.DpSp, and CR.HCR.Xfa.ByErSp were identified from the video tows along the bedrock outcrops. The shallowest areas of bedrock were not ground-truthed, and therefore there are probably additional biotopes in such regions that were not identified from the video footage of this site. The habitats SS.SCS.OCS and SS.SCS.CCS.PomB were identified from the infilled gullies between outcropping rock; the acoustic data suggested that sediments any finer than this (in grain size) were not present in this site. As with the other sites, the highest species richness appeared to be on the rock slopes, particularly further up the sides of outcropping rock where sand scour was reduced. Although six video tows were completed in this area, providing a moderate degree of ground-truthing, further video work would be required to ensure that all biotopes within the site had been correctly identified and to establish their uniqueness.

3.2.4 Barra 5

Figure 2d shows the multibeam bathymetry for Barra 5, along with ground-truthing stations. Sandy sediment (coarse and fine) appeared to dominate this deep site, with some moderately extensive areas of bedrock reef (up to 500m across) scattered throughout the site. A more extensive area of bedrock reef was recorded to the north east of the site (over 800m across), and appeared to form the edge of a larger, more extensive area of bedrock reef. Although the bedrock appeared extensively fissured on the video ground-truthing, large gullies within the bedrock outcrops were absent, unlike the other survey sites. However, the edges of these smaller bedrock outcrops were quite steeply sloping (up to 49°), and may harbour rich species assemblages. The sandy sediments between the bedrock reefs appeared to show large ribbon-like depressions 1-3m deeper than the surrounding flat sediment. These depressions were between 15 and 60m wide, ran in a north-south orientation, and extended throughout the length of the survey site. One video tow (26072004T5_2) appeared to cross one such depression; the video showed flat sediment around the ribbons consisting of fine sand with occasional comminuted shell, tusk shells and some fine-scale depressions (bioturbation). This habitat was classified as SS.SSa.OSa, and showed up as a dark reflector in the backscatter mosaics. The sediment within the ribbon-like depressions appeared to be megarippled coarse sand (classified as SS.SCS.OCS), suggesting the site was subject to a moderate degree of near-bed stress and that the sediment may be mobile. Further ground-truthing would be required to ascertain, with any level of confidence, the nature of this sedimentary area. These ribbons may represent a large-scale feature of interest, indicating possible down-slope sediment flow that could result from internal waves breaking upon the shallower reefs. The bedrock was ground-truthed with four video tows, which revealed the following habitats: CR.HCR.DpSp.PhaAxi, CR.HCR.DpSp, and CR.HCR.Xfa.ByErSp, with SS.SCS.CCS.PomB identified at the edges of the outcropping rock. CR.HCR.DpSp.PhaAxi showed the highest species richness, being present largely on the outcrop edges/sloping rock, sheltered from sand scour and subject to less near-bed stress. In order to evaluate the full conservation importance of this site, further ground-truthing is recommended, as further habitats may yet be encountered.

3.2.5 SW Barra

Figure 2e shows the multibeam bathymetry for SW Barra, along with ground-truthing stations. This was the largest site out of those surveyed, and encompassed a broad range of sediments and rock structures. Two extensive areas of bedrock reef (>3km across) (north and south within the survey site) were found that arose to 42m water depth. A number of other smaller rocky reef areas arose to approximately 70m water depth, with extensive areas of deep (over 90m water depth) bedrock reef between (though not always continuous with) the shallower reef areas. The bedrock surface was fractured, with topographic highs separated by parallel and sub-parallel gullies up to 100m in width. The gullies were often filled with coarse sands and gravels, pebbles, cobbles and boulders. The edges of the bedrock outcrops were near-vertical (up to 78°), representing a complex habitat. There were a number of sedimentary basins between the bedrock outcrops that appeared to be flat or gently sloping. The deepest of these was to the south-east of the survey area, adjacent to the southerly extensive bedrock outcrop for which a habitat map was derived. Beside the bedrock, sedimentary features were identified. The light and dark reflectors in the backscatter mosaic indicate sediment megaripples, where sediment may have been sorted into coarser and finer fractions. Two video tows, 02112004D5 and 02112004D3, crossed this sedimentary area and showed a range of habitat from megarippled coarse sand and gravel (SS.SCS.OCS) to fine, irregularly-rippled, sand (SS.SSa.OSa). The areas of finer sand correlated with the dark reflectors in the multibeam backscatter mosaic, while the lighter reflectors correlated with coarser sands and gravels (often megarippled). The two extensive areas of bedrock reef areas (discussed at the start of this paragraph) were targeted for ground-truthing; a total of nine video drops were completed, and revealed a diverse range of rock habitats including SS.SCS.CCS.PomB, CR.HCR.DpSp.PhaAxi, CR.HCR.Xfa.ByErSp, CR.MCR.EcCr.CarSp.PenPor and CR.MCR.EcCr.CarSwi. Interestingly, far more of the habitat CR.MCR.EcCr.CarSp.PenPor was encountered in the southern reef complex than in the northern reef complex, which, alongside CR.HCR.DpSp.PhaAxi, appeared to dominate the southern reef bedrock. In the northern reef complex, CR.HCR.Xfa.ByErSp was encountered more frequently than in the southern reef, typically on the top of the bedrock outcrop. This could be due to the fact that the topographic highs of the northern reef complex were shallower than the southern reef complex, and thus exposed to more wave disturbance. There was a notable absence of the habitats CR.MCR.EcCr.CarSp.PenPor and CR.MCR.EcCr.CarSwi from the video tows at the other Barra sites, but this could also be due to the limited ground-truthing that was undertaken. *Porella compressa* and *Swiftia pallida* were fairly common in the SW Barra site, with the former typically occurring on fractured bedrock and the latter occurring in boulderfields adjacent to the bedrock outcrops. These two species were rare in the other offshore Barra sites, which may indicate differences in the physical environment, possibly in terms of current regime or exposure, although further ground-truthing would be required to determine this. As with the other sites, species richness was highest on the complex, fractured slopes of the bedrock outcrops, such as at the walls of gullies. Habitat maps were only produced for the two bedrock outcrops that were ground-truthed: it is recommended that further ground-truthing is undertaken to target the deeper bedrock areas and the surrounding sedimentary regions. It is probable that different habitats would be encountered in such areas than those currently recorded.

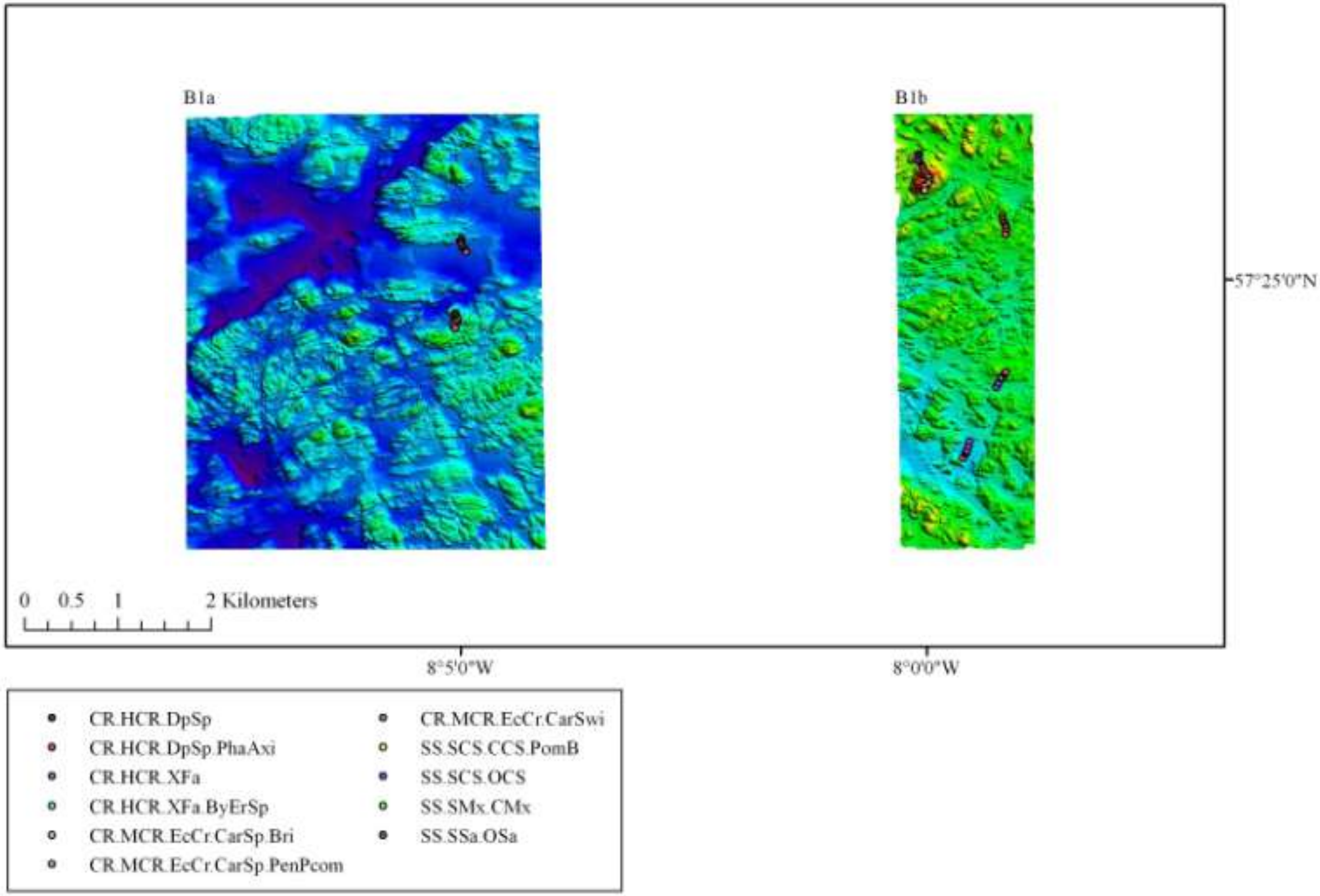

Figure 2a. Multibeam bathymetry for Barra Site 1 (1a on left and 1b on right), with classed ground-truthing video tracks overlaid.

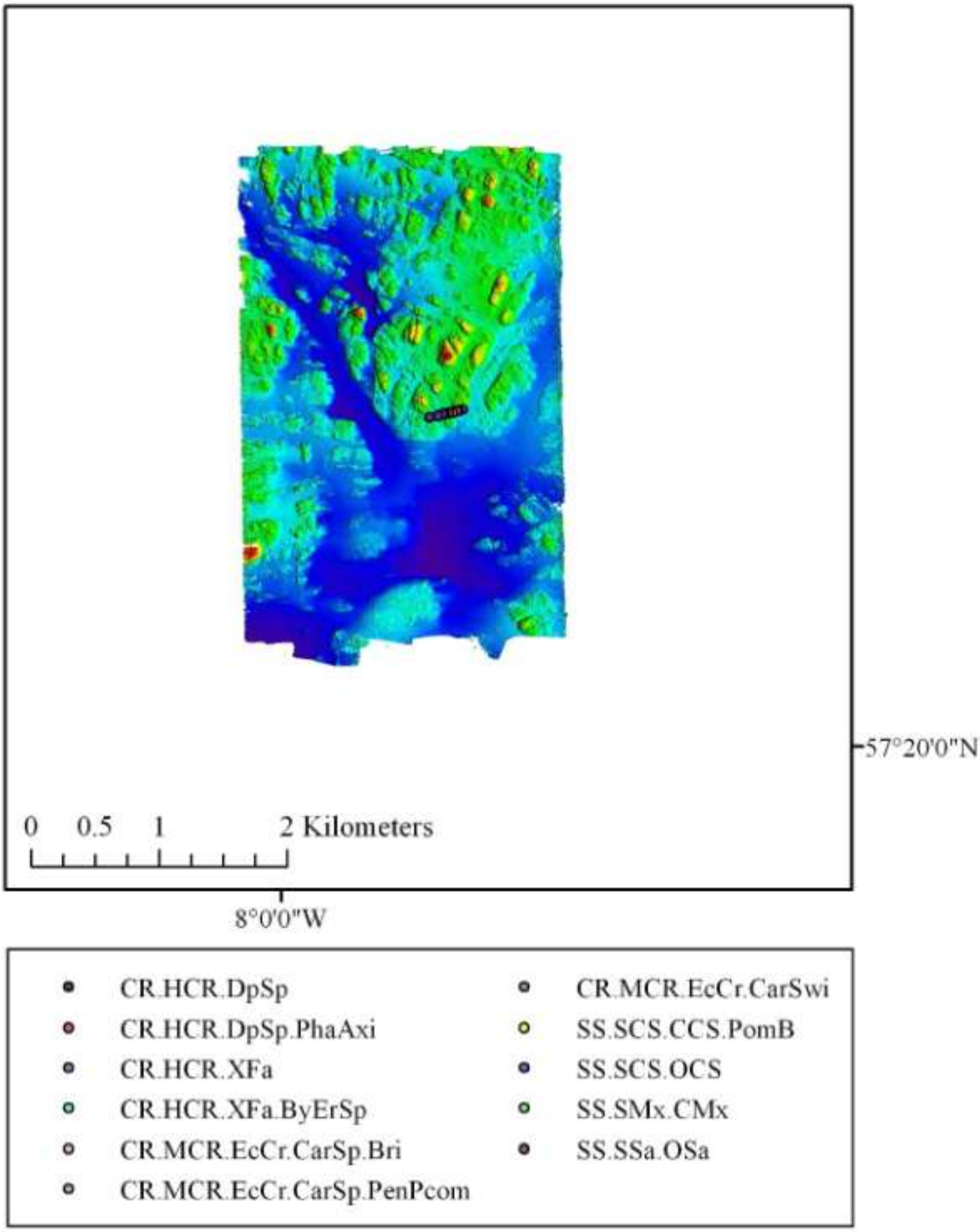

Figure 2b. Multibeam bathymetry for Barra Site 2 with classed ground-truthing video tracks overlaid.

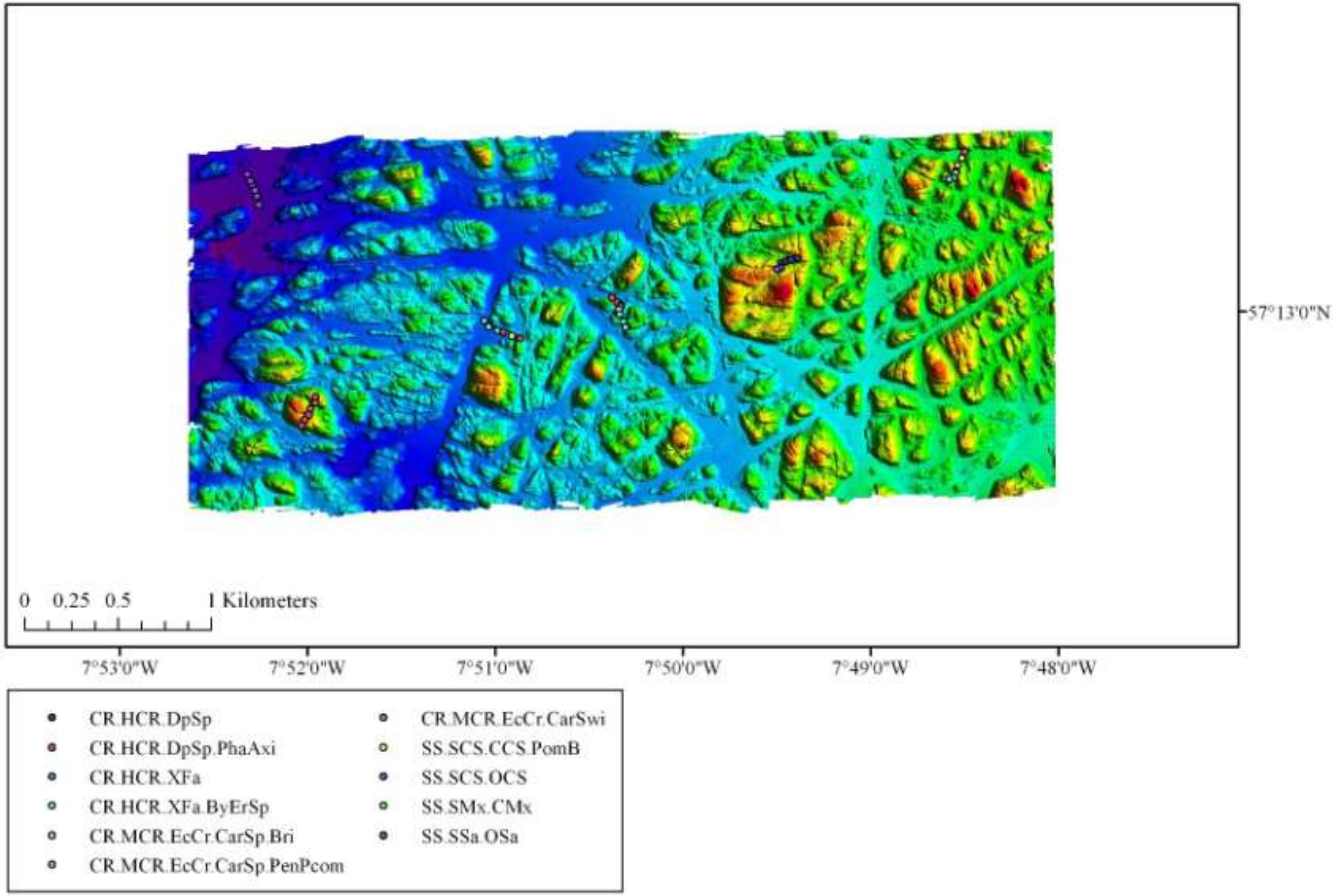

Figure 2c. Multibeam bathymetry for Barra Site 3 with classed ground-truthing video tracks.

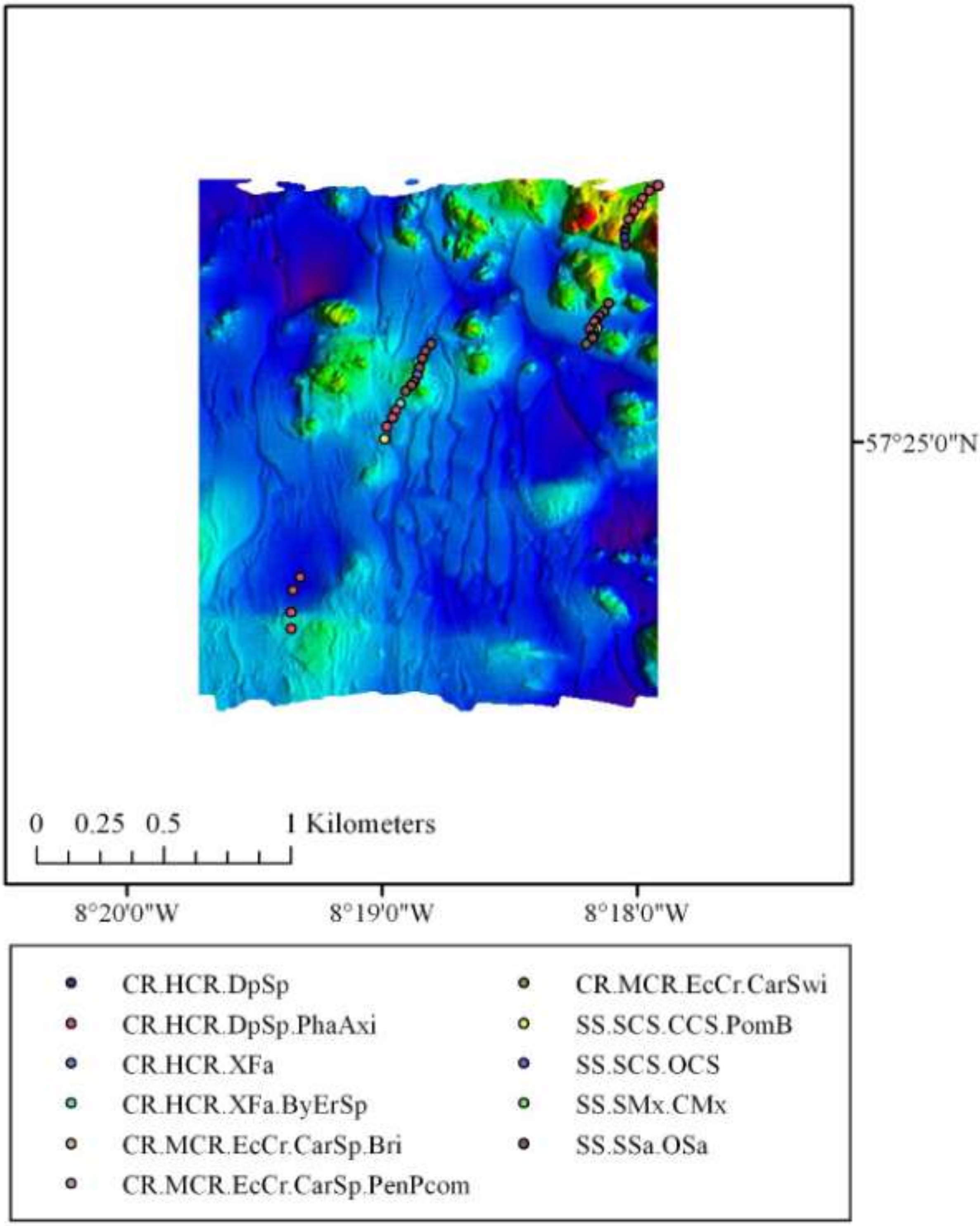

Figure 2d. Multibeam bathymetry for Barra Site 5 with classed ground-truthing video tracks.

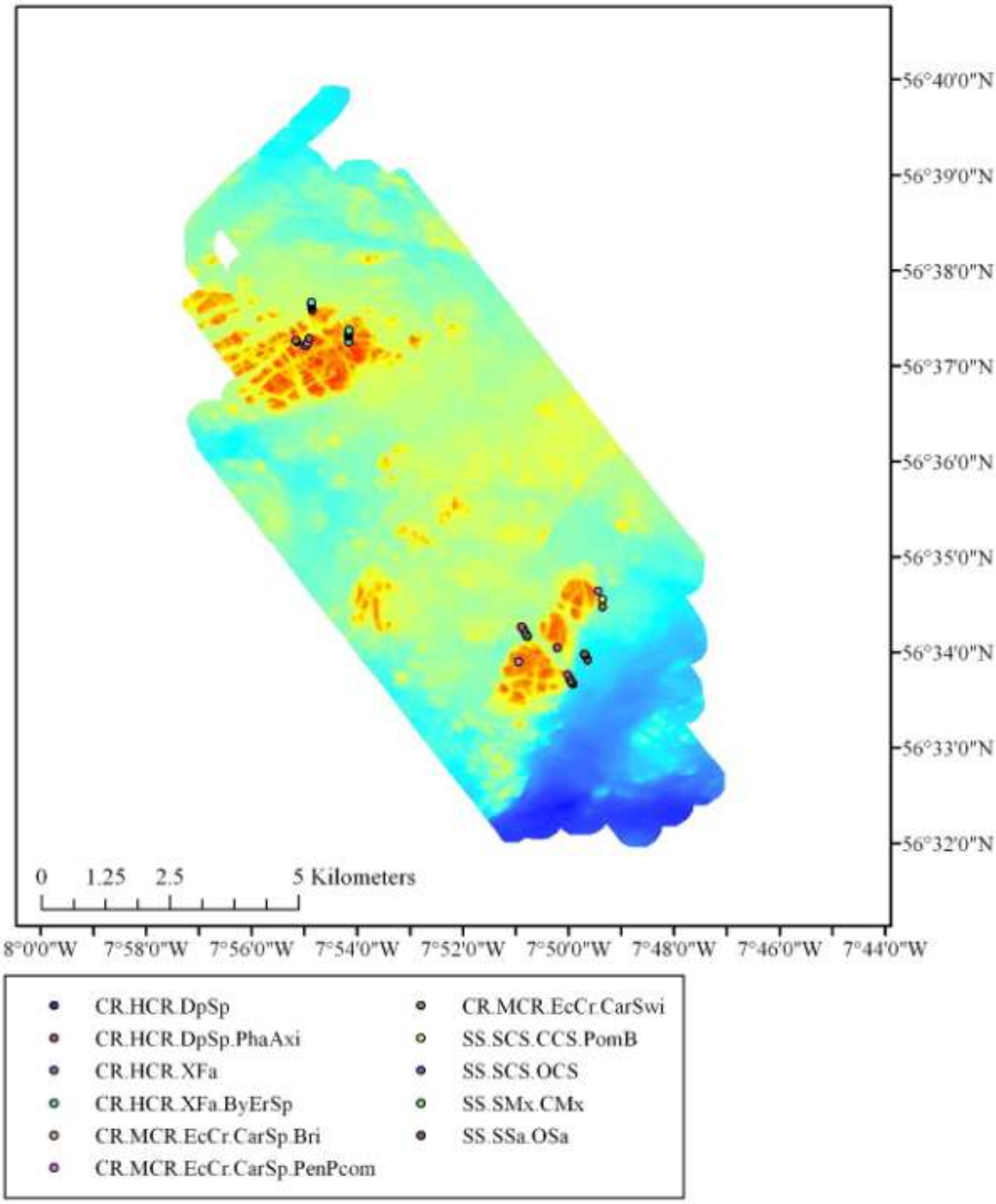

Figure 2e. Multibeam bathymetry for SW Barra Site with classed ground-truthing video tracks.

3.3 Multibeam bathymetries and ground-truthing

Figures 3a, 3b, 3c, 3d and 3e show the hillshaded multibeam sonar bathymetric grids for each survey site, along with the ground-truthing positions overlaid and AGDS data (acoustic ground-discrimination system: RoxAnn or QTC-view). Note that no AGDS data was recorded on Barra Site 5, due to interference issues. The ground-truthing positions have been coloured by biotope. For Barra Sites 1, 2, 3 and 5 these positions were generated every 2 minutes, with additional positions included where a biotope transition occurred. Therefore, although each video tow was continuous, only the recorded positions have been shown. These positions were corrected for cable layback and water depth using Pythagoras' theorem. For the SW Barra site, a drop frame was used so layback was assumed to be negligible. Positions for these video drops were taken every 5-10 seconds using the QTC-view navigation recording facility. This results visually in a more continuous video track. It should be noted that each figure shows bathymetric features that appear to be bedrock outcrops, surrounded by more level, homogeneous areas (softer sediments). In Barra Site 5 there are additionally 'channels' in the softer sediment which may be driven by current scour and indicate a high energy environment. Each site shows a diverse topography that potentially harbours an array of biotopes.

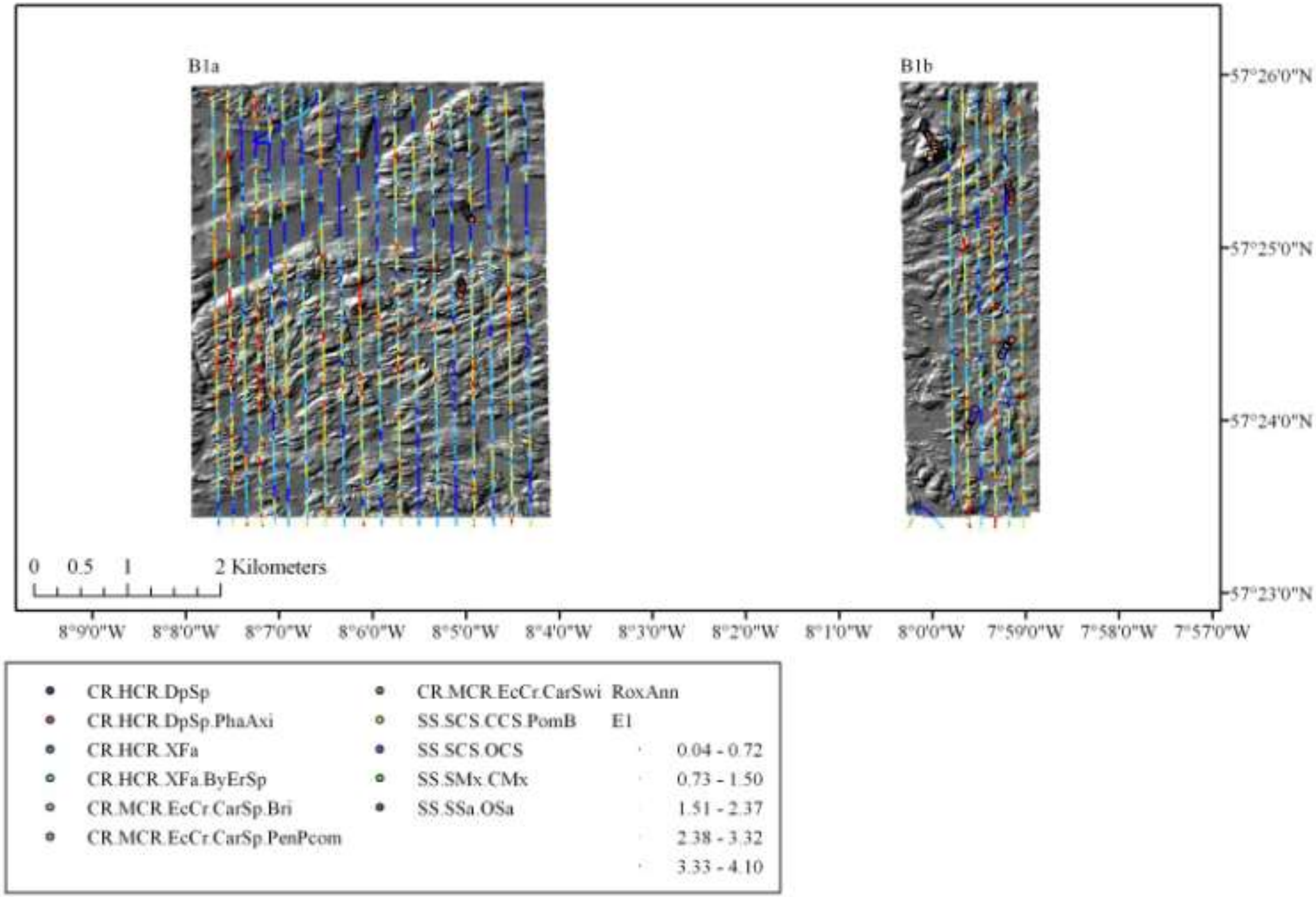

Figure 3a. Hillshaded multibeam bathymetry for Barra Site 1, with RoxAnn AGDS data overlaid (showing roughness- E1) and classed ground-truthing video tracks

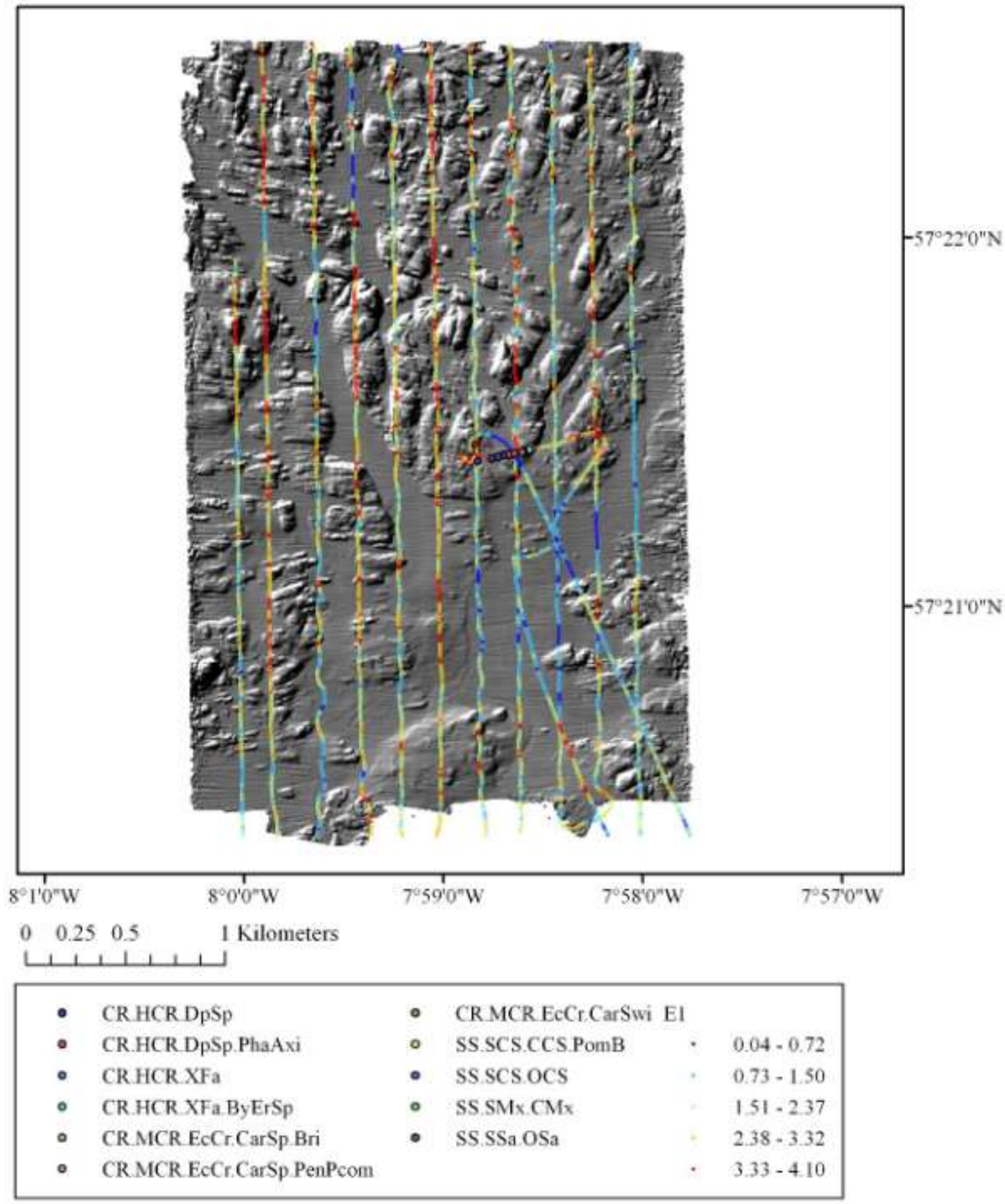

Figure 3b. Hillshaded multibeam bathymetry for Barra Site 2, with RoxAnn AGDS data overlaid (showing roughness- E1) and classed ground-truthing video tracks.

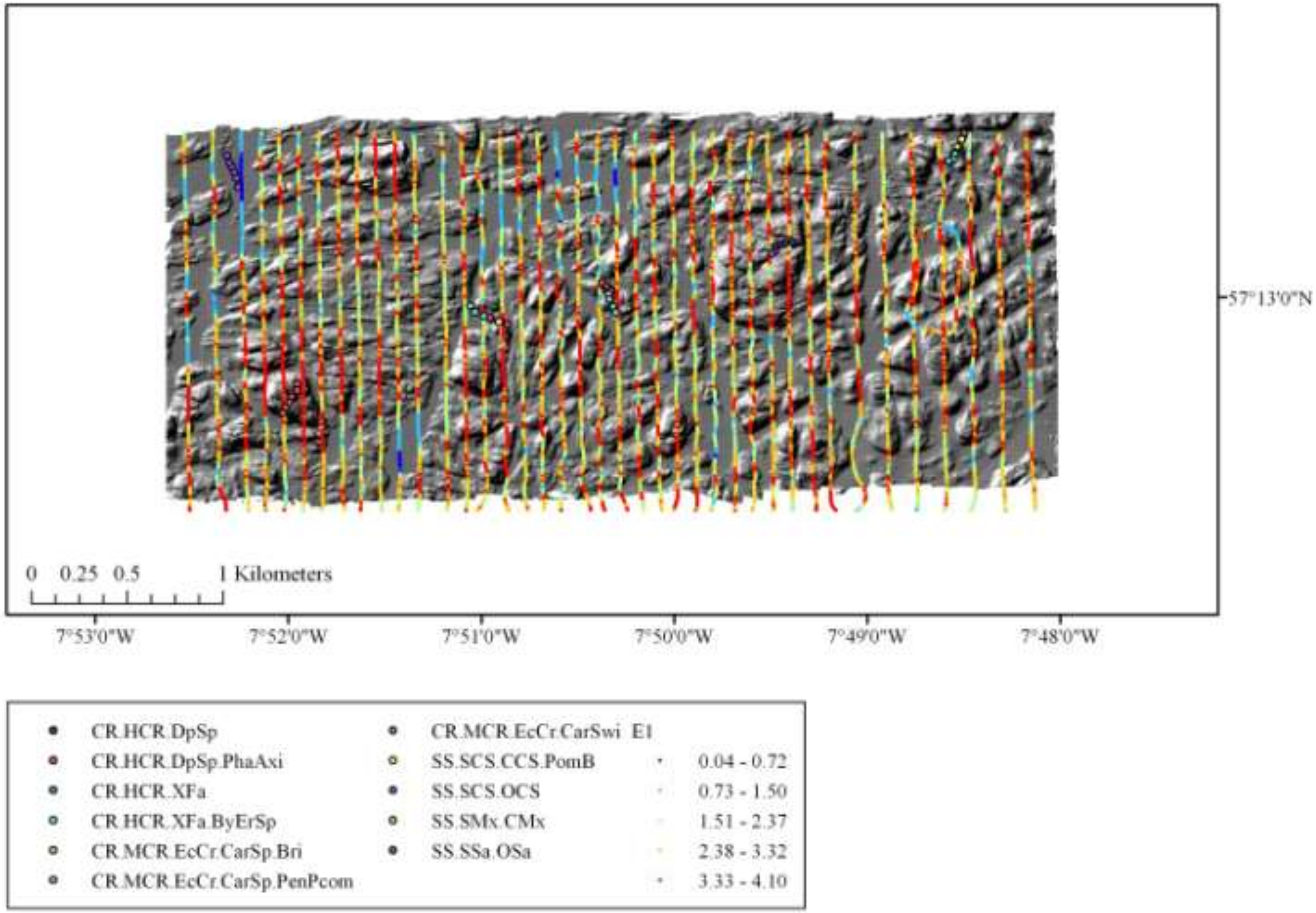

Figure 3c. Hillshaded multibeam bathymetry for Barra Site 3, with RoxAnn AGDS data overlaid (showing roughness- E1) and classed ground-truthing video tracks.

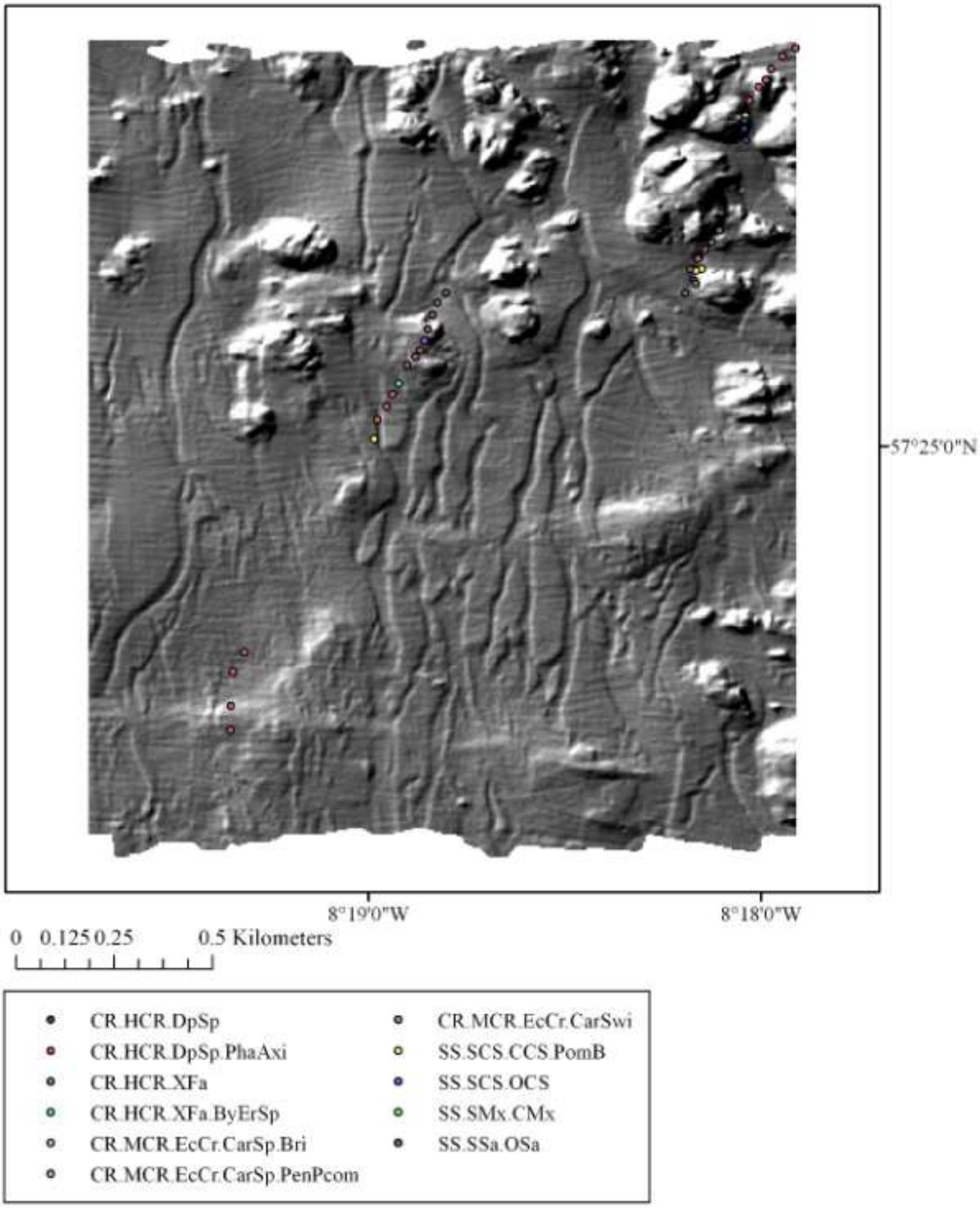

Figure 3d. Hillshaded multibeam bathymetry for Barra Site 5, and classed ground-truthing video tracks (no RoxAnn AGDS data available).

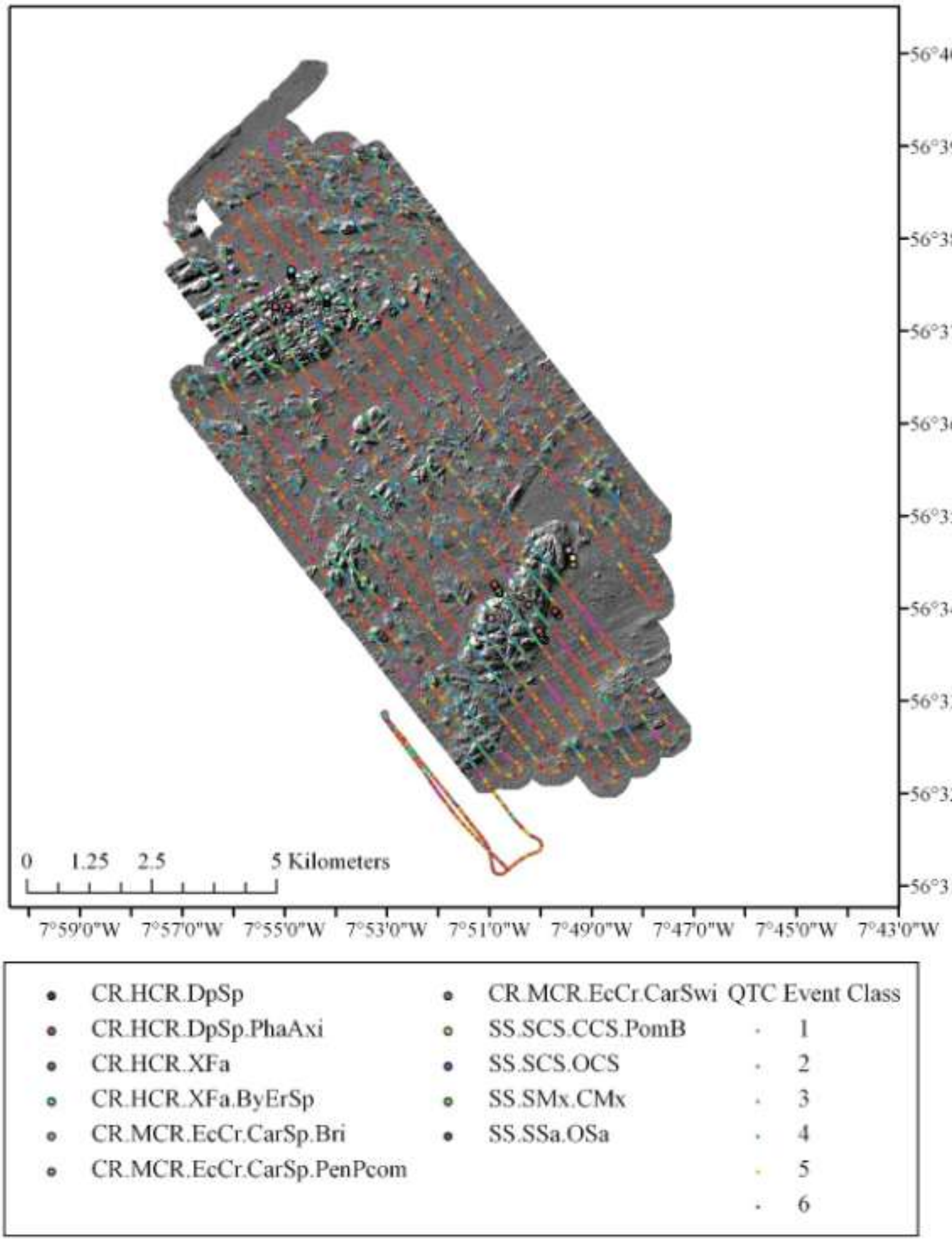

Figure 3e. Hillshaded multibeam bathymetry for SW Barra Site, with classed QTC-View AGDS data overlaid and classed ground-truthing video tracks.

3.4 Multibeam bathymetric data post-processing

In order to facilitate mapping of habitats, topographic features as shown in the previous figures may be further emphasised by post-processing of the bathymetric grid data. In particular, two datasets may be derived (Section 2): Slope angle and Rugosity. The rugosity is calculated as a ratio of surface area to planar area, hence providing a value for terrain complexity. Both slope angle and seabed rugosity/complexity may exert a significant influence upon the distribution of biotopes and it is therefore very useful to calculate these, and examine how the biotope-categorised ground-truthing falls upon these data grids. Figures 4a, 4b, 4c, 4d and 4e show slope angle with ground-truthing overlaid, while figures 5a, 5b, 5c, 5d and 5e show rugosity with ground-truthing overlaid. Slope angle and rugosity appear to follow very similar spatial patterns, with the highest values occurring at the edges/walls of bedrock outcrops.

In general the outcrops showed higher values for rugosity than surrounding areas, even with a reduction in slope angle on top of the outcrops as the topography levels out. From the ground-truthing it was observed that much of the bedrock was heavily fissured, with some such fissures being large (>10m) and containing boulders, cobbles and coarse sand. This would lead to an overall high level of rugosity over the bedrock outcrops. Both slope angle and rugosity were calculated using a 5m grid for Barra Sites 1, 2, 3 and 5, and a 4m grid for SW Barra, and therefore must be considered over this scale (ie finer scale rugosity will not be shown).

These data grids were found to be particularly valuable in the drawing of the final habitat maps, as many of the biotopes/biotope complexes occurred over distinct ranges of slope angles and/or rugosity. In SW Barra for instance, CR.MCR.EcCr.CarSp.PenPor occurred predominantly on the walls/edges of the bedrock outcrops, which were highlighted using the slope angle and rugosity datasets.

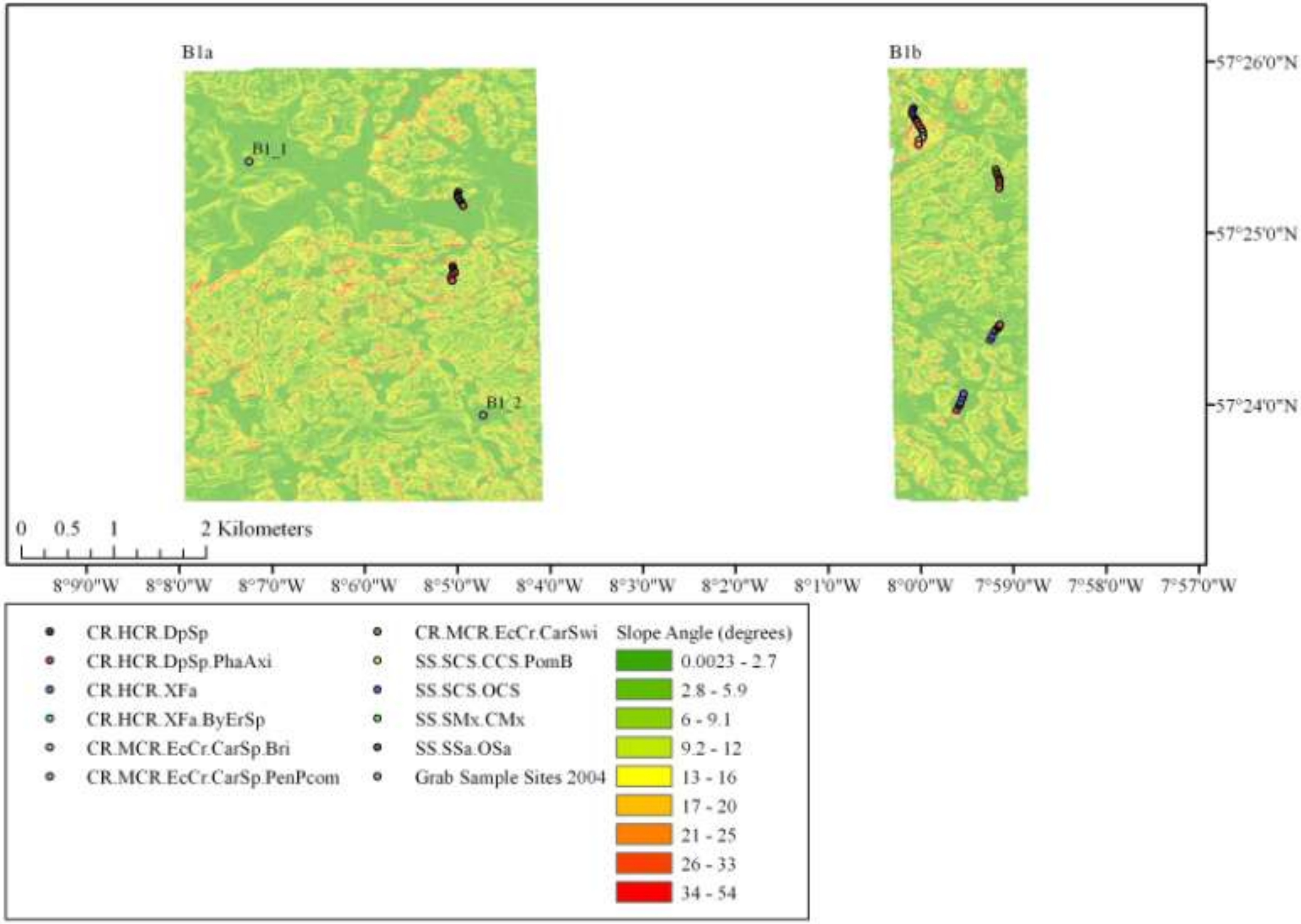

Figure 4a. Slope angle (in degrees) for Barra Site 1, with classed video ground-truthing overlaid.

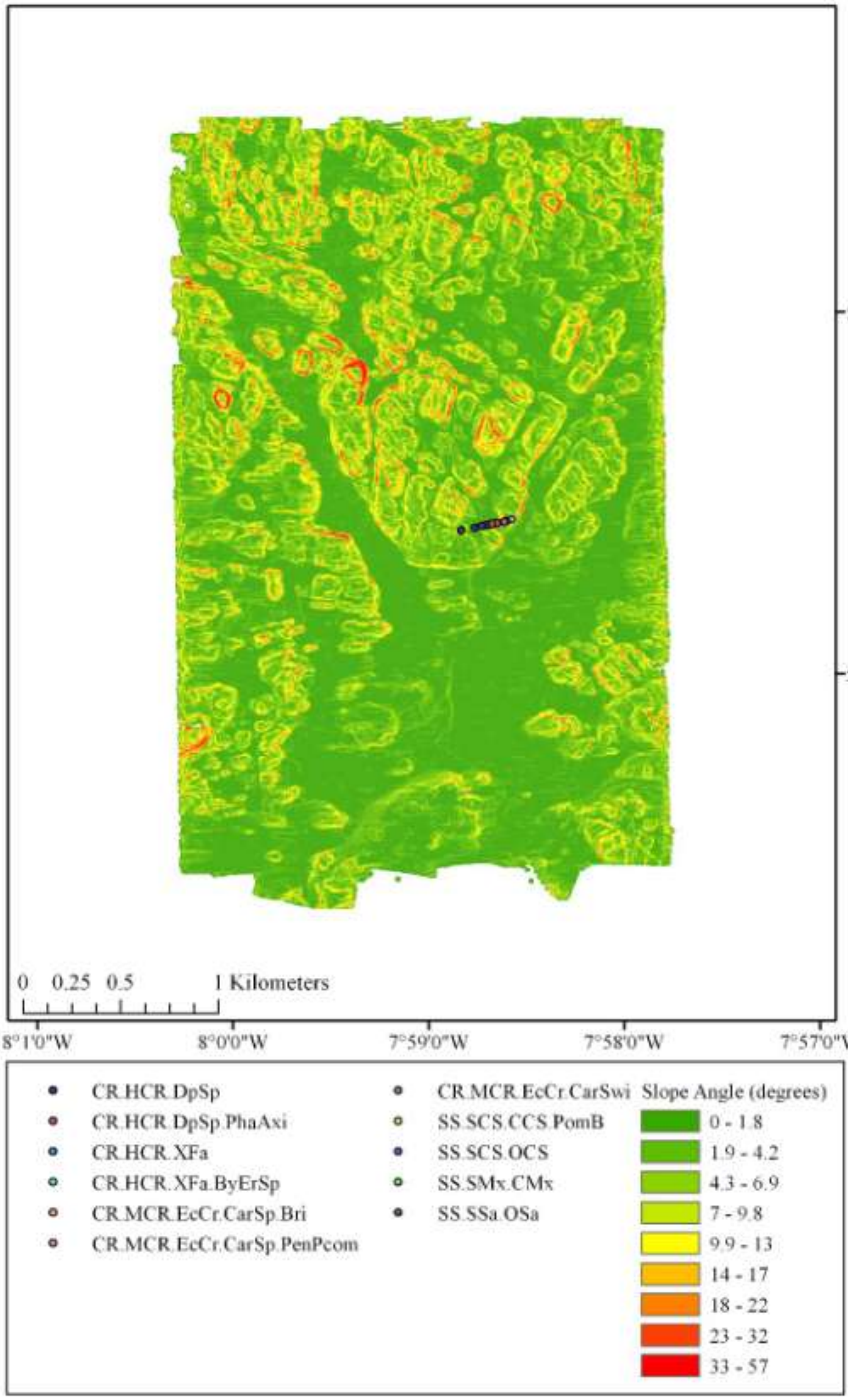

Figure 4b. Slope angle (in degrees) for Barra Site 2, with classed video ground-truthing overlaid.

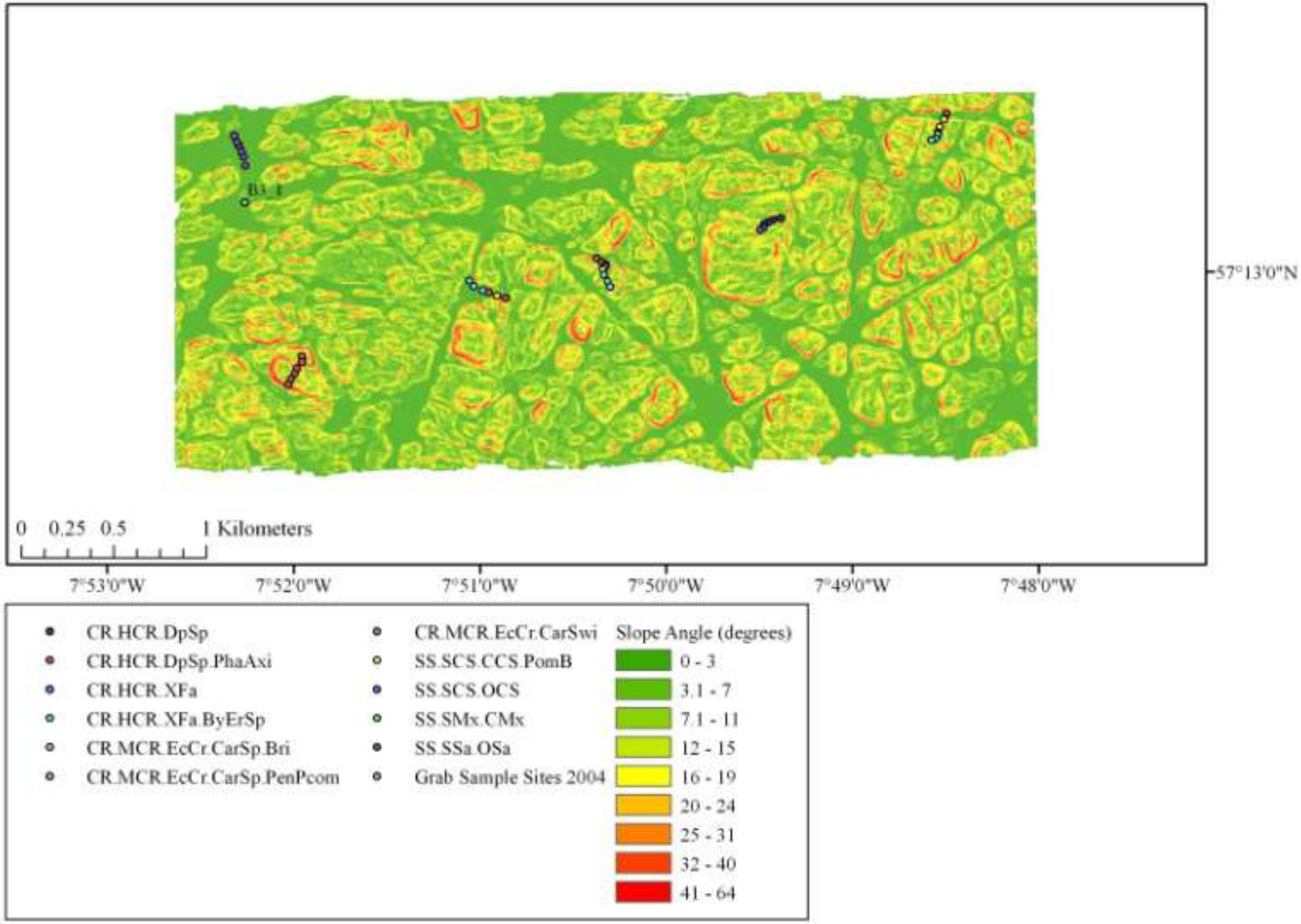

Figure 4c. Slope angle (in degrees) for Barra Site 3, with classed video ground-truthing overlaid.

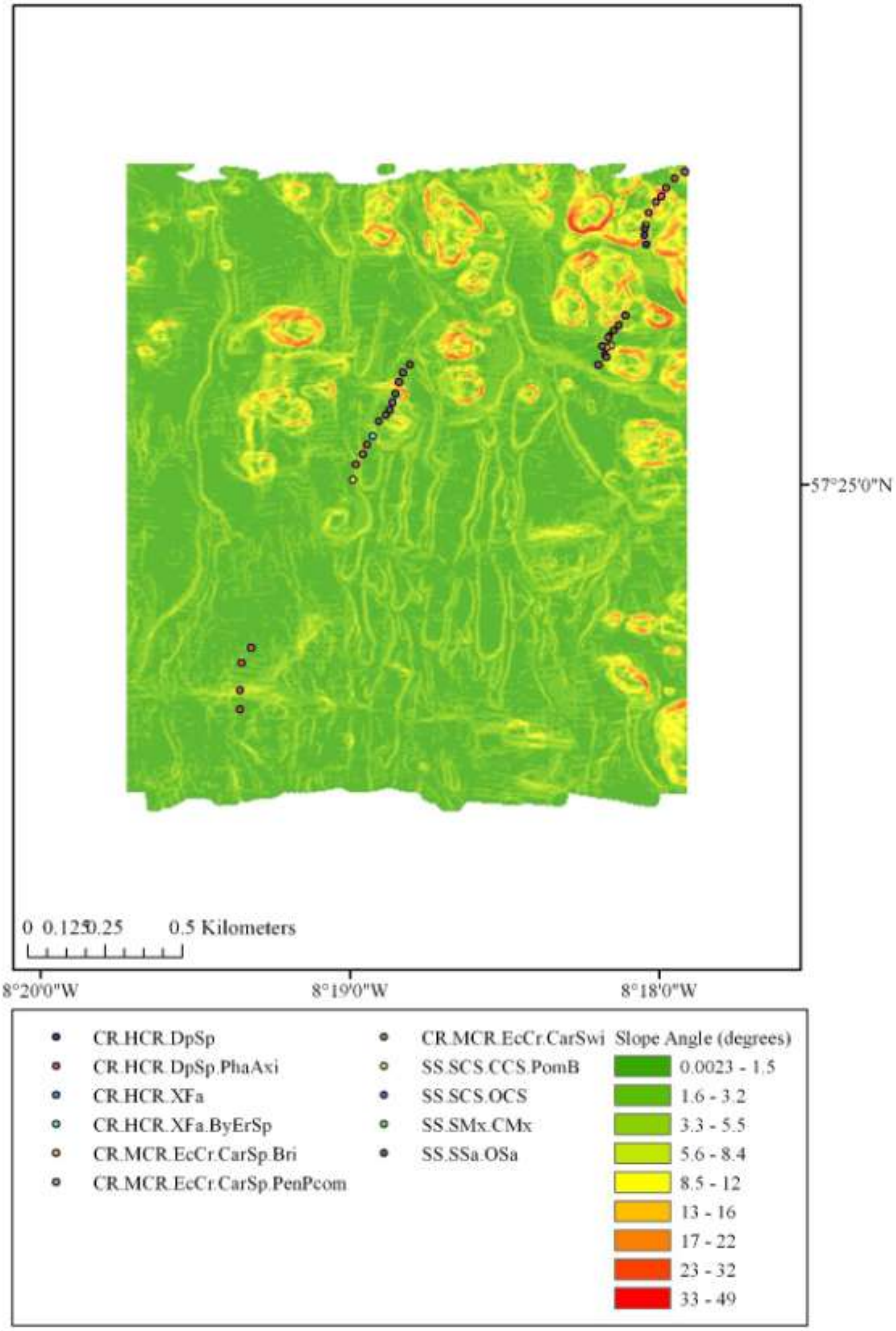

Figure 4d. Slope angle (in degrees) for Barra Site 5, with classed video ground-truthing overlaid.

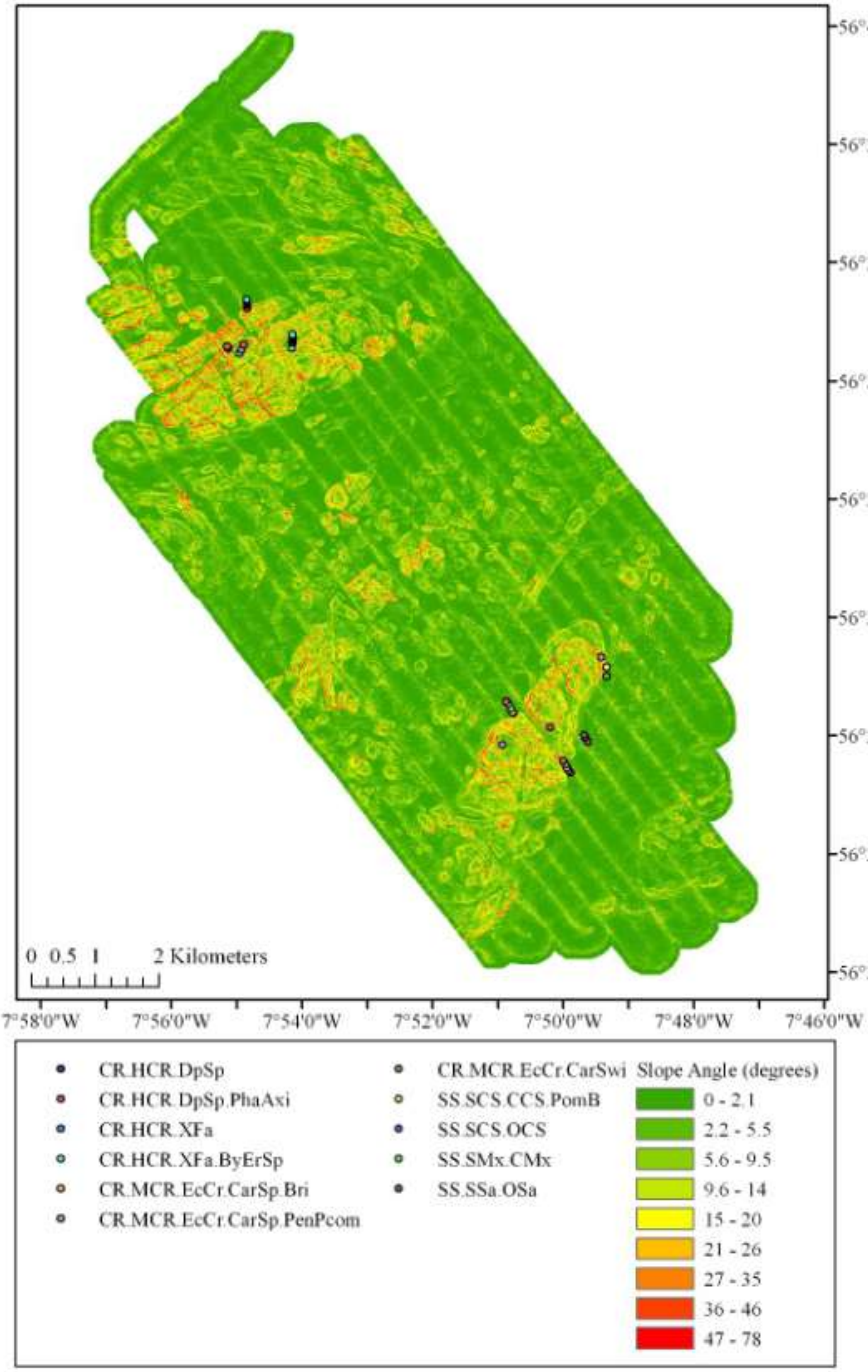

Figure 4e. Slope angle (in degrees) for SW Barra Site, with classed video ground-truthing overlaid.

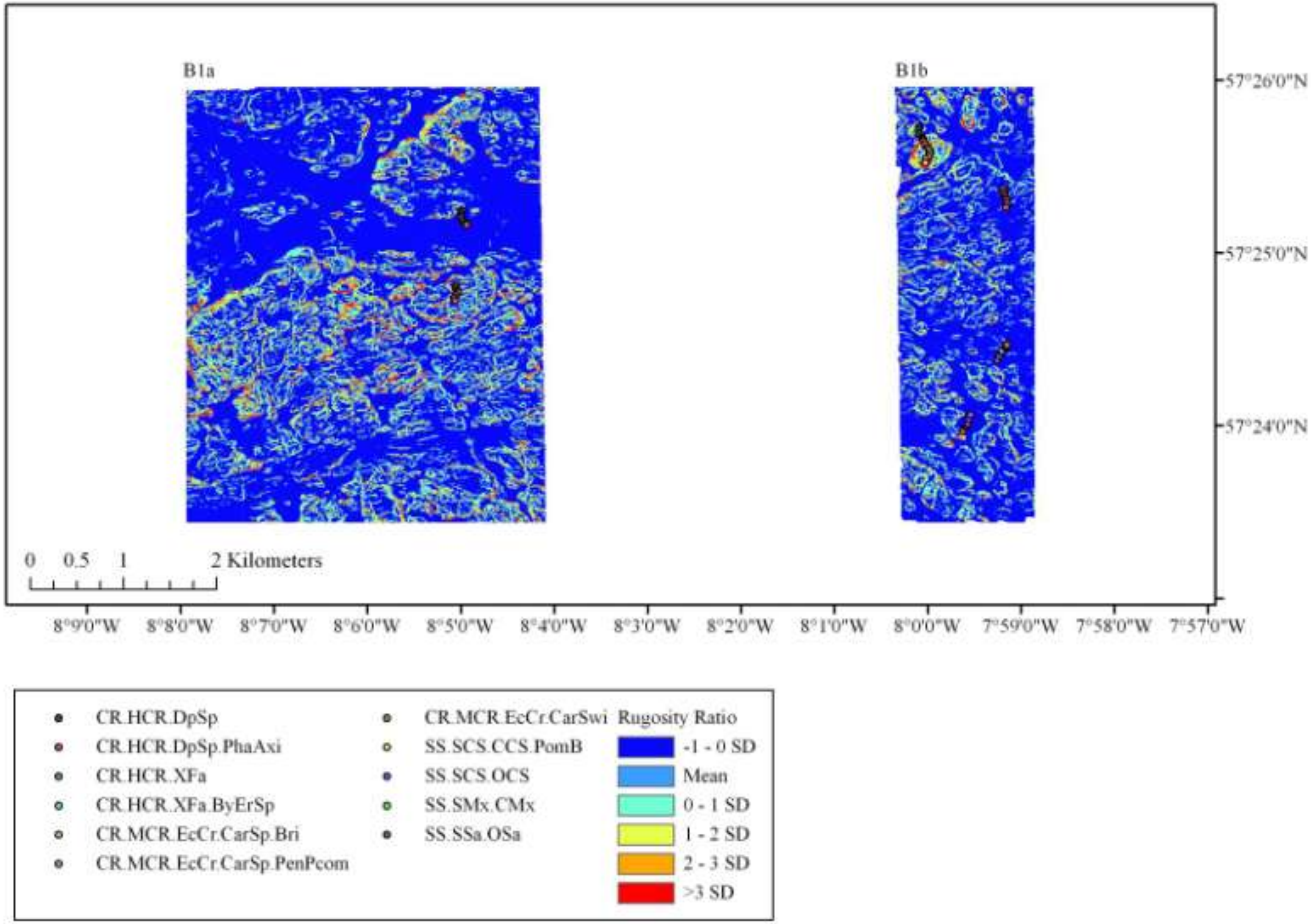

Figure 5a. Rugosity (classed into standard deviations) for Barra Site 1, with classed ground-truthing overlaid.

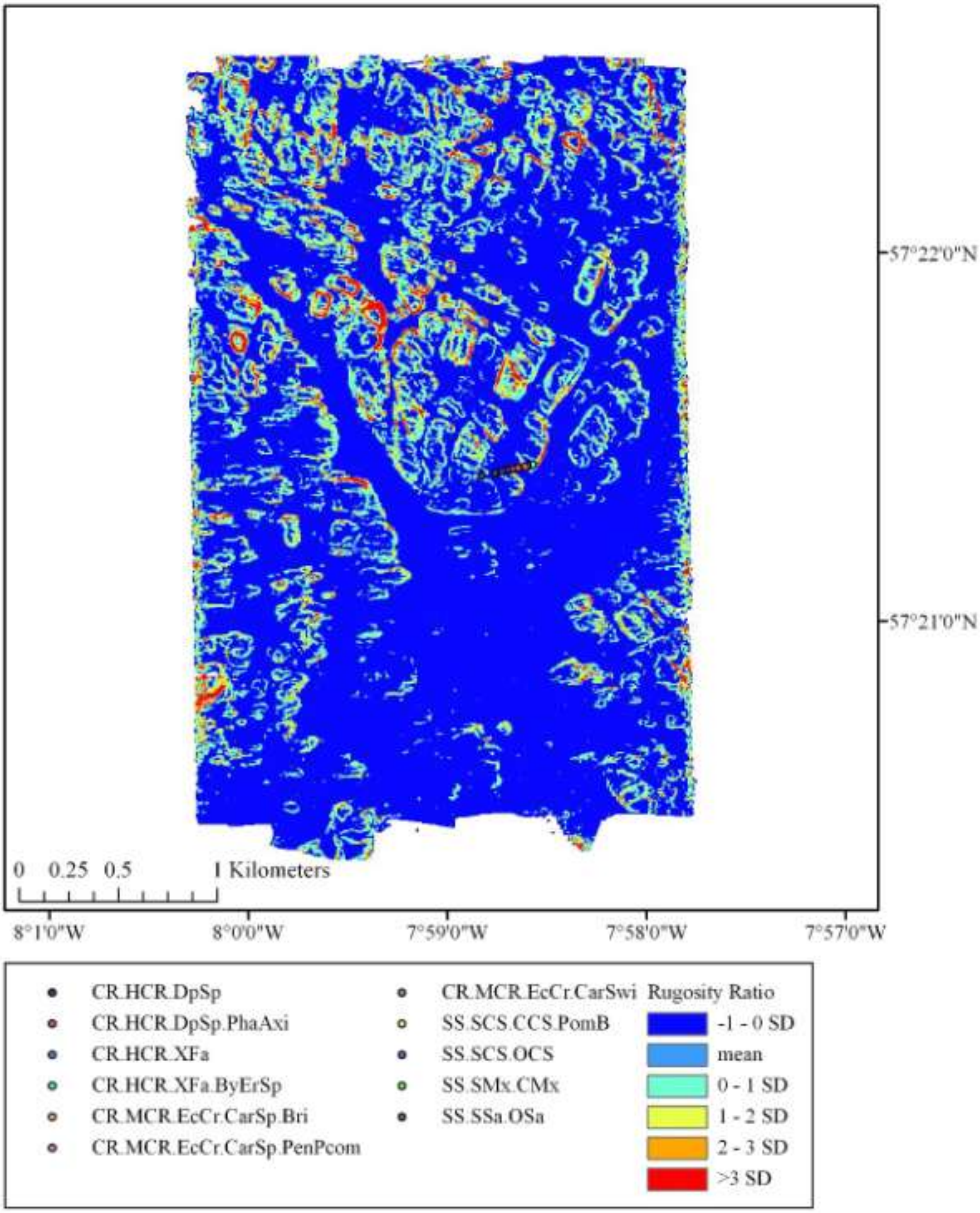

Figure 5b. Rugosity (classed into standard deviations) for Barra Site 2, with classed ground-truthing overlaid.

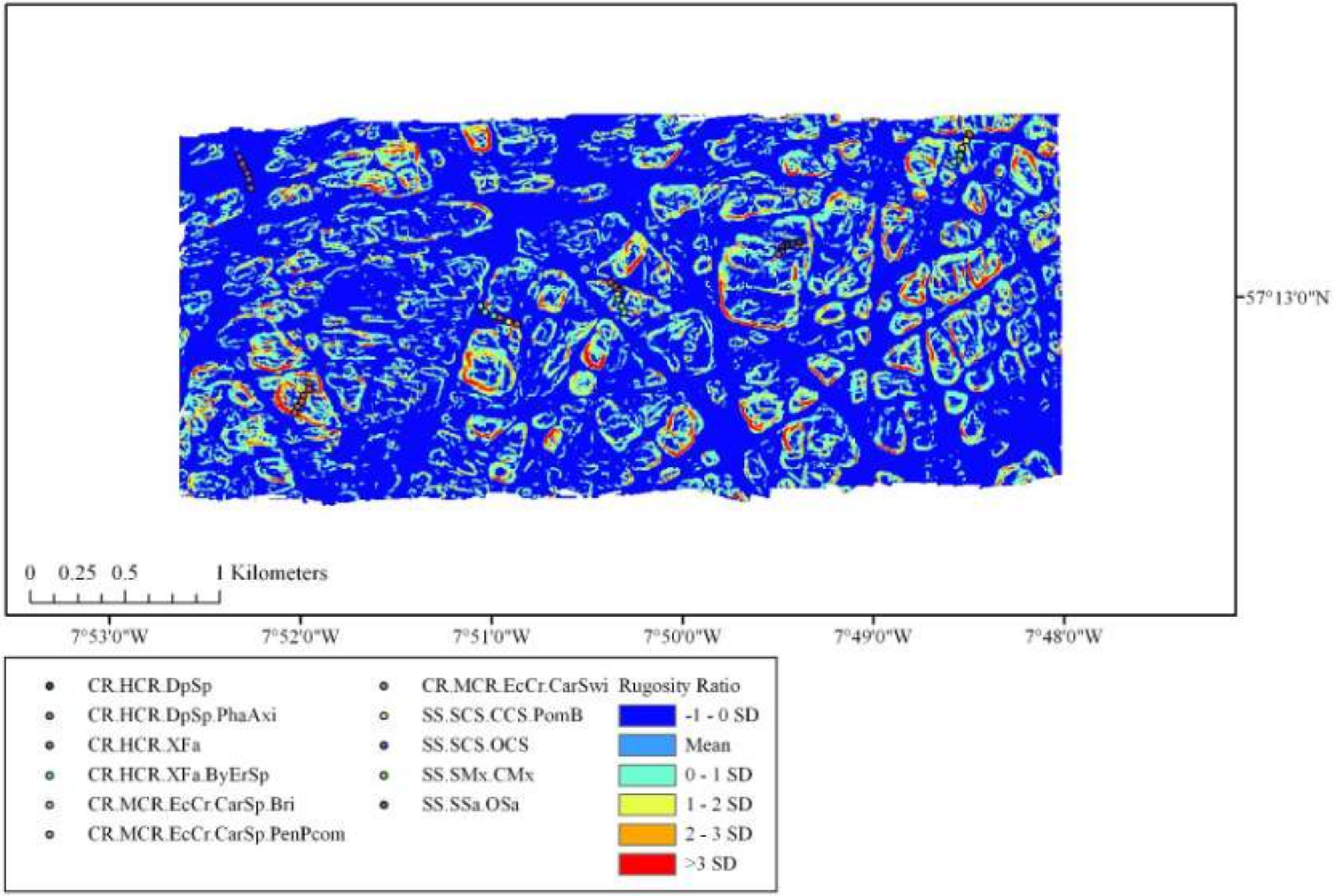

Figure 5c. Rugosity (classed into standard deviations) for Barra Site 3, with classed ground-truthing overlaid.

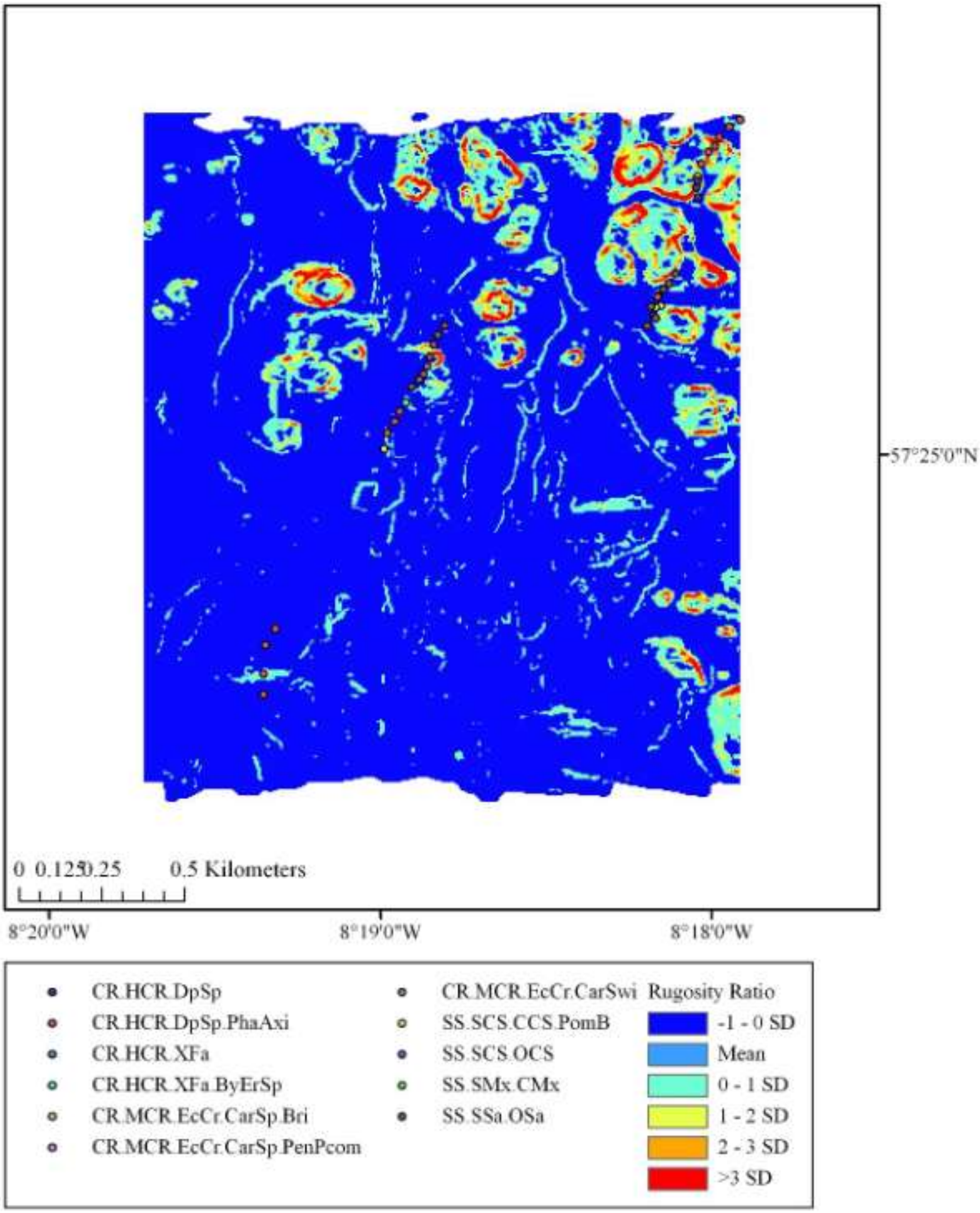

Figure 5d. Rugosity (classed into standard deviations) for Barra Site 5, with classed ground-truthing overlaid.

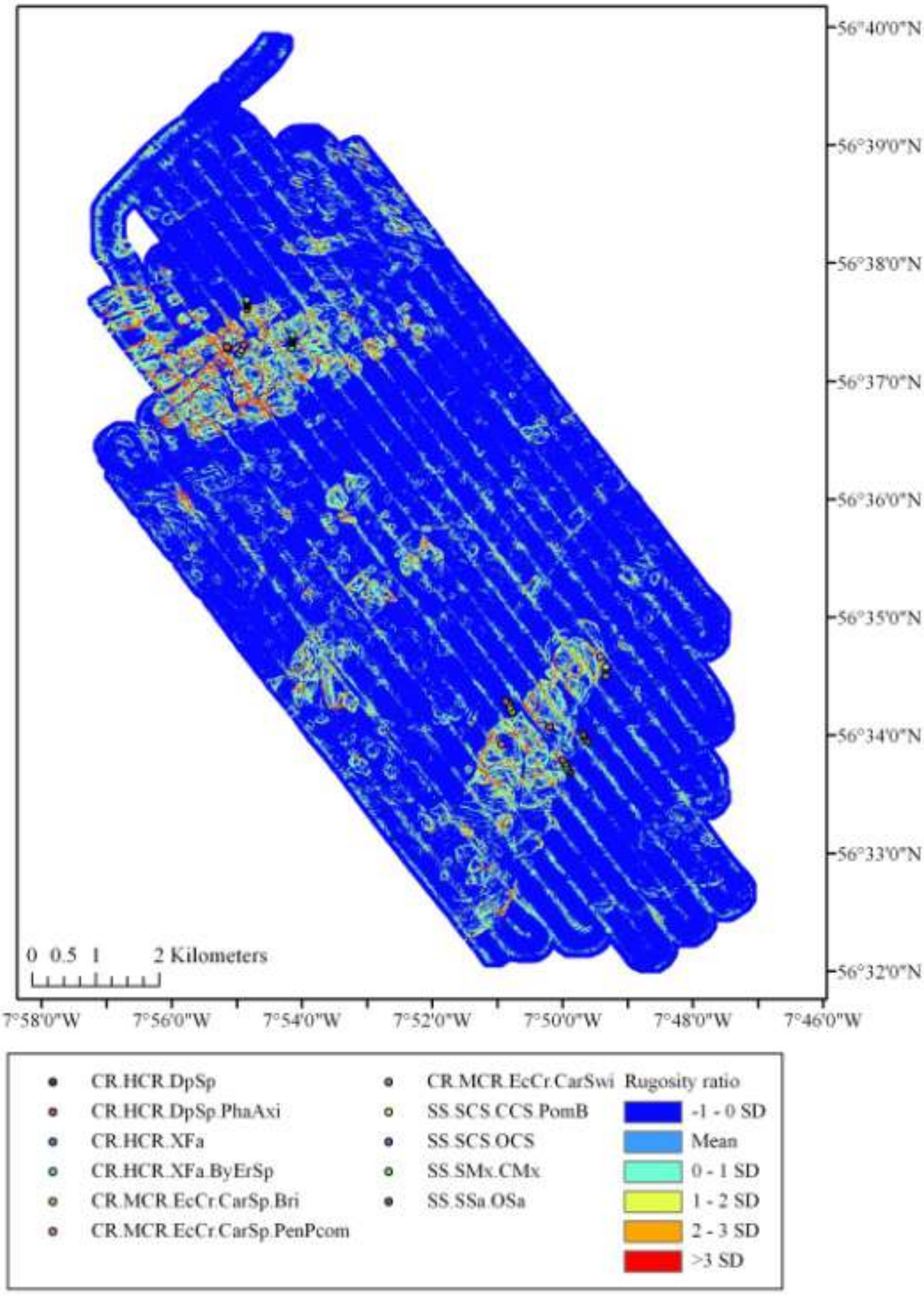

Figure 5e. Rugosity (classed into standard deviations) for SW Barra Site, with classed ground-truthing overlaid.

3.5 Multibeam backscatter mosaics

Multibeam backscatter data was provided as cleaned greyscale mosaics. These can aid interpretation of data for habitat mapping by indicating areas of hard/soft and rough/smooth ground, as shown in the greyscale ‘textures’. However, it was found that there were notable differences in the quality of these mosaics between sites, and most extremely between those processed using Caris SIPS (Barra Sites 1, 2, 3 and 5) and those processed by Tim Le Bas using in-house developed software PRISM (SW Barra site). This may also be in part due to the recording of backscatter data in ‘snippets’ from the Reson 8101 system while in the field (which was not completed for Barra Sites 1, 2, 3 and 5, as Caris SIPS is currently unable to handle data in this format). Snippets were utilised by the Southampton Oceanography Centre team and enabled processing by the PRISM software resulting in high quality, high resolution backscatter data mosaics. The mosaics from SW Barra provided information of a similar clarity to that expected from sidescan sonar, and reveal a great variety of seabed features and textures that were not visible from the mosaics for Barra Sites 1, 2, 3 and 5. The SW Barra backscatter mosaics enabled the delineation of habitat polygons with comparative ease, but also indicated that a range of features had not been ground-truthed adequately enough to permit habitat designation. Figures 6a, 6b, 6c, 6e and 6d below provide the backscatter mosaics for each survey site, overlaid by ground-truthing data.

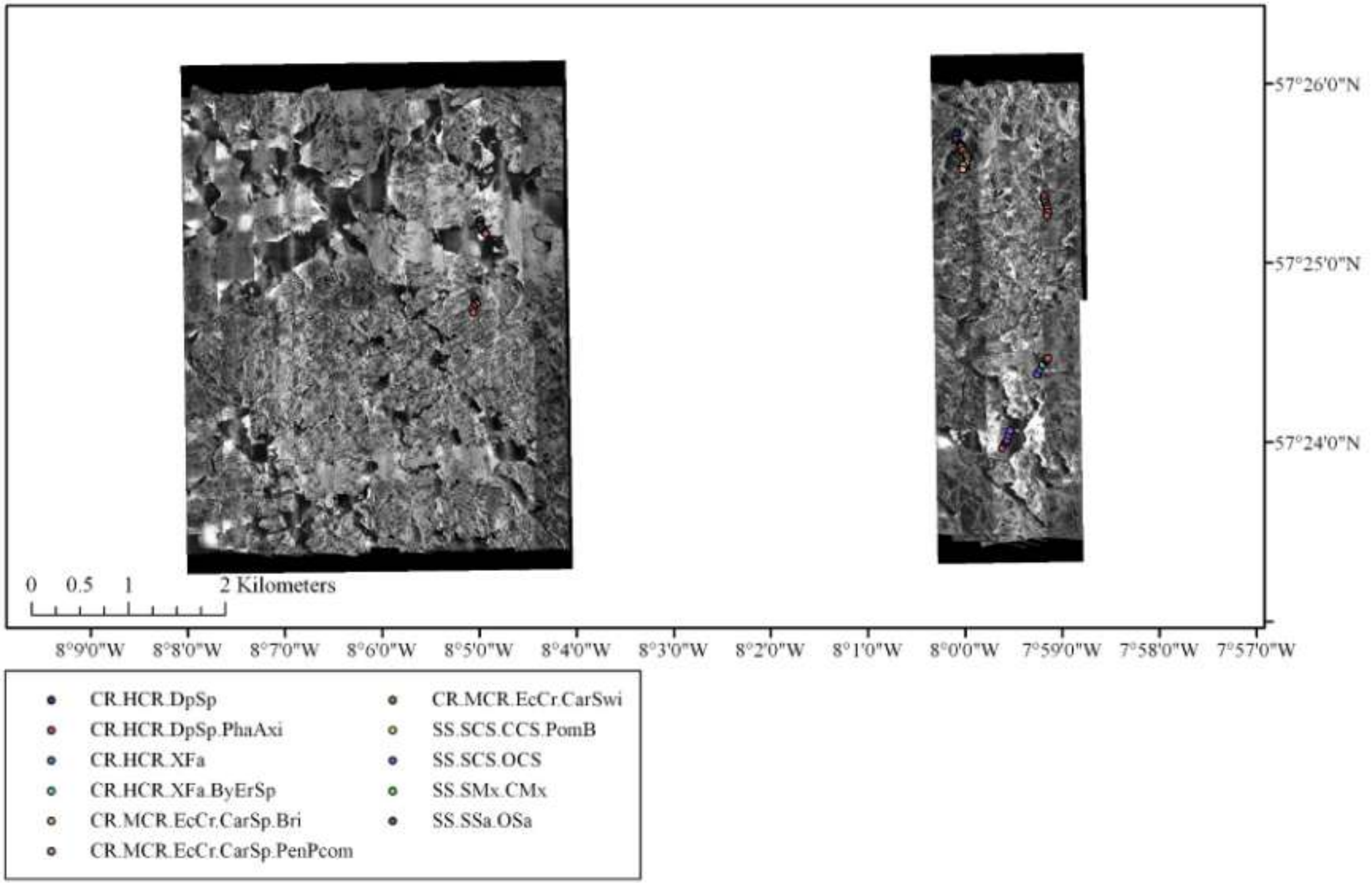

Figure 6a. Backscatter mosaics (processed using Caris SIPS software) for Barra Site 1, with classed ground-truthing video tracks overlaid.

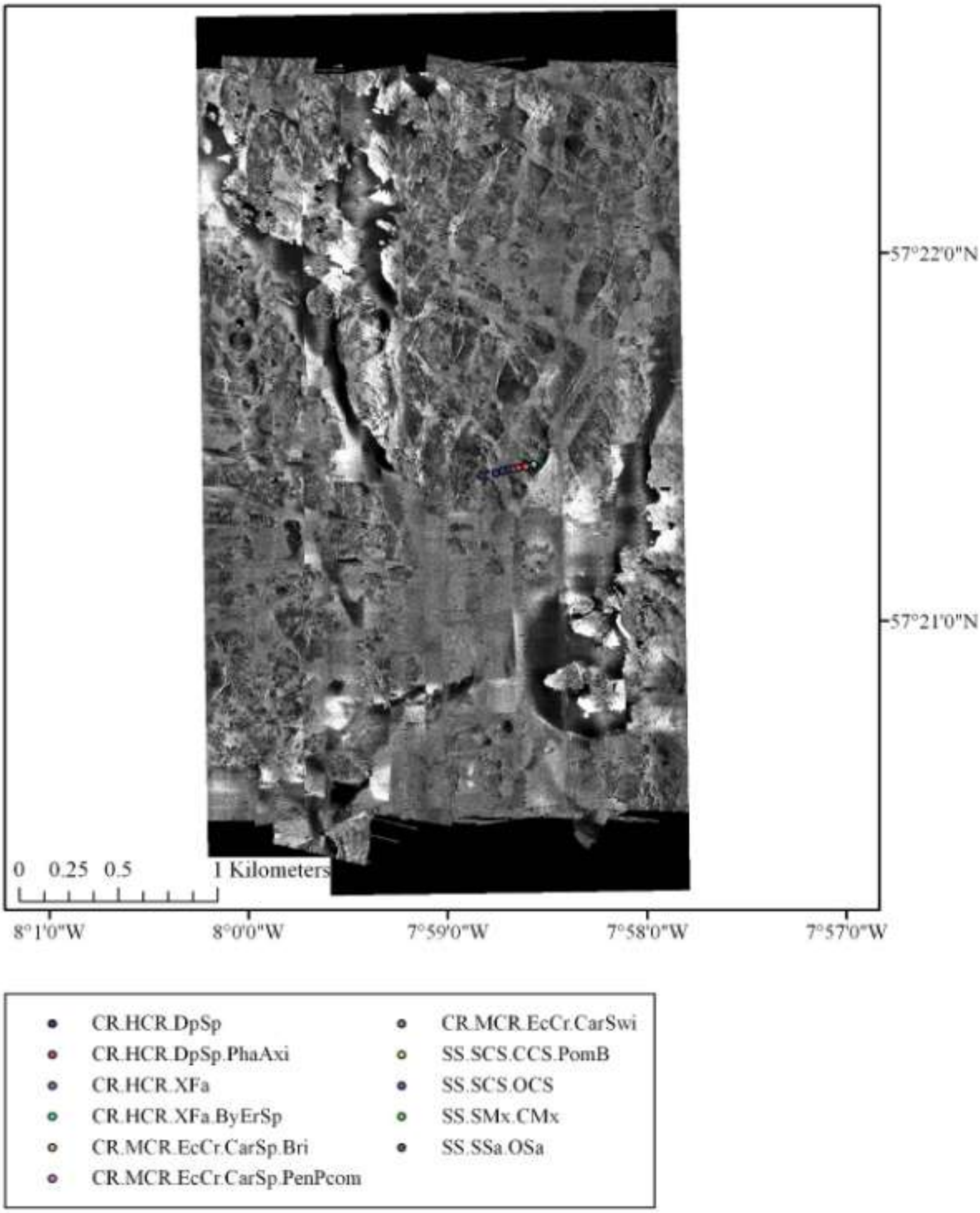

Figure 6b. Backscatter mosaics (processed using Caris SIPS software) for Barra Site 2, with classed ground-truthing video tracks overlaid.

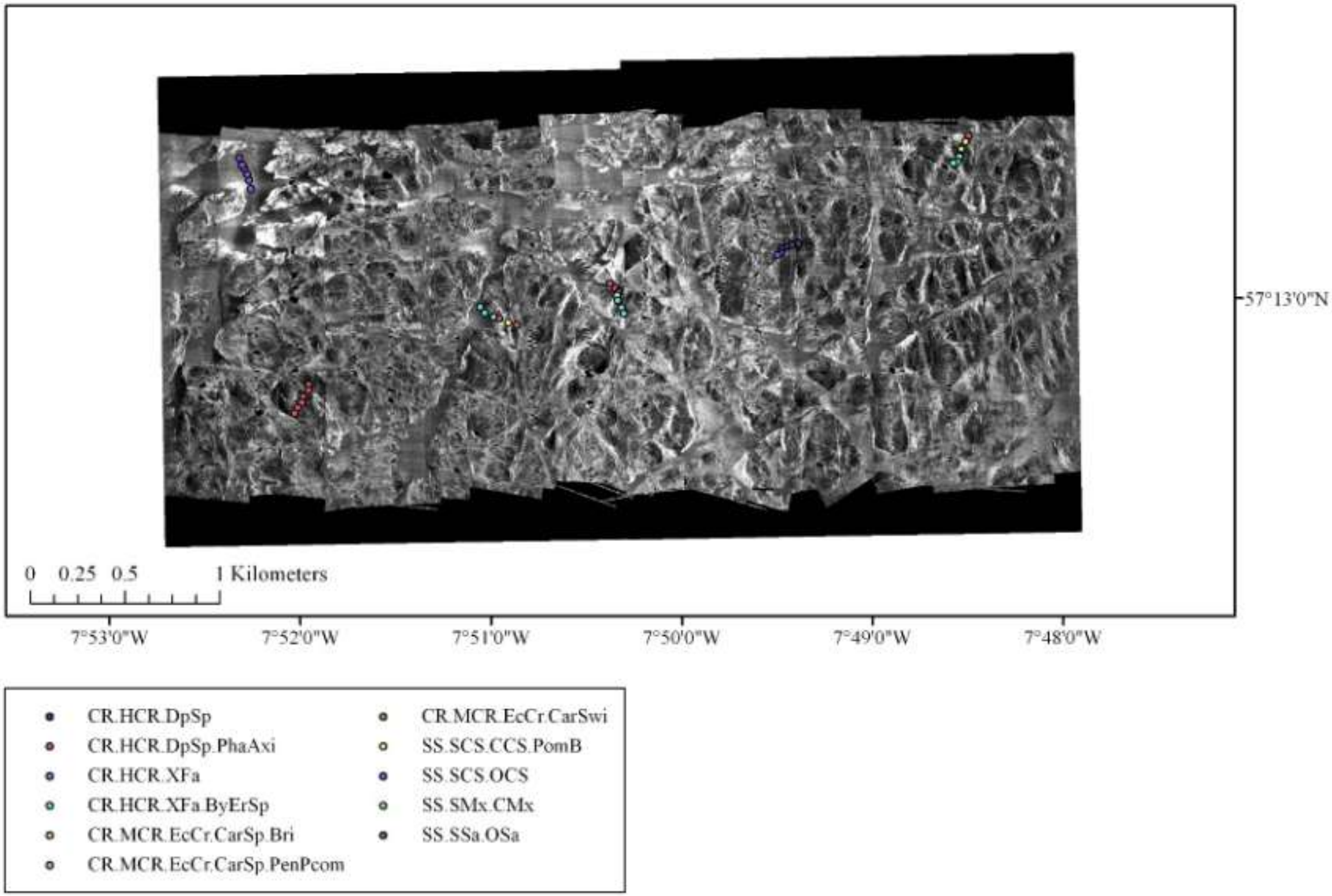

Figure 6c. Backscatter mosaics (processed using Caris SIPS software) for Barra Site 3, with classed ground-truthing video tracks overlaid.

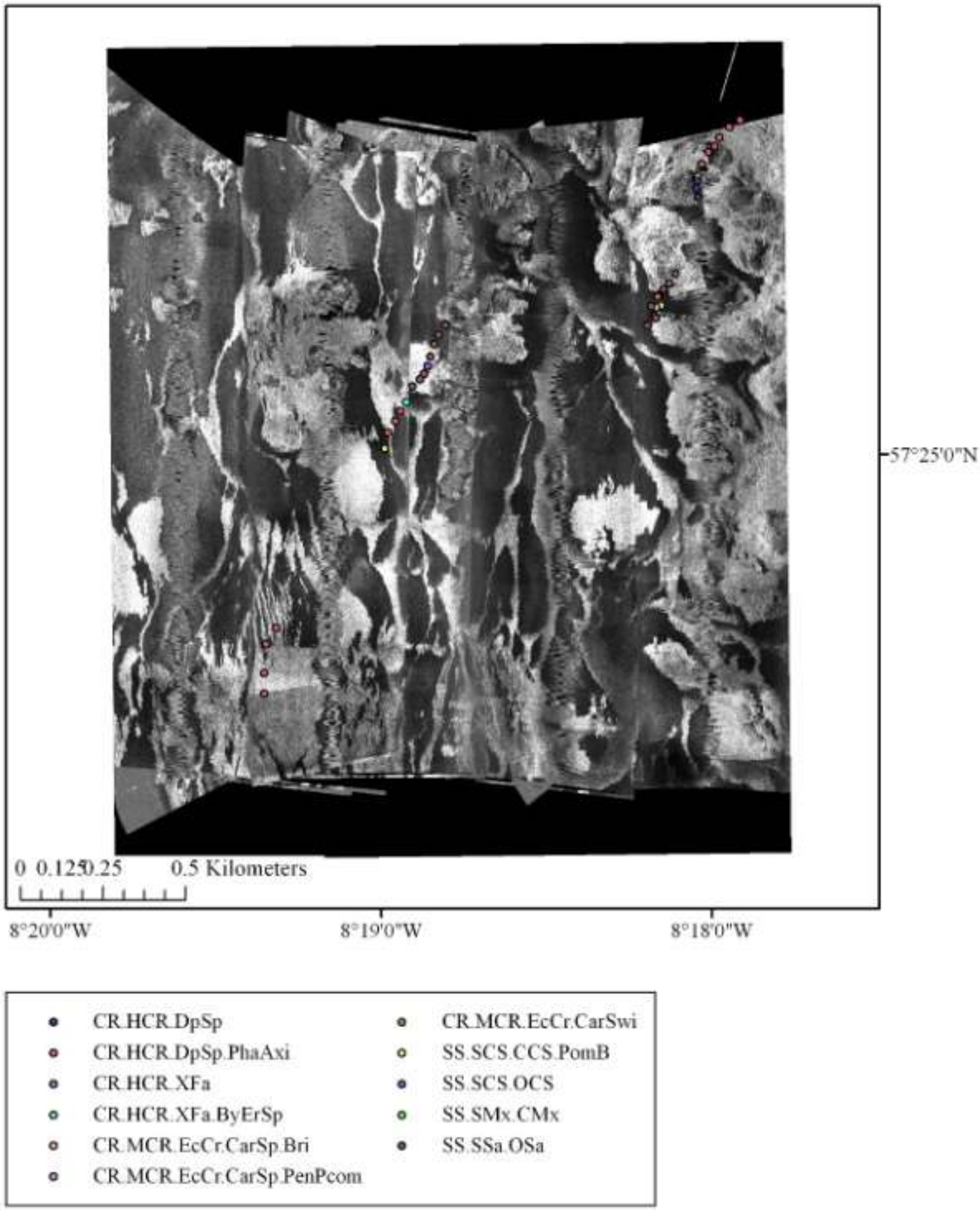

Figure 6d. Backscatter mosaics (processed using Caris SIPS software) for Barra Site 5, with classed ground-truthing video tracks overlaid

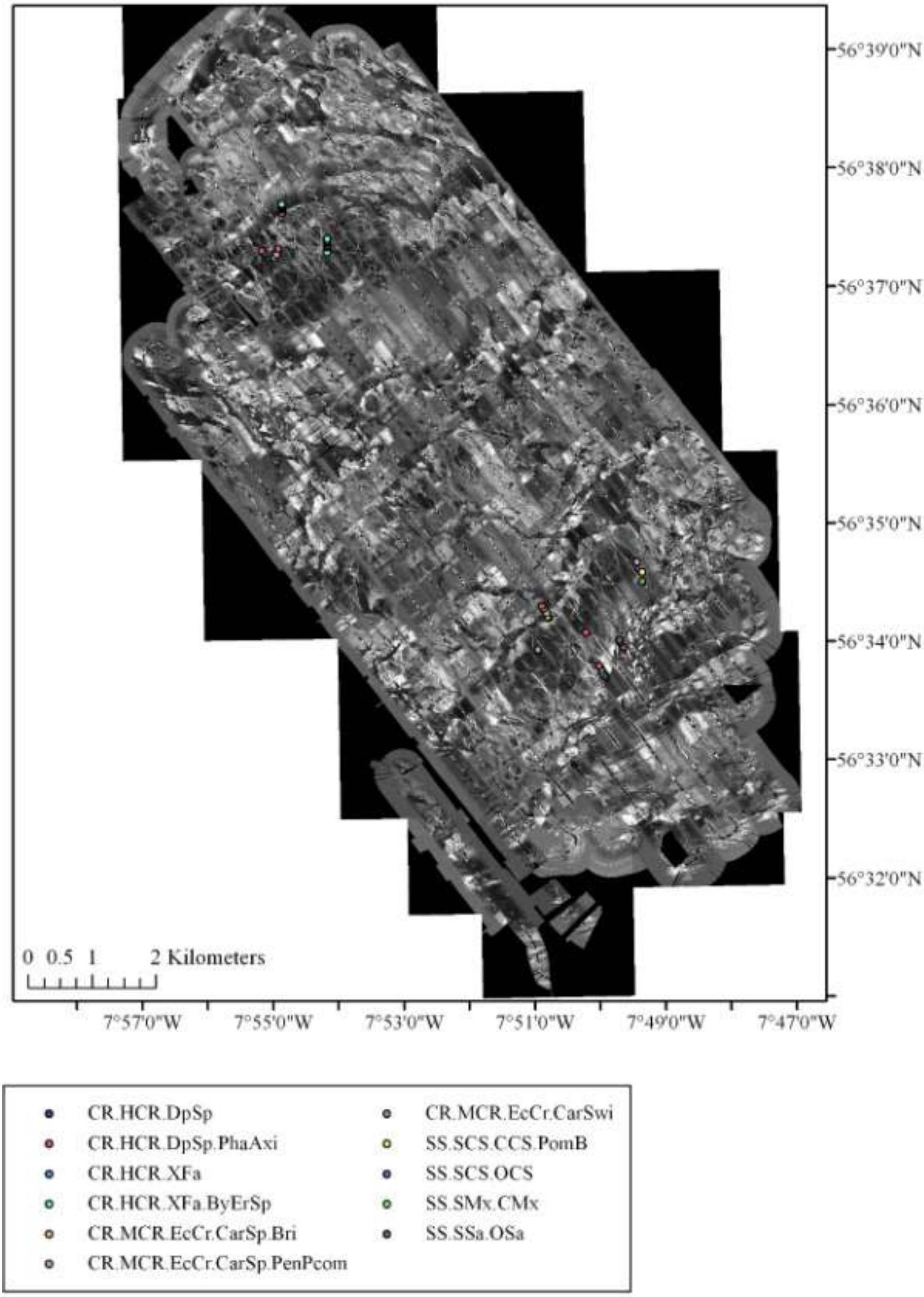

Figure 6e. Backscatter mosaics (processed using PRISM, from Reson 8101 snippets data) for SW Barra Site, with classed ground-truthing video tracks overlaid. Nadir runs through the mid-line of all tracks.

3.6 Final interpreted habitat maps

Figures 7a, 7b, 7c, 7d and 7e (i), (ii) and (iii) show the final habitat maps for each survey site, categorised to biotope level where possible. Classification of mapped habitats to biotope level was only undertaken where each biotope had a adequately-distinct 'signature' in terms of bathymetric features, slope angle, rugosity, backscatter and/or AGDS data values. This was assessed upon examination of the data layers underlying the relevant ground-truthing records in a GIS; each survey site was treated separately. Habitats were mapped in the immediate vicinity of the ground-truthing data, and were only drawn further from ground-truthing within a survey site where it was deemed there was a sufficiently distinct signature to allow this to have scientific credence. Great care was taken to avoid over-interpolation of data, and therefore some gaps exist between habitat polygons and also over entire areas with the survey sites. It is recommended that where such data gaps exist, future survey programmes should attempt to target these areas to improve ground-truthing coverage, and allow a complete interpretation of the multibeam sonar data. As all habitat polygons have been delineated manually, there are obvious issues with repeatability. However, as yet there is no other means of integrating and interpreting this many datasets for such a purpose.

For the purposes of this report, where bathymetric data is of a very high quality, it was possible to use Raster Calculator (ArcGIS; ESRI) to generate a predicted dataset showing the bedrock areas within each survey site. In each site the bedrock habitat ground-truthing samples were examined in terms of depth range and typical slope angles. This information was then used to select areas with such a depth range and slope angle within the survey site. This was only possible for Barra Sites 1, 2, 3 and 5, and the resulting maps (with predicted rock areas in orange) are provided in figures 8a, 8b, 8c and 8d, along with the raster calculation. Within the project GIS these raster datasets may be converted to vector datasets and the total area of bedrock within these sites calculated if required, as each raster has a cell size of $5m^2$. Unfortunately due to the time constraints in the field during the SW Barra site survey (due to weather), the multibeam sonar track spacing could not be altered with depth changes as would be the normal survey procedure, and this resulted in some data artefacts that although not clearly visible on the maps (apart from in the contour lines) are emphasised by any raster calculations. Therefore no similar calculation to those for Barra Sites 1, 2, 3 and 5 were performed on the SW Barra dataset.

In general, it appears that all sites contained biotopes typical of high energy environments (deep wave-exposed and tide-swept). In particular, deep sponge communities dominated the bedrock, which also appeared to be covered with some silt material. In the shallower areas, which may be more wave-exposed, bryozoan turf communities were frequently found. In the shallowest area of Barra Site 1b, at the top of a large outcrop, the CR.MCR.EcCr.CarSp.Bri biotope was identified (53-64m depth); the only example of this biotope recorded throughout the 5 survey areas by the video ground-truthing. The CR.MCR.EcCr biotopes appeared to be largely absent from the more northerly Barra Sites 1, 2, 3 and 5 but were notable in the SW Barra site, with the presence of CR.MCR.EcCr.CarSp.PenPor at the edges of large bedrock outcrops and on vertical rock walls. *Porella compressa* was generally far more common at the SW Barra site than at the other sites. CR.MCR.EcCr.CarSwi was also found in the SW Barra site on the dense boulderfields that surround the bedrock outcrops. Again, *Swiftia pallida* was frequently encountered at the SW Barra site but rarely found at the other sites. This may be due to a different hydrodynamic regime between these sites. Interestingly in the boulder areas of Barra Site 5, classed as a deep sponge community biotope (CR.HCR.DpSp.PhaAxi), there were many sightings of *Sebastes* spp rock/redfish on the video and photographic stills. These fish were not seen elsewhere, although on bedrock areas of all sites there were frequent sightings of wrasse. The sediment biotope complexes were typically highly mobile and, therefore, harboured few epifaunal species, with many such areas characterised by megaripples of 1-2m wavelength, or in finer sand areas by irregular small ripples. The megarippled sediment indicated a high energy environment, and also suggested that the neighbouring bedrock and boulderfields may be subject to sand scour, which may drive down species diversity in such areas, and particularly reduce the occurrence of erect sponges. This conclusion was upheld at many sites by the occurrence of the biotope SS.SCS.CCS.PomB on cobble areas adjacent to bedrock and to the coarse sand regions (*Pomatoceros triqueter* is commonly found on sand-scoured, hard substrates), and by the reduced frequency of erect sponges in boulderfields adjacent to coarse sand megaripples. In general, vertical or highly sloping bedrock walls harboured the greatest diversity of conspicuous epifauna, in particular erect and encrusting sponges (typified by the Axinellid sponges, along with *Phakellia ventilabrum* and *Polymastia boletiformis*), *Caryophyllia smithii*, and, in the SW Barra site, *Porella compressa.* The reader is encouraged to refer to the GIS project to examine species composition of the video records over different substrates.

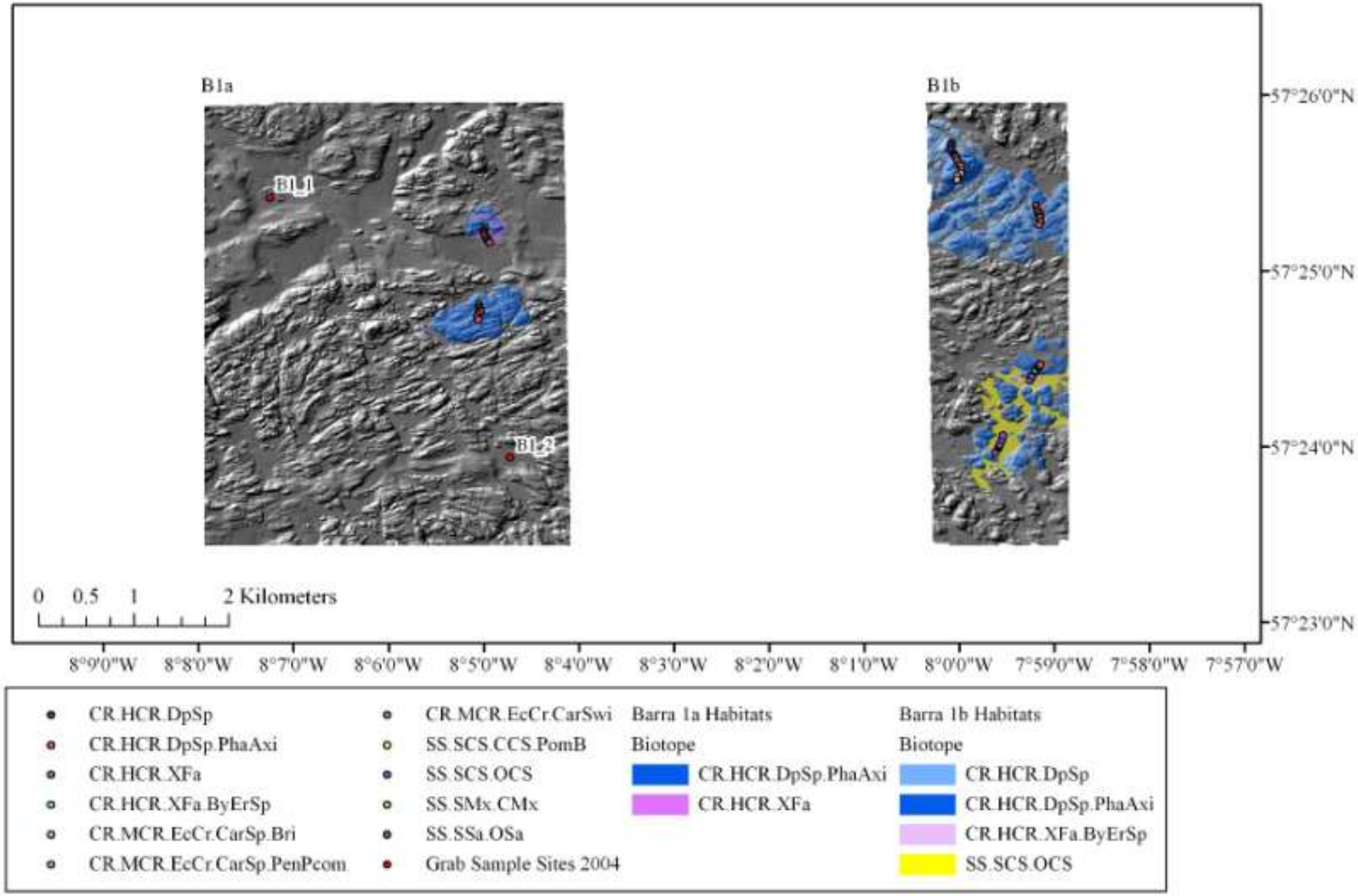

Figure 7a. Interpreted habitat maps for Barra Sites 1a and 1b overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps.

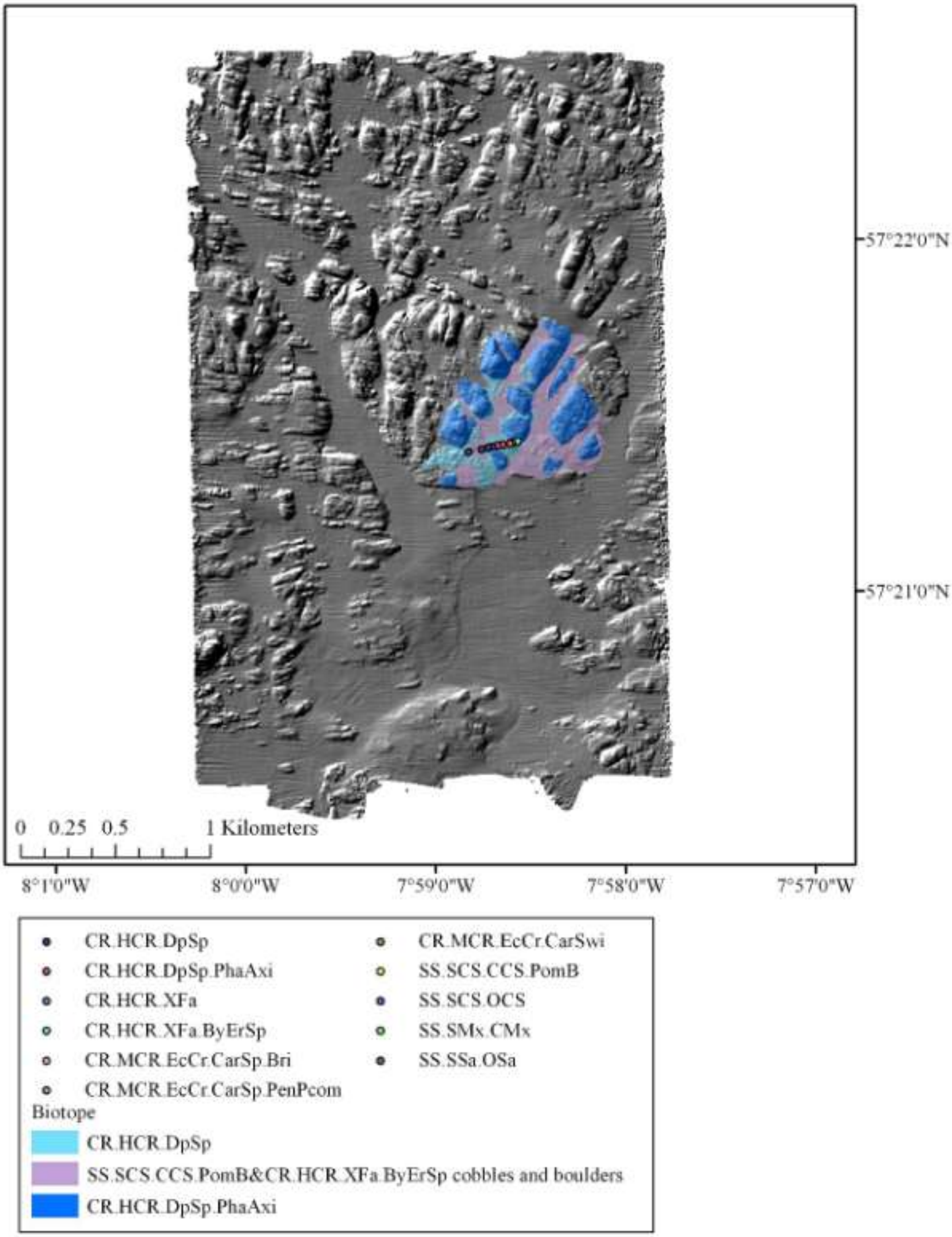

Figure 7b. Interpreted habitat maps for Barra Site 2 overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps.

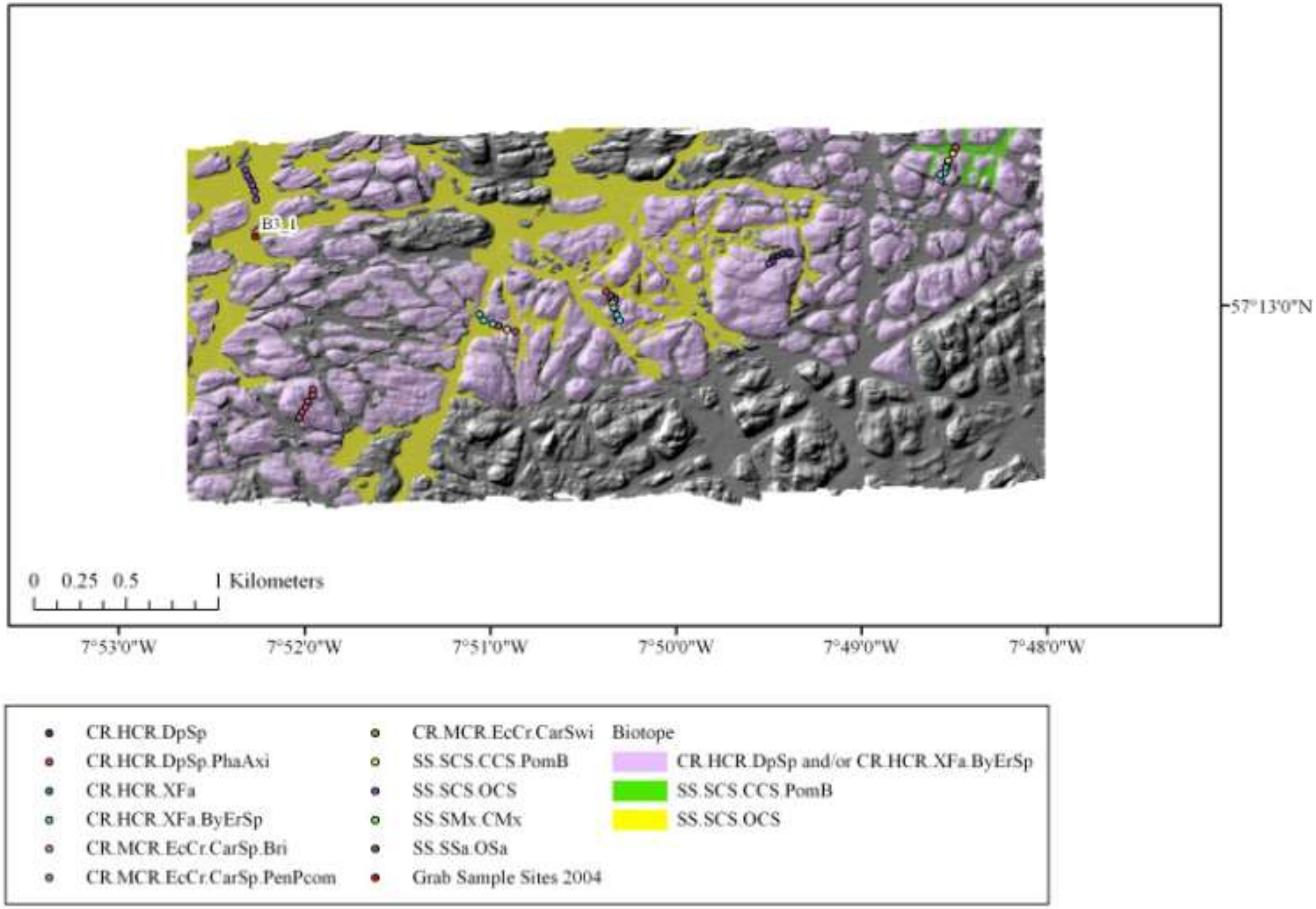

Figure 7c. Interpreted habitat maps for Barra Site 3 overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps.

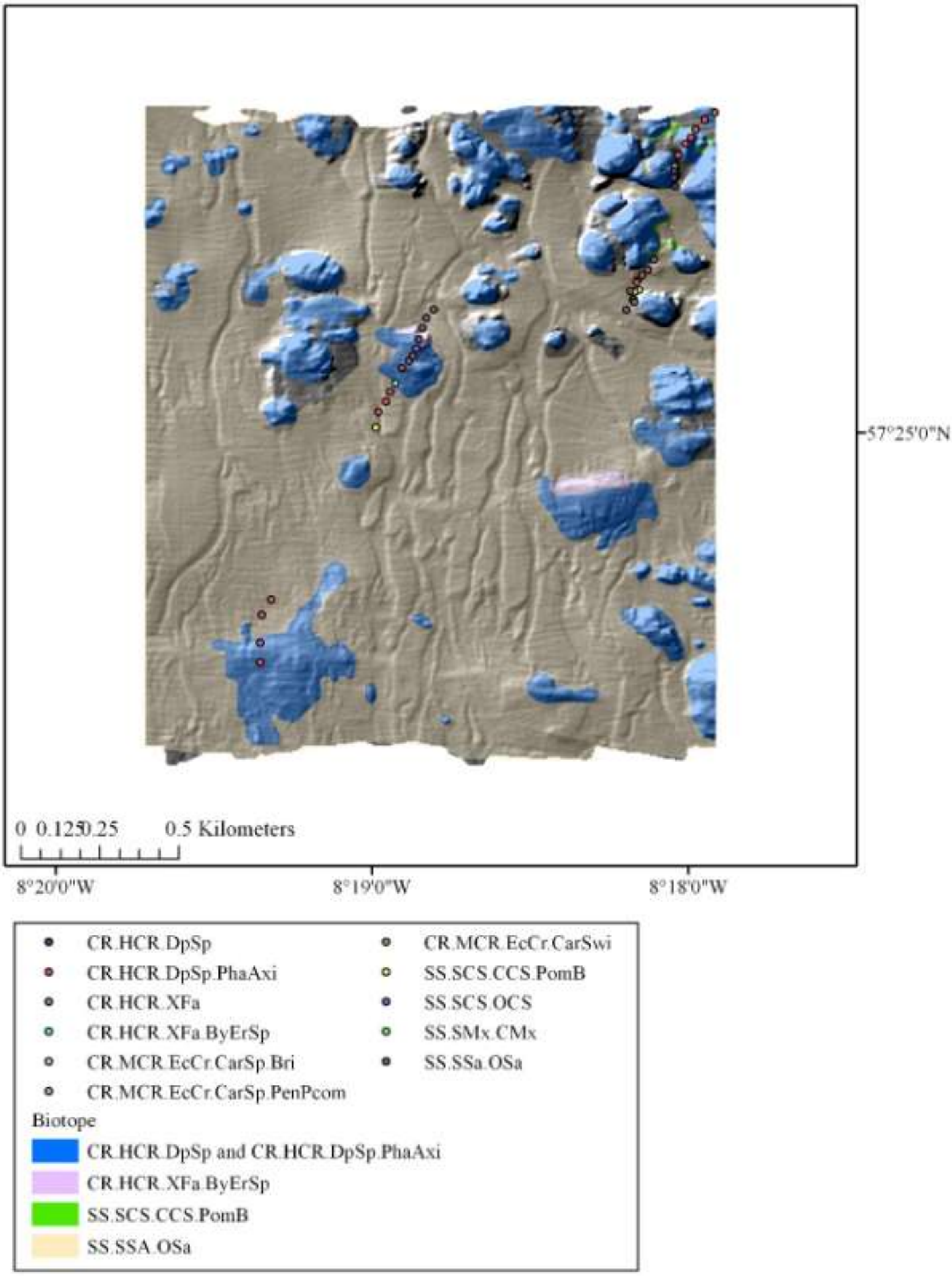

Figure 7d. Interpreted habitat maps for Barra Site 5 overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps.

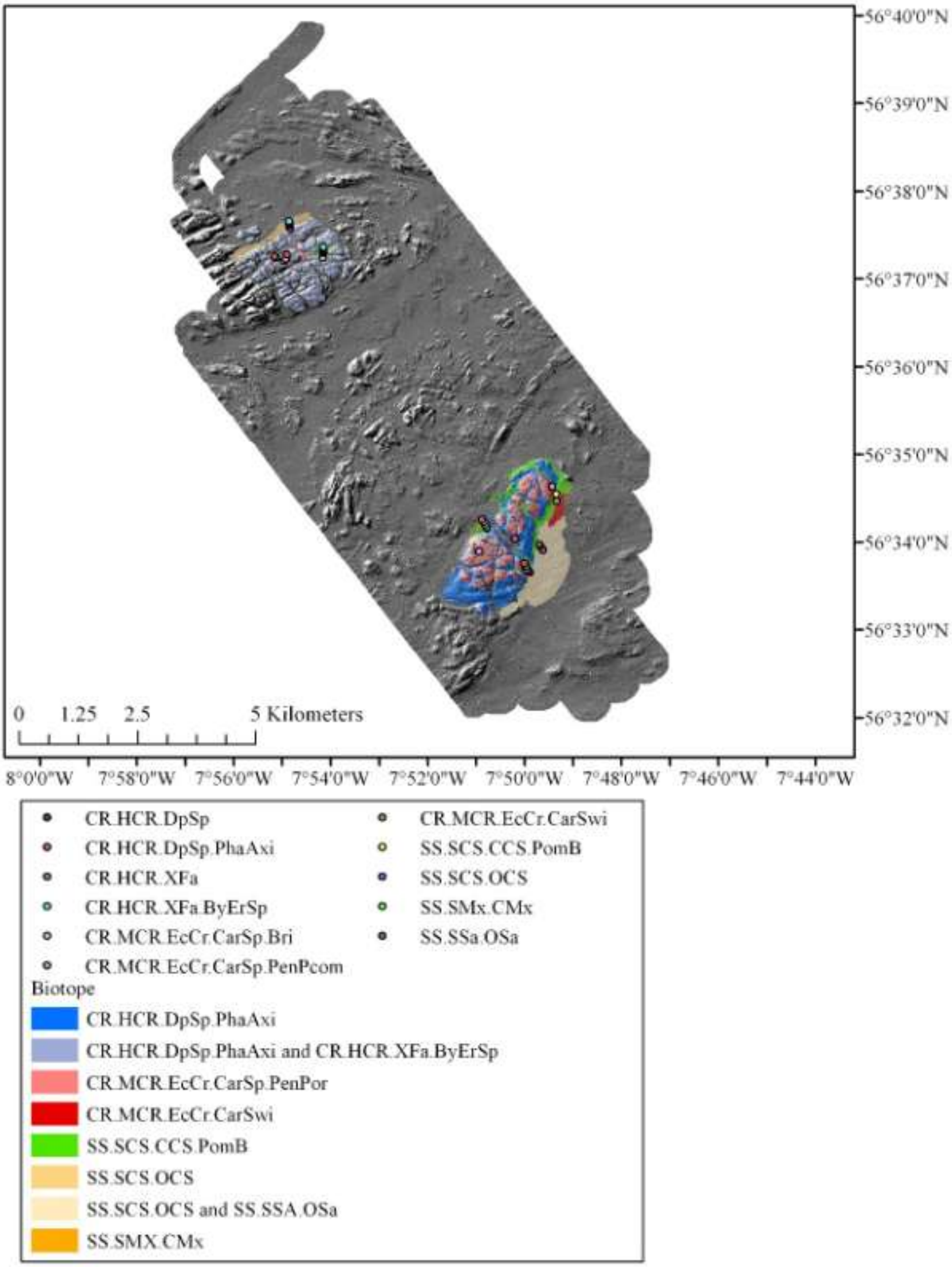

Figure 7e (i). Interpreted habitat maps for SW Barra site overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps.

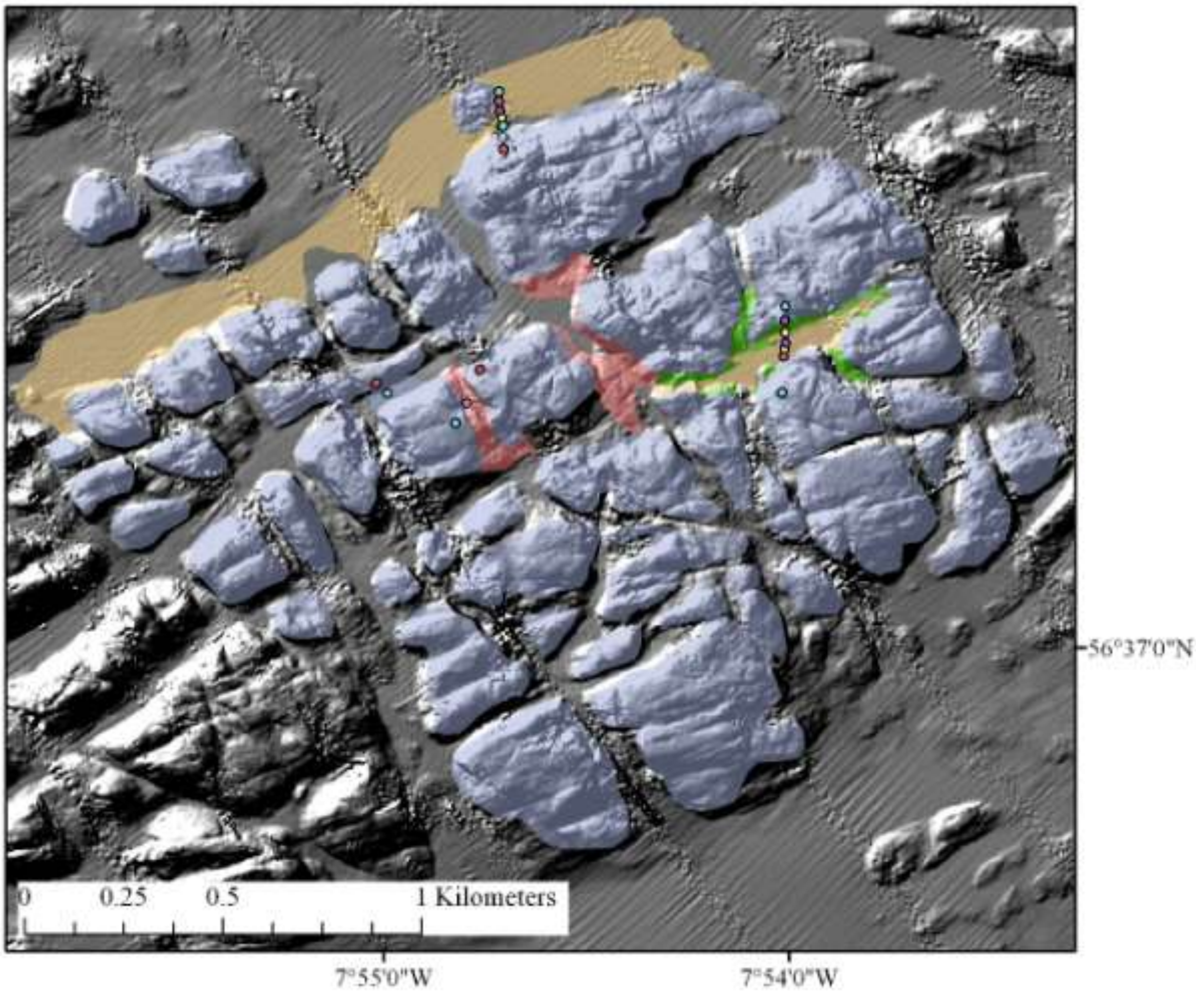

Figure 7e (ii). Enlarged northern section of interpreted habitat maps for SW Barra site overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps (see Figure 7e (i).

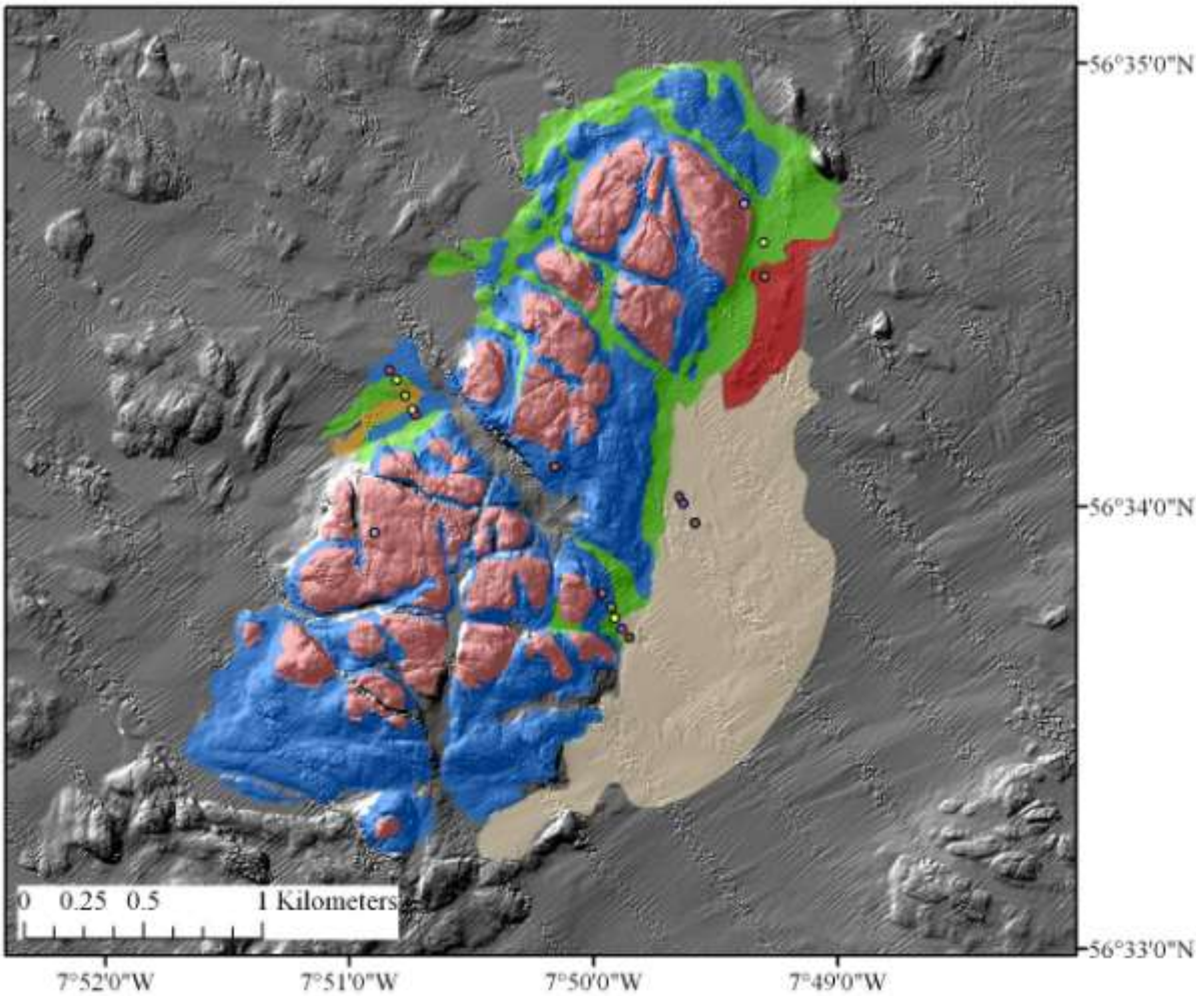

Figure 7e (iii). Enlarged southern section of interpreted habitat maps for SW Barra site overlaid upon a hillshaded bathymetry, with ground-truthing sites shown on top of maps (see Figure 7e (i).

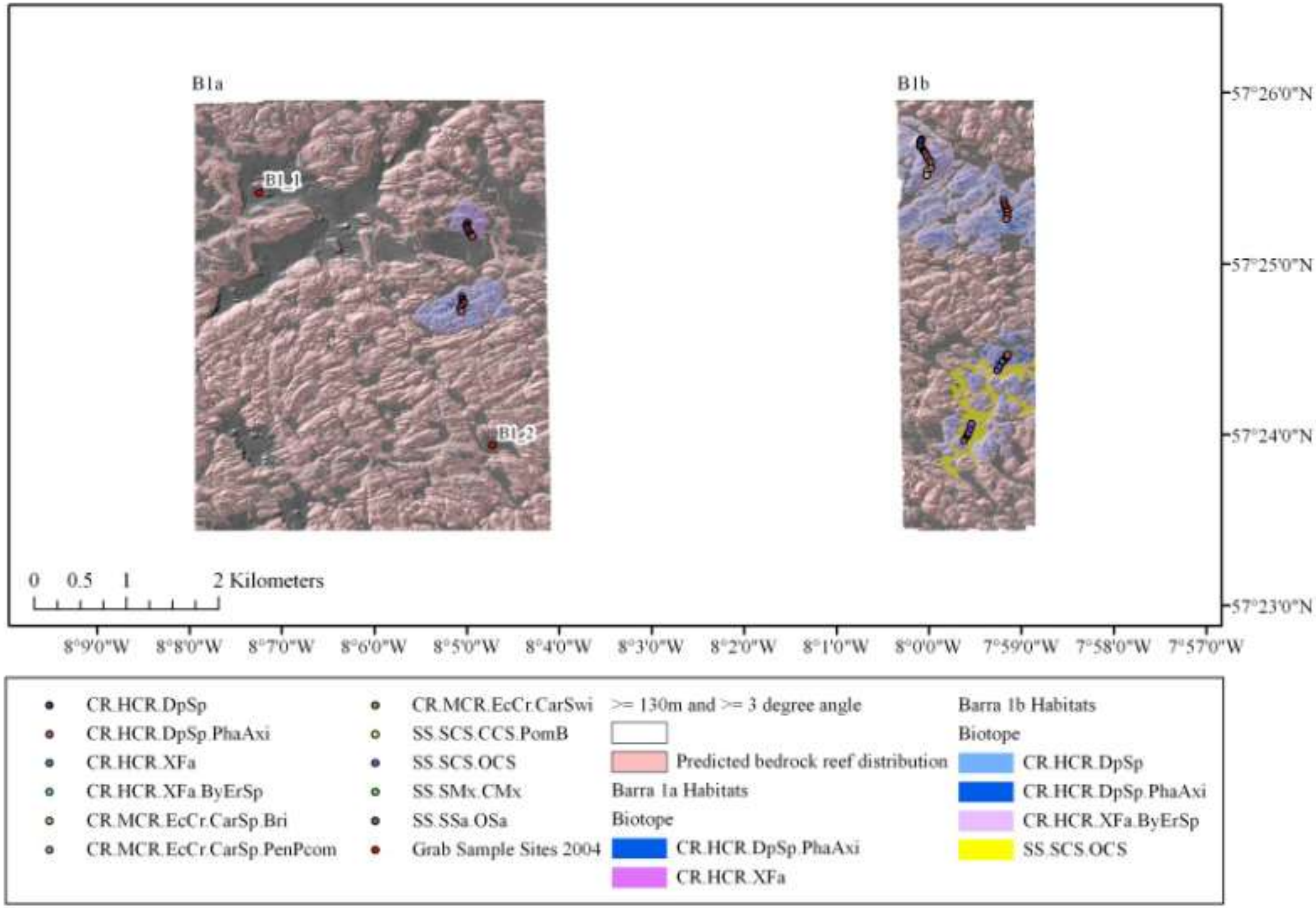

Figure 8a. Interpreted habitat map and predicted distribution of bedrock reef for Barra Site 1, with ground-truthing data overlaid.

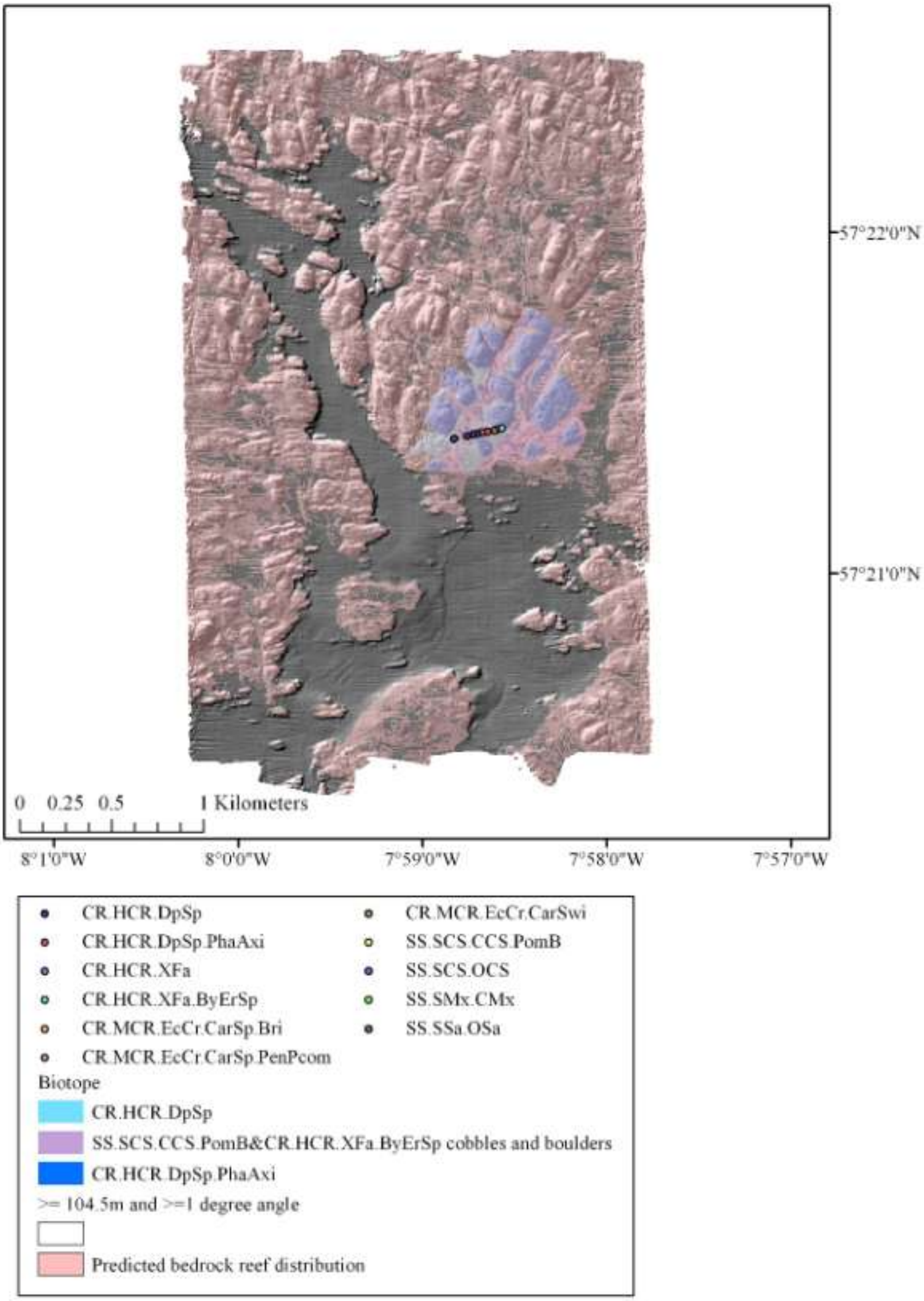

Figure 8b. Interpreted habitat map and predicted distribution of bedrock reef for Barra Site 2, with ground-truthing data overlaid.

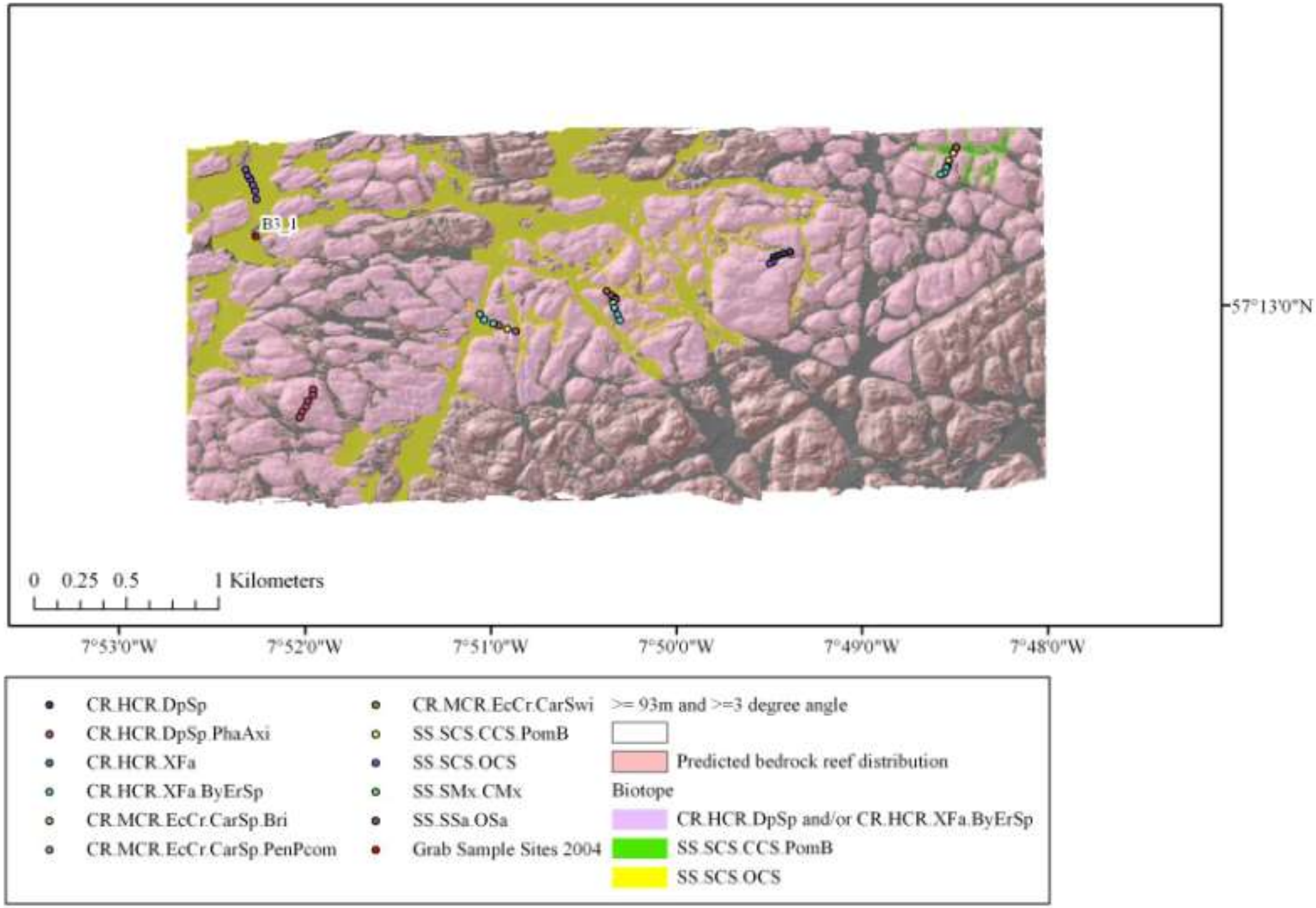

Figure 8c. Interpreted habitat map and predicted distribution of bedrock reef for Barra Site 3, with ground-truthing data overlaid.

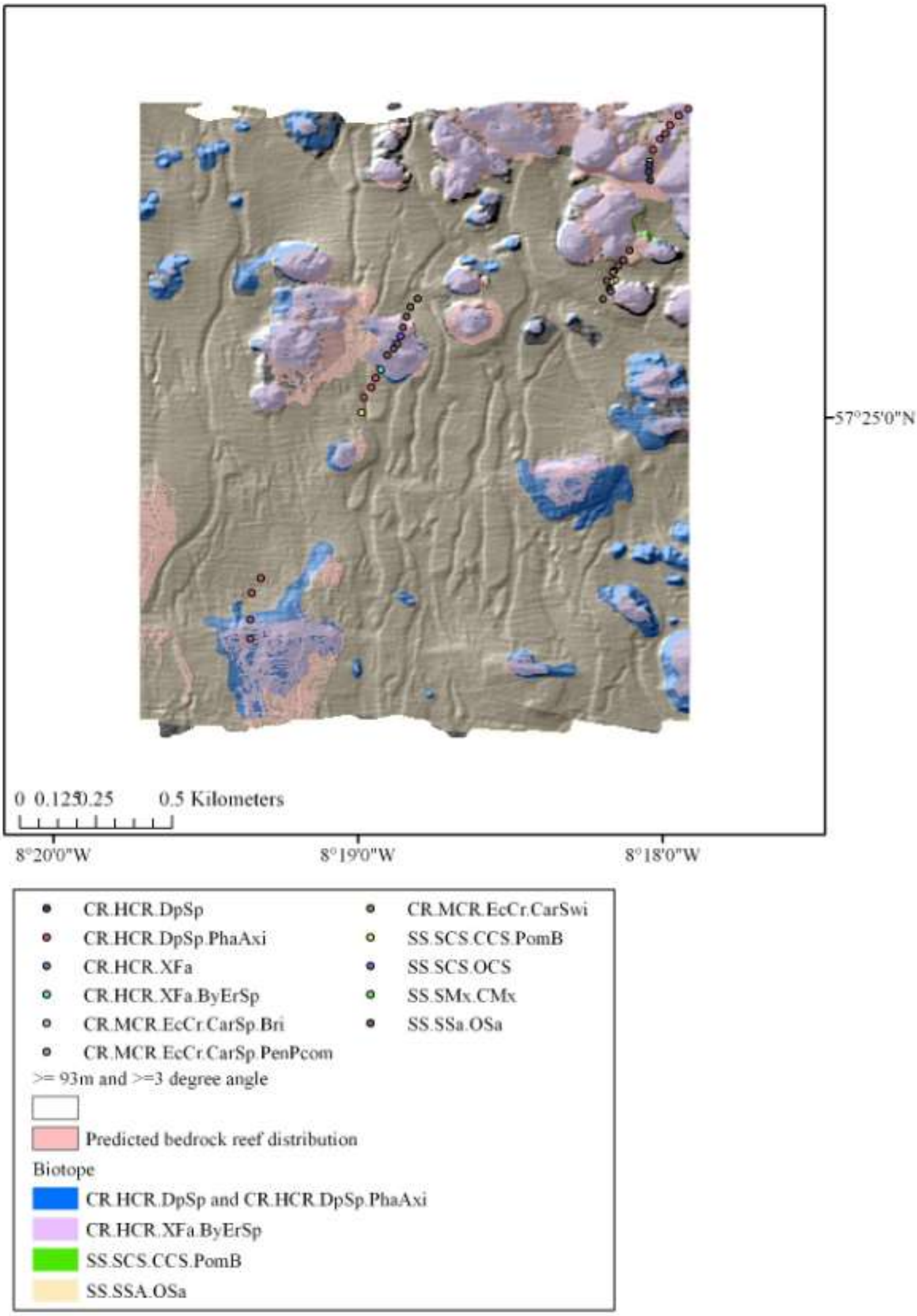

Figure 8d. Interpreted habitat map and predicted distribution of bedrock reef for Barra Site 5, with ground-truthing data overlaid

3.7 Conservation importance and recommendations for future work

The high degree of natural, physical disturbance occurring at the Barra survey sites is reflected in the composition and density of the communities found. With regard to the methodology, there was a clear relationship between the effort put into ground truthing and the number of biotopes recorded within each site. The variability in the ground truthing between sites does prevent comparisons of habitat richness between sites. Further ground truthing of these sites is recommended to enable further interpretation of the unclassified survey areas. In addition, further ground truthing would be particularly beneficial for greater quantification of communities present and the formal defining of Special Area of Conservation boundaries, should the relevant bodies consider this area to be of conservation value.

The limited national records for deepwater bedrock reefs severely limit the ability to compare the Barra sites to other known habitat types, and hence establish conservation importance. Only with further habitat mapping of deepwater habitats can the overall importance of the Barra sites be put into context. At which point, the relevant conservation bodies can make an informed decision regarding the value of the Barra sites. This study has undoubtedly added a significant volume of information about deepwater bedrock reef habitats in the UK and thereby added a good comparison for future work on similar habitats. Furthermore, the generation of additional biotope codes should facilitate the mapping and interpretation of future sites.

Following the project workshop, held on 22 March 2005, several specific recommendations were made for future work:

- i Additional ground-truthing required (especially Barra Sites 1, 2 and 3). Where possible, opportunistic ground-truthing will be undertaken on RV *Corystes* cruises in forthcoming years when surveying near these areas.
- ii Enhanced backscatter data processing where possible: recommend asking Dr. Tim Le Bas to re-process backscatter data for Barra Sites 1, 2, 3 and 5 to see if significant improvements can be made. Completed: new mosaics added to GIS Project January 2006.
- iii Increased use of modelling/numerical approaches (eg through Raster Calculator) in order to extrapolate habitat interpretations away from ground-truthing sites in a scientifically robust way: build a catalogue of bathymetric data properties 'beneath' each ground-truthing point (biotope).
- iv Examination of biotope classification through multivariate data analysis of video SACFOR data. If possible, re-analyse Stanton Banks and Blackstone Banks video footage to extract SACFOR data and compare results with Barra sites (particularly deep sponge communities).
- v Confirmation and additional species identification by sponge expert: build video/stills catalogue of species to aid future efforts. Experts suggested Bernard Picton (Ulster Museum), Jean Vacelet (Centre d'Oceanologie de Marseille) and Prof. Joachim Reitner (Goettingen University).
- vi Calculate aspect for each of the sites from multibeam bathymetry grids.
- vii Source relevant physical/oceanographic data for survey sites (eg tidal currents, wave base depth etc. from models) in an attempt to explain differences between sites and potential differences in biotopes founds on different bedrock faces.

4. References

CONNOR, D.W., ALLEN, J.A., GOLDING, N., HOWELL, K.L., LIEBERKNECHT, L.M., NORTHEN, K.O. & REKER, J.B., 2004. *The Marine Habitat Classification for Britain and Ireland Version 04.05* [online]. Peterborough: JNCC. Available from: www.jncc.gov.uk.MarineHabitatClassification

GRAHAM, C., CAMPBELL, E., CABILL, J., GILLESPIE, E. & WILLIAMS, R., 2001. JNCC Marine Habitats GIS Version 3: its structure and content. *British Geological Survey Commissioned Report, CR/01/238.*

5. Appendix

5.1 West of Outer Hebrides Biotope Mapping Project Workshop

22 March 2005

5.2 Workshop attendees

Dr Kerry Howell (JNCC), Charlotte Johnston (JNCC), Dr Tim Le Bas (SOC), Dr Veerle Huvenne (SOC), Veit Huhnerbach (SOC), Dr Matt Service (DARD), Tom Stevenson (UMBS Millport), Dr Adam Mellor (QUB), Dr James Strong (QUB), Andrew McDougall (QUB), Dr Richard Briggs (DARD), Annika Mitchell (QUB).

Apologies: Dr Matt Dalkin (SNH), Dr Craig Brown (UU).

5.3 Specific project recommendations

- Additional ground-truthing required (especially Barra Sites 1, 2 and 3) in such heterogeneous regions. Where possible, opportunistic ground-truthing will be undertaken on Corystes cruises in forthcoming year when surveying near these areas (Action: Matt Service and Annika Mitchell).
- Enhanced backscatter data processing where possible: recommend asking Dr Tim Le Bas to re-process backscatter data for Barra Sites 1, 2, 3 and 5 to see if significant improvements can be made (Action: JNCC to make appropriate arrangements through MESH project for funding Tim Le Bas). Completed: new mosaics added to GIS Project January 2006.
- Increased use of modelling/numerical approaches (eg through Raster Calculator) in order to meaningfully extrapolate habitat interpretations away from ground-truthing sites: build a catalogue of bathymetric data properties 'beneath' each ground-truthing point (biotope) (Action: Annika Mitchell, under MESH project/PhD studies).
- Examination of biotope classification through multivariate data analysis of video SACFOR data. If possible, re-analyse Stanton Banks and Blackstone Banks video footage to extract SACFOR data and compare results with Barra sites (particularly deep sponge communities) (Action: Annika Mitchell, under MESH project/PhD studies).
- Confirmation and additional species identification by sponge expert: build video/stills catalogue of species to aid future efforts. Experts suggested Bernard Picton (Ulster Museum), Jean Vacelet (Centre d'Oceanologie de Marseille) and Prof Joachim Reitner (Goettingen University). (Action: Annika Mitchell to contact experts to gauge interest, and build simple catalogue that fits onto DVD for distribution to experts with JNCC/SNH/DARD permission).
- Calculate aspect for each of the sites from multibeam bathymetry grids (Action: Annika Mitchell)
- Source relevant physical data for survey sites (eg tidal currents, wave base depth etc from models) in an attempt to explain differences between sites and potential differences in biotopes founds on different bedrock faces (Action: Annika Mitchell)

5.4 Open Discussion: Recommended future practise / further research:

1. Production of accurate bathymetric grids: to what resolution?

In all cases, bathymetric grids should be produced to the finest resolution possible by attempting to grid data at a number of resolutions (eg 1m, 2m, 4m, 5m) and examining the amount of erroneous data in each grid.

2. Use of bathymetric grids (post-processing) eg production of slope angles, rugosity, hillshaded grids and contour lines: how does this influence what is required of the initial bathymetric data grids?

Post-processing of bathymetric grids requires very clean data grids, as any erroneous data or data gaps will be 'emphasised' by numerical procedures such as generation of slope angle grids, contour lines etc. The value of such post-processing is in the subsequent possibility of using these datasets to perform numerical calculations on the data to find 'rules' relating to acoustic signatures of habitats (eg through Raster Calculator). This is very important when attempting to build catalogues of acoustic 'signatures' for biotopes between and within survey areas.

3. Production of backscatter mosaics: quality differences, resolution issues and equipment settings

Backscatter mosaics have proved to be very useful in the drawing of final habitat polygons when such mosaics are of high resolution and good quality (eg SW Barra site). However, great variations exist between multibeam surveyors/processors as to the quality of the resulting mosaics and data settings used. Recommend the collection of 'enhanced' backscatter data in the field, which is often an unused option on multibeam systems. Although currently there is not commercially-available software for processing such data, in-house software is being developed by academics (eg PRISM at Southampton Oceanography Centre), which creates superb sidescan-sonar quality mosaics in depths of up to 200m. Enhanced backscatter data collection options are given different names on different systems and it is recommended that project leaders identify these prior to fieldwork (eg on the Reson 8101 Seabat multibeam the enhanced backscatter is the 'snippets' setting). All work principally by gathering a suite of data values from each first return echo (based on an integration of the sound wave shape) rather than recording a single data value for each first return echo.

It should be noted that good quality backscatter data can be collected along with good quality bathymetric data even where track overlap is >50%. As with sidescan sonar data processing, certain overlapping data tracks can be removed to enhance the resulting mosaic (which is recommended in such situations). A good degree of track overlap (>25% nominally) is required to produce 100% coverage bathymetric data with no 'holes' which is required for post-processing and Raster calculations (above). Both bathymetric data and backscatter data are deemed of equal importance in habitat mapping and emphasis should not be placed on one at the expense of the other, as survey design and data processing can allow for both to be generated at a high level of quality, accuracy and resolution. (However it is acknowledged that weather conditions may thwart the best of survey designs resulting in some 'downgrading' of bathymetric data).

4. Specifications for future projects: requirement for all raw data for future work (eg use in auto classification packages such at QTC-Multiview)

Due to the advent of a number of commercially-available 'auto classification' software packages, which require multibeam data in its raw format, it is recommended that project leaders/funders specify that raw data is provided in addition to the more standard requirement for cleaned XYZ data and backscatter mosaics. Autoclassification software uses clustering techniques to identify and map a specific number of 'ground-types' based upon raw data in a specific search area (eg a 20x30m rectangle). Such software has yet to be fully tested by habitat mappers and, therefore, little is known as to how such unsupervised clusters may relate to habitats. However, it is believed such software may be of particular use in focussing ground-truthing effort. By ensuring users have access to raw multibeam data such software can be assessed in the future.

5. Level of ground-truthing required and investment of effort into ground-truthing

It was generally agreed by all workshop participants that there is currently an under-investment in ground-truthing of multibeam data for habitat mapping. This is due to a range of reasons, which are not dealt with here. It is recommended where possible that multibeam/acoustic data is processed prior to the ground-truthing such that the distribution of ground-types and the degree of heterogeneity is established to enable focussed ground-truthing. This procedure was followed for the SW Barra site, whereas the other survey sites had ground-truthing undertaken on a more ad-hoc basis, based upon preliminary examination of multibeam data collected during the nights with ground-truthing undertaken during the day. Further research is required to establish how much ground requires examination using ground-truthing (eg as a percentage of ground surveyed by multibeam) in order to produce meaningful habitat polygons, however for the meantime it was emphasised that researchers should not be tempted to over-extrapolate data from limited ground-truthing. In addition, 'objective' methods of extrapolating biotopes to multibeamed areas that have not been ground-truthed are encouraged (eg through the use of Raster calculator - above) so long as their limitations are understood and shown visually on the resulting maps if possible.

6. Data management & dissemination issues / databasing

Currently there are few, if any, protocols on data management for multibeam data, AGDS data or ground-truthing data. Metadata issues are being well addressed by MESH and it is recommended that metadata recording is encouraged on surveys. Databasing issues such as facilitating exchange of data between interested parties require addressing, especially with regard to ground-truthing data which may be of interest to NBN. Formats that are both GIS-compatible and compatible with national databasing initiatives are in development (JNCC) and should be adopted where possible. Currently Marine Recorder is not amenable to habitat mapping data, which is databased primarily such that it can be readily displayed and interrogated through GIS.

7. How to interpolate/extrapolate ground-truthing data to produce final habitat maps: the 'black-art' of data interpretation

Much research is required to build catalogues of data relating acoustic 'properties' to biotopes/habitats as identified by ground-truthing. Such catalogues may help generate a set of 'rules' that can be applied through GIS in order to help classify data and facilitate drawing of habitat polygons (above). As yet most sites have been examined on a site-by-site basis so it is not known if such 'rules' may exist or are even appropriate.

8. Adding data for development of deeper-water biotope classifications

It was agreed by all that where possible data should be extracted from ground-truthing that may be fed into the JNCC database used to develop the biotope classification, as in particular such data is in short supply for deeper-water (>40m) areas. In particular this would require video footage to be subjected to the semi-quantitative SACFOR species abundance analysis. Feedback on the existing biotopes should be encouraged. It has been found in this project that data fitted the biotope classification well, with only a few exceptions (such as the lack of Pentapora foliacea in the CR.MCR.EcCr.CarSp.PenPor biotope, but frequent occurrence of Porella compressa resulting in areas being classified into this biotope anyway).

Annika Mitchell wishes to thank the following workshop attendees for their enthusiastic and informative participation in the open discussion: Kerry Howell, Charlotte Johnston, Tim Le Bas, Veerle Huvenne, Veit Huhnerbach, Matt Service, Adam Mellor, Tom Stevenson and James Strong. The views expressed in this document attempt to summarise the views expressed by the above participants in the workshop and the author (Annika Mitchell).