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Isles of Scilly Seagrass Mapping

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Foreword

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

Background

Under the requirements of the EU *Habitats Directive* the UK Government has established a series of Special Areas of Conservation (SACs) which, with Special Protection Areas, form a series known as Natura 2000 (N2K). Articles 11 and 17(1) of the *Habitats Directive* require that member states regularly assess the ecological condition of the designated features within the N2K series. Condition Assessment of European Marine Sites is carried out on a six yearly cycle, and it is the responsibility of Natural England to report this to Europe through the JNCC (Joint Nature Conservation Committee).

One of the qualifying marine features for SAC designation is *sandbanks which are slightly covered by sea water all the time.* Extensive meadows of the seagrass *Zostera marina* are a key sub-feature of this biotope. The Isles of Scilly SAC was selected for subtidal sandbanks and *Zostera* meadows.

The objectives of this study are to utilise aerial survey and GIS methods, along with historic information, contextual information, and ground truthing to produce an up to date, accurate, GIS based map showing the current extent of seagrass *Zostera marina* in the Isles of Scilly. The results will enable changes in the extent of the seagrass to be monitored and so inform the site managers as to any changes that may need to be made to the future management of the SAC.

This report is being published to inform managers and to allow others to review the work, as well as to develop and adapt monitoring programmes for this and other SACs.

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Further information
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Plate i A striated seagrass bed off the island of Tresco, Isles of Scilly

Project details

This report results from research commissioned by Natural England in order to utilise aerial surveys to accurately map the current extent of seagrass *Zostera marina* in the Isles of Scilly. The work was undertaken under Natural England contract SWR/CONTRACTS/08-09/114 by MarLIN at the Marine Biological Association of the UK, with sub-contract to the Diving and Marine Centre, University of Plymouth.

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Summary

Background

Under the requirements of the EU *Habitats Directive* the UK Government has established a series of Special Areas of Conservation (SACs) which, with Special Protection Areas, form a series known as Natura 2000 (N2K). Articles 11 and 17(1) of the *Habitats Directive* require that member states regularly assess the ecological condition of the designated features within the N2K series. Condition Assessment of European Marine Sites is carried out on a six yearly cycle, and it is the responsibility of Natural England to report this to Europe through the JNCC (Joint Nature Conservation Committee).

One of the qualifying marine features for SAC designation is *sandbanks which are slightly covered by sea water all the time.* Extensive meadows of the seagrass *Zostera marina* are a key sub-feature of this biotope. The Isles of Scilly SAC was selected for sandbanks and *Zostera* meadows. The JNCC Marine Monitoring Handbook (2001) states that the extent (ha) of seagrass is a key structural component of some sandbanks and provides a long-term integrated measure of environmental condition across the feature.

Much of the area between the islands is shallow and sheltered and provides suitable habitat for seagrass. Granitic sediments settle rapidly and leave the water clear, providing good conditions for photosynthesis and encouraging the growth of seagrass beds. The majority of the seagrass beds are subtidal but at several sites (Hugh Town Harbour, Porth Cressa, Gimble Porth, the cove between St Agnes and Gugh and Porth Conger) there are occasional intertidal areas of seagrass.

Following the decline of seagrass from wasting disease in many parts of the country since the 1930's, the Isles of Scilly has become one of the most important areas nationally for beds of Zostera *marina* var. *marina*. However, even in Scilly, the once vast meadows which extended over hundreds of acres of sandflats including intertidal areas have largely been lost due to this disease (Harvey, 1969). Recovery has occurred to some extent but is still very limited in intertidal areas.

The Isles of Scilly seagrass beds, however, remain some of the most extensive in southwest Britain, and are of national significance due to the rich associated flora and fauna.

Broad aims

The aim of this project was to integrate aerial survey and GIS methods with historic information, contextual information, and ground truthing to produce an up to date, accurate map showing the current extent of seagrass *Zostera marina* in the Isles of Scilly.

Alongside this, the project aimed to contribute to a methodology, with known confidence limits, for monitoring other marine SACs using the Defra funded South West Coastal Monitoring Programme data (SWCMP). This data, being collected to inform the Shoreline Management Plan Review, is free to partners and includes: aerial photographic survey (orthorectified); Light Detection and Ranging (LIDAR) measured bathymetry (in some places); topography; coastal processes and post storm monitoring.

Detailed objectives

The objectives of this project were:

- To utilise up to date technology, of aerial photography and GIS analysis, to map the current extent of seagrass in the Isles of Scilly and, therefore, to facilitate future monitoring of:
    - recovery of seagrass from wasting disease;

- changes in the future due to climate change; and
- changes caused by anthropogenic activity (propeller scarring and anchor/mooring damage in particular) which can be managed through the SAC designation as required under the *Habitats Directive*, and or any future Marine Protected Area designation.

- To examine the necessity to utilise Compact Airborne Spectrographic Imager CASI hyper-spectral technology to further enhance data collected by aerial photography methods.
- To map the current extent of seagrass beds as required by the *Water Framework Directive* (See Section 1.3).
- To utilise historic data, such as biotope data collected using RoxAnn acoustic ground determination techniques to provide contextual information to inform the seagrass extent mapping.
- To develop a methodology, with known confidence limits, to map seagrass beds that meets requirements of the Habitats Directive and the Water Framework Directive and, therefore, can be used by other marine SAC's in monitoring programmes.

Methods

Seagrass mapping was carried out using a combination of image analysis, ground truthing and historical data mining. The South West Coastal Monitoring Programme provided 10 cm resolution georectified[1] colour digital aerial photographs. Pre-processing of the aerial photographs involved image selection, mosaic creation and land masking. All processing of digital imagery was carried out using ERDAS Imagine™ version 9.3. Unsupervised classifications of the processed images, was carried out using combined data from the red, blue and green bands to objectively classify pixels into categories containing similar values for each of the three variables.

Ground truthing was carried out to validate the clusters from the unsupervised classification, to identify training sites for the supervised classification (see below) and to keep in reserve to validate and assess the 'thematic' accuracy of the final supervised classifications of images. At each of 628 ground truth position, the presence or absence of seagrass was identified, in shallow water (< 3m) by either looking over the side of the boat, and in deep water (> 3m) by real time drop video camera. If seagrass was present the percentage cover within view was noted. If there was no seagrass the type of seabed was classified.

In addition to the surveys carried out during 2009 as part of this contract, previous records of seagrass distribution were also used to aid the selection of training areas, including:

- Isles of Scilly seagrass annual survey data (Cook 2002, 2004a, b, Cook & Foden 2005, Cook 2006, Cook & Paver 2007);
- National Biodiversity Network data (**http://data.nbn.org.uk**);
- Environmental Records Centre for Cornwall and the Isles of Scilly (Hocking & Tompsett 2002); and
- Isles of Scilly Subtidal Habitat and Biotope Mapping Survey (Munro & Nunny 1998)

Water column correction techniques were used to distinguish the likelihood of a pixel being seagrass, sand or algae, particularly at depth and for those images where no seagrass ground truthing points were available (see section on knowledge editing).

[1] The photograph has been morphed to a grid whose cells are regularly spaced in a geographic (i.e., lat / long) or map coordinate system.

A supervised classification was implemented using regions (training areas) confirmed during the ground truthing phase, which were representative of the different habitat classes. The relevant pixels were selected on the images and their spectral information used to specify 'signatures' (numerical descriptors for processing algorithms) of the different classes present in the image scene. In some cases, field validation identified clusters that either did not represent sufficiently certain classes or described two or more classes. Therefore, a hybrid classification method was adopted by augmenting the unsupervised with a supervised classification. The final signature set was entered into a maximum likelihood classification program, which assigned each pixel to a particular signature using a probability density function.

Finally knowledge, or contextual, editing was carried out to improve the accuracy of final classified images. In this work we applied five different methods of knowledge editing to the supervised classified maps, including application of shallower depth limit, removal of areas of unsuitable substrate and use of local knowledge.

A measure of accuracy of the whole image across all classes was calculated using the multivariate Khat statistics.

Results

Analysis of the aerial photographs estimated 196.5 ha of seagrass in the Isles of Scilly, with patch sizes ranging from 10cm (resolution of the images) to 46 ha. Maximum depth recorded for seagrass from the ground truthing positions was 5.2m (off the North coast of St Mary's), with a mean depth of 2.9m. The current study and an assessment of recent surveys did not identify seagrass beyond 6m depth.

The majority of predicted seagrass overlap with seagrass mapped during the 1997 biotope survey using RoxAnn (Munro & Nunny 1998). Exceptions occur on the northerly coasts where possible seagrass has been identified through the supervised classification. These northerly coasts receive little shelter from Northerly winds and are unlikely to be suitable sites for seagrass habitat. Also in Great Bay (St. Martin's) there are a number of areas of soft sediment suitable for seagrass (obvious visually from the aerial photographs), which are not mapped as soft sediment by the biotope survey. There are also large areas of the *Zostera* biotope in the waters between St. Mary's and Tresco, where seagrass has not been predicted to occur by the present study. A depth clip of 5m removed a large area of mapped seagrass about 2km North West of St Mary's Harbour. This particular location of possible seagrass appears to be fairly contentious. In addition to being identified as seagrass by the supervised classification analysis of the current study, it was also identified as seagrass during the RoxAnn biotope survey (Munro & Nunny 1998) and previous aerial image analysis (ERICC site 26, Hocking & Tompsett 2002), however no GCP from the current study or local knowledge confirms that seagrass occurs here. Further survey is recommended for this location.

There was good correlation between the image analysis of the current study and the boundaries outlined by Cook *et al.* (2009), which highlights the usefulness of the latter for monitoring the extent on an annual basis. However the method of Cook *et al.* (2009) only identifies the outer edge of a focal bed. This means that much of the inner configuration of the bed is missed, as are adjacent patches which may be beyond the view of the divers. These are, however, both picked up by the aerial image analysis, making this a valuable method for identifying internal fragmentation or re-colonisation within the bed and for predicting the locations of meadows beyond commonly surveyed areas.

The lowest accuracies/ confidence (Kappa coefficient <0.4, i.e. where less than 40% of the error has been reduced by the classification) were evident for the north and south coasts of St Martin's, South Bryher and Porth Cressa. The highest accuracies (Kappa coefficient >0.6) were found for the mosaics covering St. Mary's Harbour, the area between Tresco and St. Martin's, and the Eastern Isles, but also for Great Bay (St. Martin's) where according to local knowledge seagrass has not been effectively identified by the image analysis.

Summary of main recommendations

The following recommendations are proposed for mapping other seagrass beds using the SWCMP and other aerial photographs:

Before the start of the project:

- Collate as much data in relation to the site that already exists as early as possible, in particular establish availability and format of historical photographs, acquire detailed bathymetry if available as it reduces time on image analysis processing, water column correction techniques and knowledge editing. If it is not available, collect it.

Aerial survey:

- Careful consideration should be given to the timing of the survey, for example in relation to seasonal changes in turbidity, in order to maximise chances of obtaining images of high enough quality. Organisations should be aware of this when commissioning surveys and should try to influence the timing of photograph acquisition.
- Aerial photograph should be provided to the analyst geo-rectified, in the highest resolution and unadjusted or merged into mosaics. These files will be very large so may need to be provided on hard drives.

Ground truthing:

- Randomised primary ground truthing should be used, alongside or in instead of transects, with some ground control positions retained for accuracy assessment.
- Where a large number of ground truthing positions are required to aid analysis and validate the classification a drop down camera is far more cost effective than the use of divers

Analysis of data:

- When editing images, local knowledge, and images taken in winter (when areas of drift algae are less prevalent) will improve accuracy of final images.
- For smaller areas where mosaics are not necessary, water column correction techniques should be applied to individual photographs, as this will aid in differentiating seabed habitat types.

Monitoring and interpretation:

- Monitoring the health of the habitat based on an overall change extent of seagrass should be performed with caution (particularly where different methods of measuring extent have been used).
- To aid monitoring, individual seagrass “landscapes” should be identified. For each identified landscape, total landscape metrics could be calculated using the layer created during the current study to describe the configuration of the seagrass meadow, thus allowing comparisons of configurations between meadows.
- Landscape metrics should also be used to examine changes in predefined reference polygons within areas of human pressure (for example, mooring locations and anchorages).
- It is strongly recommended that other environmental measurements are considered such as nutrient concentrations, light attenuation in the water column (the two most important water quality parameters affecting seagrass growth), salinity, water temperature, rainfall or freshwater run-off and wind exposure. The latter would help to identify beds which are less likely to recover following disturbance.

Future work and technique:

- The use of Hyper-spectral imagery, such as The Compact Airborne Spectrographic Imager (CASI), could improve the cost effectiveness of surveys particularly in areas where green algal blooms are common.

The full list of recommendations can be found in Chapter 6.

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1 Introduction

1.1 The Isles of Scilly archipelago was selected as a Special Area of Conservation (SAC) in part due to the extensive subtidal and intertidal sandy sediments that occur between the islands. These sediment features form the Annex I Habitats "sandbanks which are slightly covered by sea water all the time" and "Mudflats and sandflats not covered by seawater at low tide**"**, as defined in the 1992 EC Habitats Directive (92/43/EEC), incorporated into UK law by the Conservation of Habitats and Species Regulations 2010. In the Isles of Scilly these sandbanks are particularly important due to their extent and associated communities, which are very specific due in part to the combination of sheltered conditions, mild climate, constant salinity and low silt conditions. The latter are primarily a result of the oceanic nature of the surrounding seas which have a low suspended sediment concentration and the lack of any major riverine input. These factors provide ideal conditions for some of the most extensive and diverse beds of seagrass *Zostera marina* found in the UK.

1.2 *Zostera marina* (commonly referred to as eelgrass or seagrass) bed communities are one of three key sub-features of the 'shallow sandbanks' feature of the SAC. Articles 11 and 17(1) of the European Habitats Directive require that member states regularly assess the ecological condition of the designated features within the N2K site series. Condition Assessment of European Marine Sites is carried out on a six yearly cycle, and it is the responsibility of the UK Government to report this to Europe (through the JNCC (Joint Nature Conservation Committee). The original advice for the SAC (English Nature 2000) regarding the overall assessment of the site's condition, listed a number of attributes relating to the eelgrass which would require monitoring:

- the extent (area in ha of seagrass measured during peak growth, twice within the reporting cycle);
- water clarity (average light attenuation measured periodically throughout the reporting cycle); and
- the density of *Zostera marina* (average shoot density, measured in July twice during reporting cycle).

1.3 In addition, seagrass bed extent is also one of the key monitoring metrics for the EU Water Framework Directive (Directive 2000/60/EC), the others being taxonomic composition and shoot density. The density of the *Zostera marina* at five main beds (Old Grimsby Harbour, Tresco; Higher Town Bay, St. Martin's; Broad Ledge, Tresco; West Broad Ledge, St Martin's, and Little Arthur, Eastern Isles) have been recorded as part of an annual diving expedition for the past 12 years (Cook 2005). Densities at these sites range from 50 to over 200 shoots per m^2 (Foden & Brazier 2007).

1.4 There have also been a number of previous attempts to map the extent of the *Zostera marina* beds. Between 1984 and 1988 the Nature Conservancy Council (NCC) monitored the density of seagrass in Scilly through diver survey work, and again in 1991 after a gap of two years which showed a deterioration of seagrass with the appearance of wasting disease, invasion by wireweed (*Sargassum muticum*) and extensive storm damage.

1.5 Since 1992, a volunteer diver based monitoring programme has run almost annually to look at the health of seagrass in Scilly. This was initiated by the Coral Cay sub aqua club and funded by English Nature. Initially the research targeted sites of English Island East Higher Town Bay, St Martin's and Old Grimsby Harbour, and additional sites at West Broad Ledge, St Martin's and East Broad Ledge were added. In 1999 beds at Bar Point, St Marys and Rushy Bay were added (Cook 2002, 2004a, b, Cook & Foden 2005, Cook 2006, Cook & Paver 2007, Cook *et al.* 2008). The work concentrated on density, health, associated flora and fauna at point samples, but in 2008 some initial extent monitoring work was done in a few select areas to assess the viability of including extent in the future.

1.6 In 1997, Ambios Environmental Consultants, funded by English Nature, carried out a Marine Nature Conservation Review (MNCR) biotope exercise in the Isles of Scilly, to inform the SAC designation process (Munro & Nunny 1998). The survey used RoxAnn acoustic methodology and dropdown video ground truthing, but also used the 1996 aerial photographs and some side scan sonar to assist in biotope identification.

1.7 In 1984 oblique aerial photography, with ground truthing, was carried out using a hand held camera and the results used by Robert Irving to provide a baseline map of seagrass (Irving 1987). Although the survey failed to identify the St Mary's harbour seagrass, and it is known that some of the mapped areas of seagrass do not exist today, it has acted as a fairly good baseline to date. In 1996 an aerial survey was done by BKS based on 3-dimensional interpretation of 1:10,000 scale aerial photographs. A student from Plymouth University analysed these images using Erdas Imagine software and estimated the total area of to be 307ha (Hocking and Tompsett 2002). However, the work was carried out with very little ground truthing information and no accuracy assessment was carried out (Ludhe-Thompson 1999). In 2002 the Environmental Records Centre for Cornwall and The Isles of Scilly (ERCCIS) carried out a seagrass audit (Hocking & Tompsett 2002) using the student's work, RoxAnn surveys, original baseline maps by Irving and input from Cyril Nicholas (local English Nature Boat operator). They removed lost beds and estimated the area of seagrass around Scilly to be 348.25ha.

1.8 The current project focussed on examining the extent of the eelgrass beds using aerial photography with drop-down video for ground truthing. Using aerial photography to map eelgrass beds has a number of advantages, including cost effectiveness, ability to map large areas relatively accurately, yielding complete spatial coverage at a high spatial resolution. However, analysis of the aerial images can be expensive (due to the time taken), they require extensive ground truthing, sparse seagrass can be difficult to detect, interpretation of the images can sometime be difficult and poor light penetration through the water column limits the use to very shallow and/or clear water (Green *et al.* 2000).

1.9 *Zostera marina* is renowned for the variety of substrata, salinities, temperatures and current regimes it is able to colonise and tolerate. Such a wide habitat range not only creates difficulties in predicting the large-scale distribution of *Zostera*, but also influences the various hierarchical structural characteristics of the beds themselves, and, therefore, the faunal communities inhabiting them (De Jonge & De Jonge 1992, Bowden *et al.* 2001, Boström *et al.* 2002). Mapping of seagrasses is not only important from a management viewpoint but also to the understanding of their ecology. Previous studies have established that there are significant differences in the habitat roles of seagrass beds in relation to their morphology and location (Jackson *et al.* 2001, Boström *et al.* 2006). When evaluating the relative importance, or predicting the carrying capacity of different seagrass habitats, these sources of variation need to be accounted for and there is an increasing move toward the characterisation of seagrass meadows using the concept of landscape ecology (Bell et al. 1995, Kendrick et al. 2005, Boström et al. 2006). Resource maps and Geographical Information Systems (GIS) detailing environmental and biological habitat variables at a range of spatial scales are important tools, and should be considered as a first step in any assessment of faunal-habitat relationships. Image analysis is an objective method for categorising habitats based on pixel colour values and in addition to providing full coverage maps can be used to identify potential areas of seagrass not previously mapped or recorded (Chauvaud et al. 1998, Green et al. 2000).

1.10 Much of the area between the islands is shallow (<6m) and sheltered and the water clarity is high, all of which provided suitable habitat for seagrass (Munro & Nunny 1998). The Isles of Scilly experience relatively fast tidal currents, although currents close to the shore are influenced by the shape of the coastline, with prominent headlands increasing the speed of tidal currents and causing gyres within adjoining bays (Harvey 1969, Irving *et al.* 1998). Strong current velocities result in very specific seagrass bed configurations in the Isles of Scilly (in particular the mounding and striations) which make in situ surveys of spatial extent problematic and aerial mapping a necessity.

1.11 In terms of exposure, reports exist of *Zostera* growing in wave-stressed environments. However, severe wave action may result in increased mobility of sediments, dislodging and blanketing seagrass and hence sheltered habitats are more favorable. In the Isles of Scilly, the predominant wind direction is westerly, with western coasts therefore exposed to strong wave action, where the fetch is long distance, and seagrass distribution is limited. The seagrass beds are also highly dynamic and may die back and re-colonize areas as part of a natural cycle, reliance on historical mapping is therefore not recommended and losses and gains of seagrass should be interpreted with caution in relation to anthropogenic pressures.

1.12 *Zostera marina* is essentially a subtidal species, although in the Isles of Scilly very low spring tides expose seagrass at several sites (Hugh Town Harbour, Porth Cressa, Gimble Porth, the cove between St Agnes and Gugh and Porth Conger)(Lewis *et al.* 2008). In the 1930s UK seagrass beds fell victim to a disease caused by a slime-mold-protist (*Labyrinthula* spp), commonly known as “the wasting disease” due to the symptomatic black lesions. The disease, possibly due to high sea temperatures at this time, reached epidemic levels and resulted in massive losses of seagrass across the North Atlantic (Den Hartog 1987, Giesen et al. 1990, Hily et al. 2002). In the Isles of Scilly the once vast meadows, which extended over hundreds of acres of sandflats including intertidal areas, have largely been lost due to this disease. Recovery has occurred to some extent but is still very limited in intertidal areas (Harvey 1969, see also section 6.3).

1.13 The main advantage of aerial image analysis for mapping and monitoring seagrass beds over other methods (for example, diver or acoustic survey) is that full coverage of the bed extent and configuration is provided, making this a valuable method for identifying internal fragmentation or re-colonisation within the bed and for predicting the locations of meadows beyond commonly surveyed areas.

2 Objectives

2.1 The objectives of this project (as set out in the project specification) were:

- To utilise up to date technology of aerial photography and GIS analysis to map the current extent of Isles of Scilly seagrass, to allow future monitoring:

  a) recovery of seagrass from wasting disease;
  b) changes in the future due to climate change; and
  c) changes caused by anthropogenic activity which can be managed through the SAC designation as required under the *Habitats Directive*, and or any future Marine Protected Area designation.

- Map the current extent of seagrass beds as required by the *Water Framework Directive* and site condition monitoring.
- To utilise historic data such as RoxAnn biotopes, to provide contextual information to inform the seagrass extent mapping.
- To create a formula for other marine SAC's to utilise South West Coastal Monitoring Programme data taken in other marine SAC's, to map seagrass beds for requirements under the Habitats Directive, and also the Water Framework Directive.

3 Methods

Phase 1 Unsupervised classification

Aerial photograph acquisition

3.1 The 10cm resolution RGB (Red, Green, Blue) and IR (Infra red) digital aerial photographs used in this study were taken by Blom Aerofilms using a 90 mega pixel digital camera on the 26th September 2008 between 0925 and 1153 (BST). The photographs were taken as part of the South West Coastal Monitoring Programme. Coverage for the Isles of Scilly is shown in Appendix 1.

3.2 The aerial photographs were not taken specifically for the purposes of the present study; however the aerial the survey conformed to many of the ideal criteria suggested for seagrass mapping (Mumby & Green 2000). They were taken when seagrass biomass was at its height, with minimal cloud cover and after a period of calm weather. However the date did not coincide with a spring tide and the start of the survey did not coincide with one hour either side of low tide (with a low tide of 1.48m occurring at 0939 BST, POLTIPSv3). In the final runs this resulted in approximately 1m of additional water depth above the seabed. Infra red can only penetrate the top few cm of water and therefore was not useful for mapping subtidal seagrass, image analysis was carried out on density level information for each pixel using the Red, Green and Blue bands only, which at 24 bit gave a possible 256 density levels.

Pre-processing

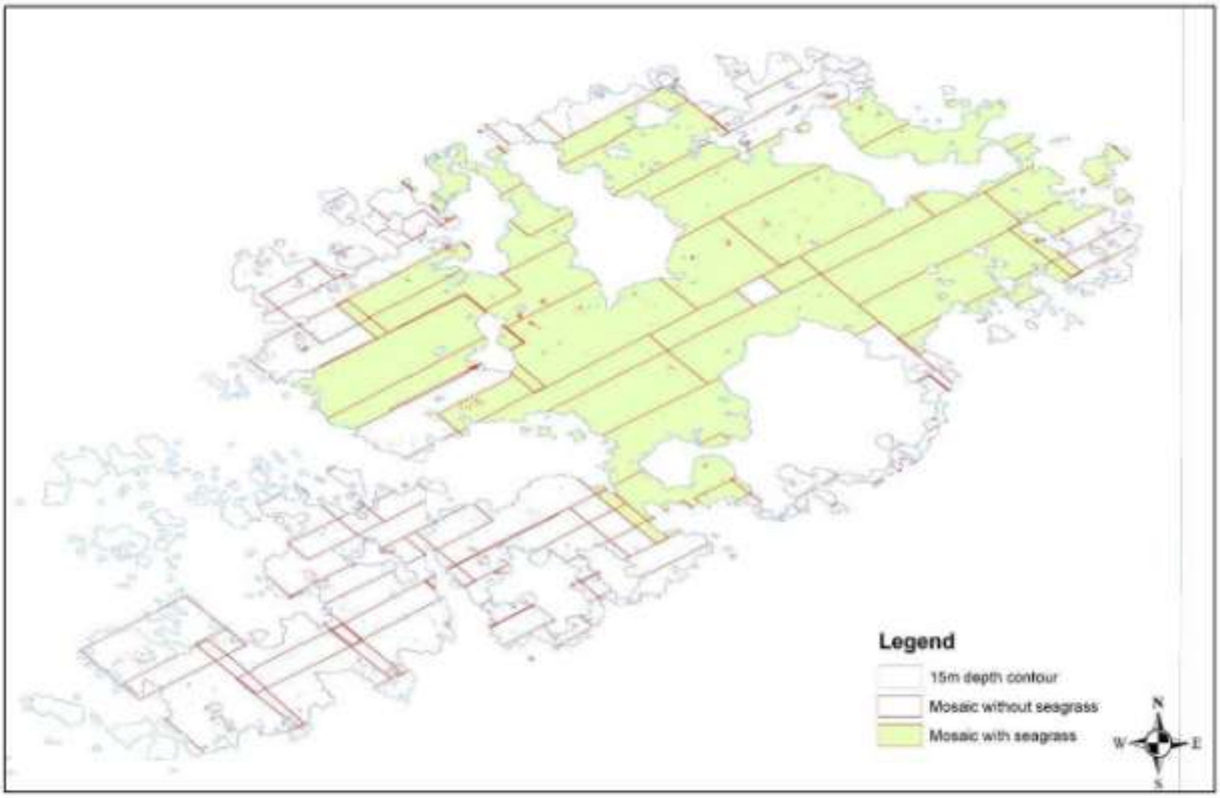
3.3 Unless mentioned below, all processing of digital imagery was carried out using ERDAS Imagine™ version 9.3, which was 'spectral pattern recognition' based (Lillesand & Kiefer 2000). Pre-processing of the aerial photographs involved image selection, mosaic creation and land masking.

3.4 A GIS shapefile of the Isles of Scilly coastline (mean high water spring) was used to mask out land areas. The seaward limit of the area of interest was set at the edge of the image (if less than 15m water depth) or the 15m isobath, where deep water was close inshore (as is the case on the north coast). The choice of this 15m depth was based on the apparent limit to the visibility of the seabed features, and the belief that seagrass does not occur around the UK at depths greater than 10m (Davison 1997, Jackson 2003)

3.5 For the South West Coastal Monitoring Programme Blom provided orthorectified images "cut" into 500m x 500m tiles. Due to differences in the sun angle and crops of photos occurring across known seagrass beds, the current study used orthorectified photo files which had not been mosaiced or cut into tiles. Mosaicing of the images provided by Blom for the present study was carried out based on flight paths and appropriate cropping techniques employed to select areas of interest.

3.6 As in most aerial surveys, a great deal of overlap between photos is apparent. Such overlap allows areas of sun glare to be masked by photos taken at a different angle and prevents seagrass beds that span images from being split. Photographs were viewed and relevant images selected. Once selected, the area of the image file displaying the photograph was selected using the area of interest tool. The best combinations of these areas of interest were amalgamated with a feather overlap function within the mosaic tool.

3.7 Initial examination of the survey area suggested that creation of 15 mosaics would be sufficient to cover the area of interest, however in order to maintain as much continuity as possible between the images used in each mosaic the overall number was increased to 51, using 190 separate images.



Shaded mosaics show those containing known seagrass beds (see Appendix 2 for details of constituent aerial images).

Figure 1 Delineations of the final mosaics cropped to the 15m isobath

3.8 The mosaiced images were then loaded into ARCGIS and projected using the British National Grid, each mosaic was cropped using the raster processing function and a shapefile of the area that lay between the Isles of Scilly coastline and the 15m isobath.

3.9 A second area of interest was created for each of the new clipped mosaic files, which in some cases was a considerably smaller file due to the effect of the clipping process; this was then used in the unsupervised classification process.

Unsupervised classification

3.10 Unsupervised classifications of the processed images, was carried out using combined data from the red, blue and green bands to objectively classify pixels into categories containing similar values for each of the three variables (Chuvieco & Congalton 1988, Pasqualini et al. 1998). For a number of images, the variable histograms were viewed to assess spectrally homogenous groups and from this a standard of 30 classes was decided upon (Green et al. 2000). Classes were then identified using the ISODATA algorithm (Iterative Self-Organising Data Analysis Technique). This clustering method uses the minimum spectral distance formula to form clusters and classifies pixels repetitively, each time redefining the criteria for each class (for example cluster means) to eventually reveal spectral distance patterns in the data (Lillesand & Kiefer 2000).

Ground truthing point selection and methodology

3.11 Ground truthing was carried out to validate the clusters from the unsupervised classification, to identify training sites for the supervised classification (see below) and to keep in reserve to validate and assess the ‘thematic’ accuracy of the final supervised classifications of images (Mumby & Green 2000). Class stratified random positions were generated using ERDAS accuracy assessment processor. Stratified random selection of positions was used, whereby the number of points is stratified to the distribution of the thematic layer. Current best practice advises that 10 sites are visited per habitat per image/mosaic (if you consider seagrass, algae and bare sand at three different depth bands, 90 positions). It is also good practice to visit a further 30 sites for accuracy assessment and validation. Due to the cost in time and resources incurred by sampling high numbers of truly random sites, driving the vessel in the proximity of a smaller number of randomly generated sites with periodic stops was deemed adequate.

3.12 To aid ground truth survey the positions were split by zone (see Please note bathymetric data is derived from © British Crown and SeaZone Solutions Limited, 2009. All Rights Reserved. Products Licence No. 062006.004. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (**www.ukho.gov.uk**). NOT TO BE USED FOR NAVIGATION.

3.13 **Figure 1**). Different zones were ground truthed at different times, but all were surveyed within 2 months of each other and within 1 year of the aerial photo survey. Positions were identified in the field using Differential Global Positioning Satellite (DGPS) system on board. At each ground truth position, the presence or absence of seagrass was identified, in shallow water (< 3m) by either looking over the side of the boat, and in deep water (> 3m) by real time drop video camera. If seagrass was present the percentage cover within view was noted. If there was no seagrass the type of seabed was classified as either:

- Unvegetated sand;
- Unvegetated rock;
- Green algae; or
- Brown algae.

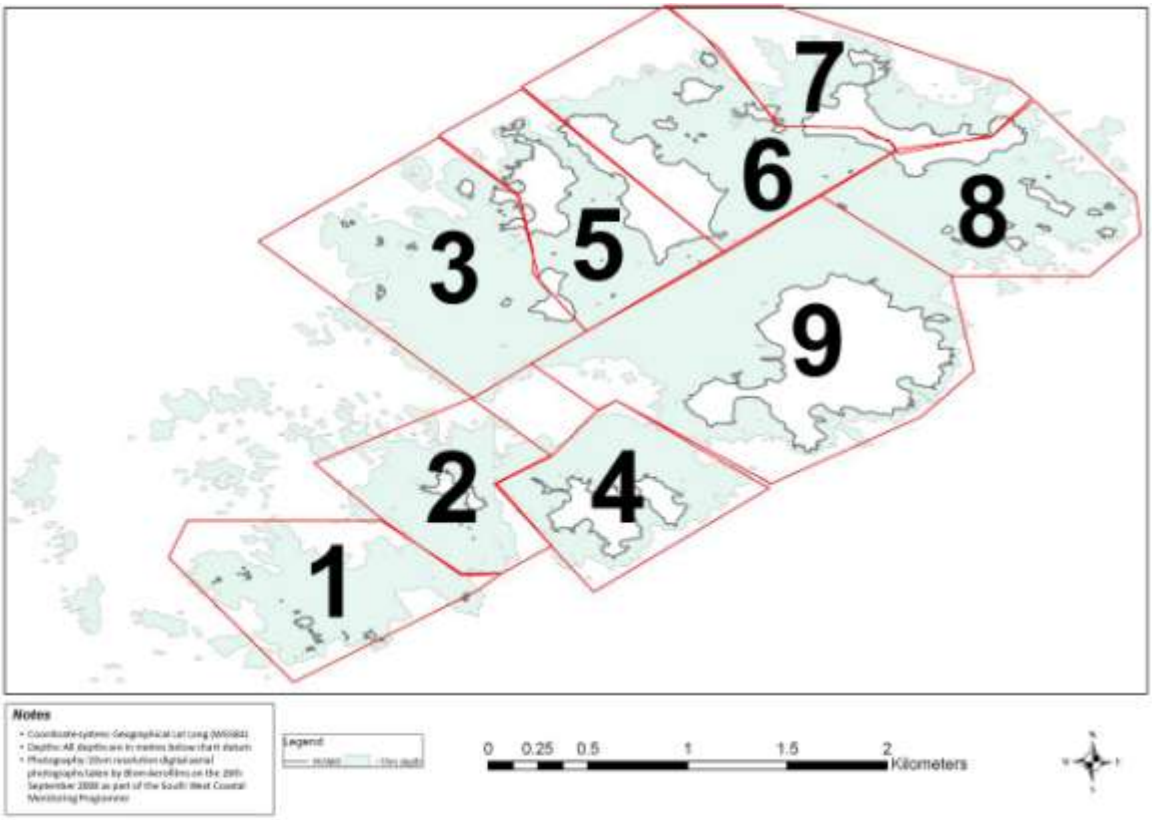


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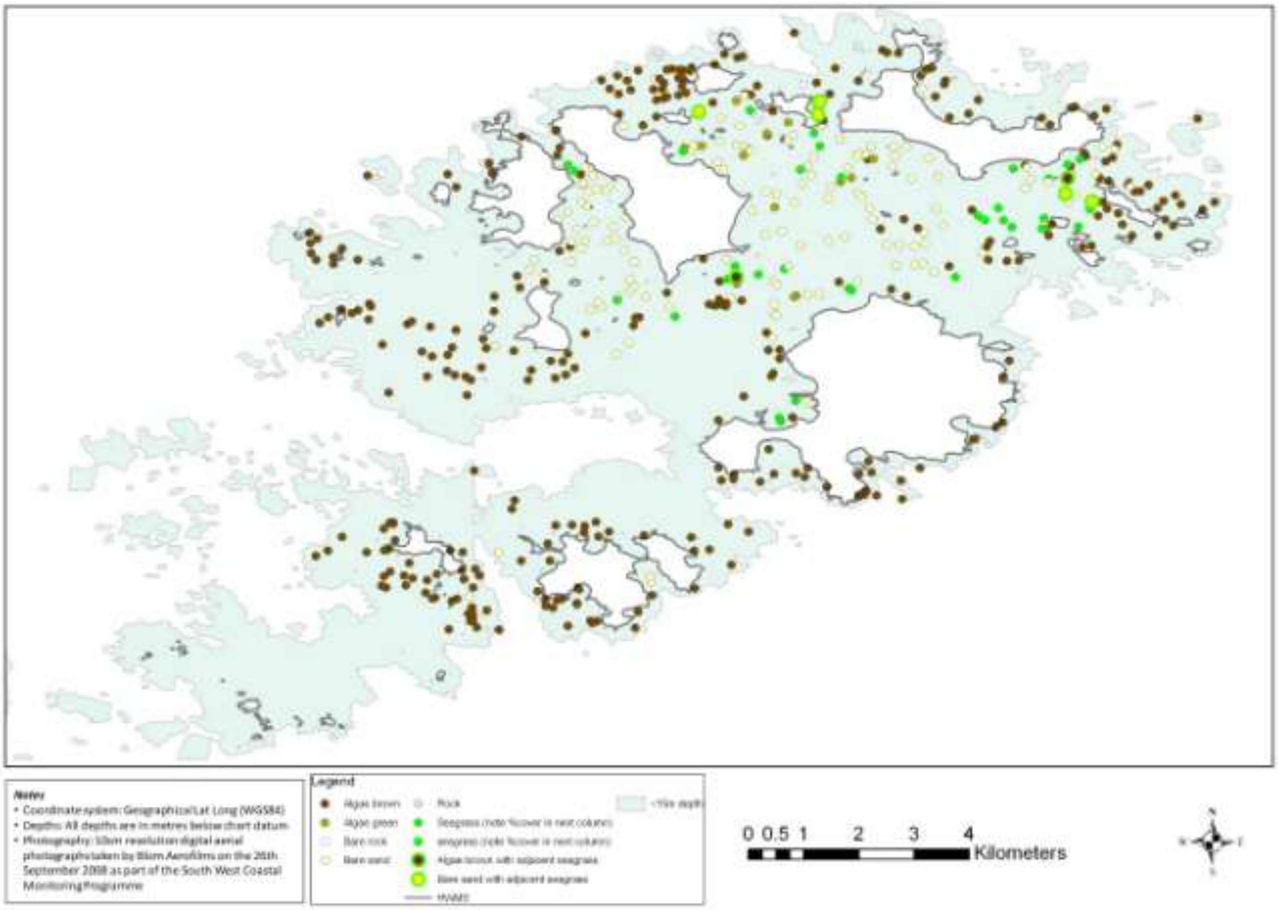
Figure 1 Areas of the Isles of Scilly aerial photos zoned to aid ground truthing

3.14 A total of 628 ground control points (GCPs) were visited during the summer 2009 (see Please note bathymetric data is derived from © British Crown and SeaZone Solutions Limited, 2009. All Rights Reserved. Products Licence No. 062006.004. This product has been derived in part from

Illustrates GCP (Ground Control Points) from the ground truthing operations carried out as part of this study (see Appendix 3 for details).

3.15 **Figure**). Of these 97 were identified in situ as too deep for seagrass growth (greater than 10m) despite bathymetry map predictions. In addition to these positions a further 282 positions of seagrass were collated from past surveys (Munro & Nunny 1998, Cook 2002, 2004a, b, Cook & Foden 2005, Cook 2006, Cook & Paver 2007) and maps form the Environmental Records centre for Cornwall and the Isles of Scilly. All ground truthing operations were undertaken by locally based company St. Martin's Diving Services.

3.16 All site positions were in recorded in Geodetic WGS84 (Lat/Long in dd mm.mmmm) using the boats differential GPS. All times were noted in British Summer Time (BST). All depths were recorded from the vessel's echo sounder as 'below sea level', but later converted to below chart datum using the date and time of the record.



Illustrates GCP (Ground Control Points) from the ground truthing operations carried out as part of this study (see Appendix 3 for details).

Figure 3 Ground truthing positions

3.17 The maximum depth recorded for seagrass from the ground truthing positions was 5.2m (off the North coast of St Mary's), with a mean depth of 2.9m.

3.18 In addition to the surveys carried out during 2009 as part of this contract, previous records of seagrass distribution were also used to aid the selection of training areas, including:

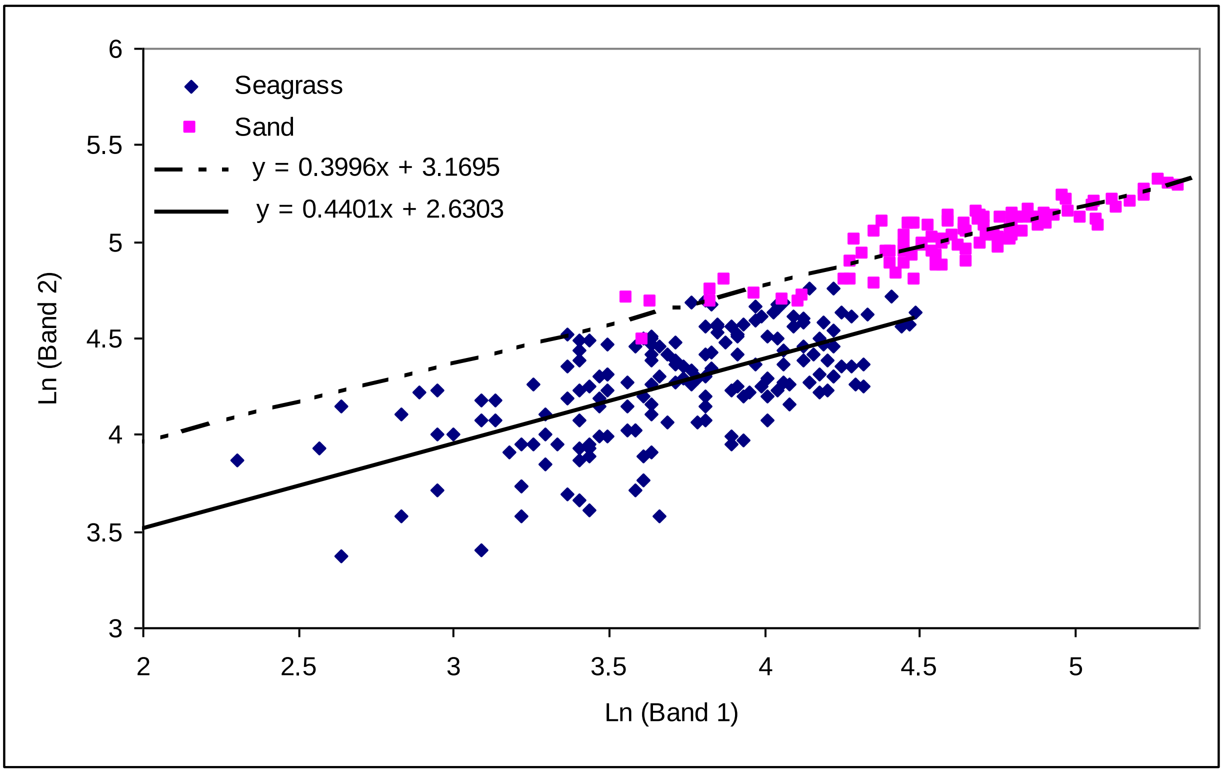
- Isles of Scilly seagrass annual survey data (Cook 2002, 2004a, b, Cook & Foden 2005, Cook 2006, Cook & Paver 2007);
- National Biodiversity Network data (**http://data.nbn.org.uk**);
- Environmental Records Centre for Cornwall and the Isles of Scilly (Hocking & Tompsett 2002); and
- Isles of Scilly Subtidal Habitat and Biotope Mapping Survey (Munro & Nunny 1998).

3.19 Due to the dynamic nature of seagrass beds, particularly in areas of high current regime historical records where used with caution. Data with no depth information were joined to SeaZone bathymetry data to give depth to the nearest isobar. An examination of this information showed that there have been no past records of seagrass in the Isles of Scilly deeper than 6m. In 2005 Cook and Foden (2005) recorded seagrass growing at 5.3 m depth Broad Ledge, Tresco.

Water column correction

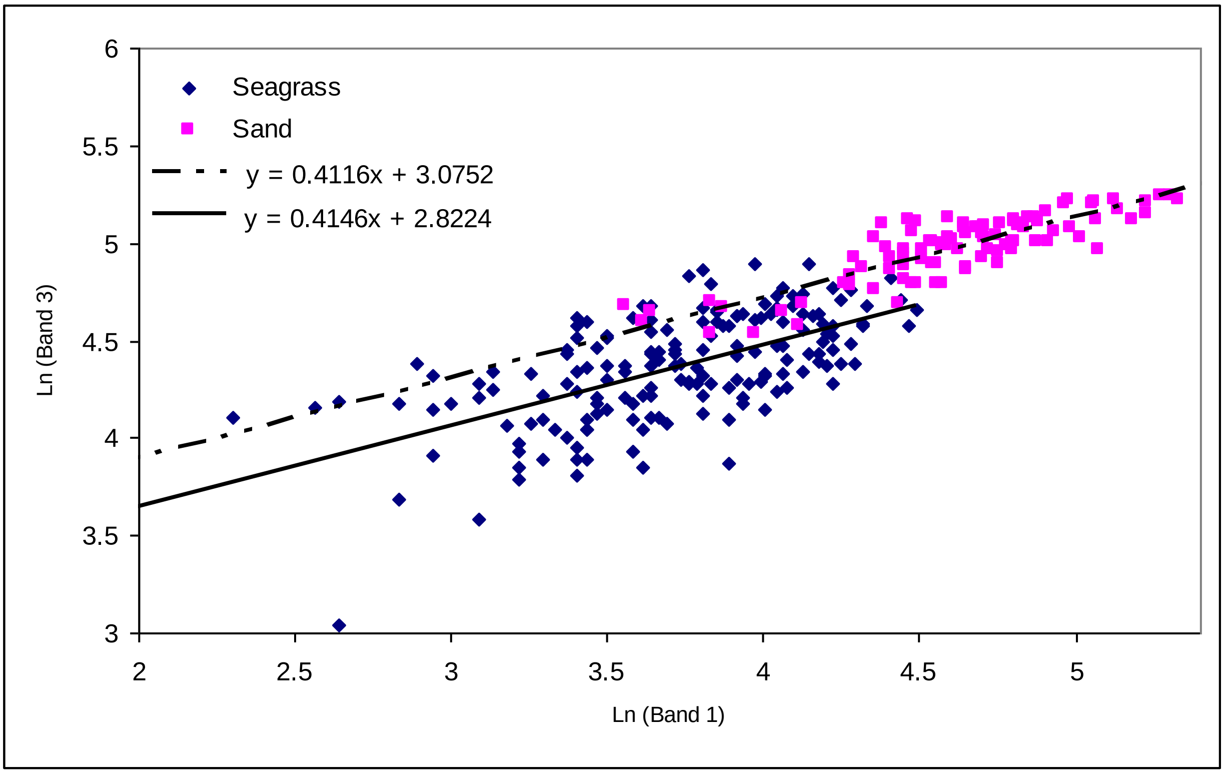
3.20 In relatively clear water like that found in the Isles of Scilly, the intensity of light decays exponentially with increasing water depth, a process known as attenuation. Attenuation differs with the electromagnetic radiation wavelength (red light attenuates more rapidly than blue, which is why infrared does not penetrate to any depth of water and also why the sea looks blue). With an increase in depth it becomes more difficult to separate out different habitats (sand at 10m may be similar to that of seagrass at 1m) (Green *et al.* 2000). It is therefore useful to remove the confounding influence of variable water depth. In relatively clear waters this can be done using a straightforward method proposed by Green *et al.* (2000) based on that of Lyzenga (1981), which produces a 'depth-invariant bottom index' from each pair of spectral bands. Although the waters of the Isles of Scilly are very clear there is still some variability in water clarity across the images. This variability and the use of mosaics in this work, which join different images of different sun angles, prevented the implementation of the depth-invariant algorithm to the whole image. However the depth invariant bottom index was used to distinguish the likelihood of a pixel being seagrass, sand or algae, particularly at depth and for those images where no seagrass ground truthing points were available (see section on knowledge editing).

3.21 In the absence of a good digital elevation model of depth for the Isles of Scilly, depth was estimated using digital bathymetric charts (SeaZone) and the tidal height added based on the height above chart datum at the date and time the individual photo was taken (information provided by Blom Aerofilms). Known locations of seagrass and unvegetated sand were used to select pixels from various depths across all the unclassified images. The pixel radiance for each of the bands was assigned a corrected depth.



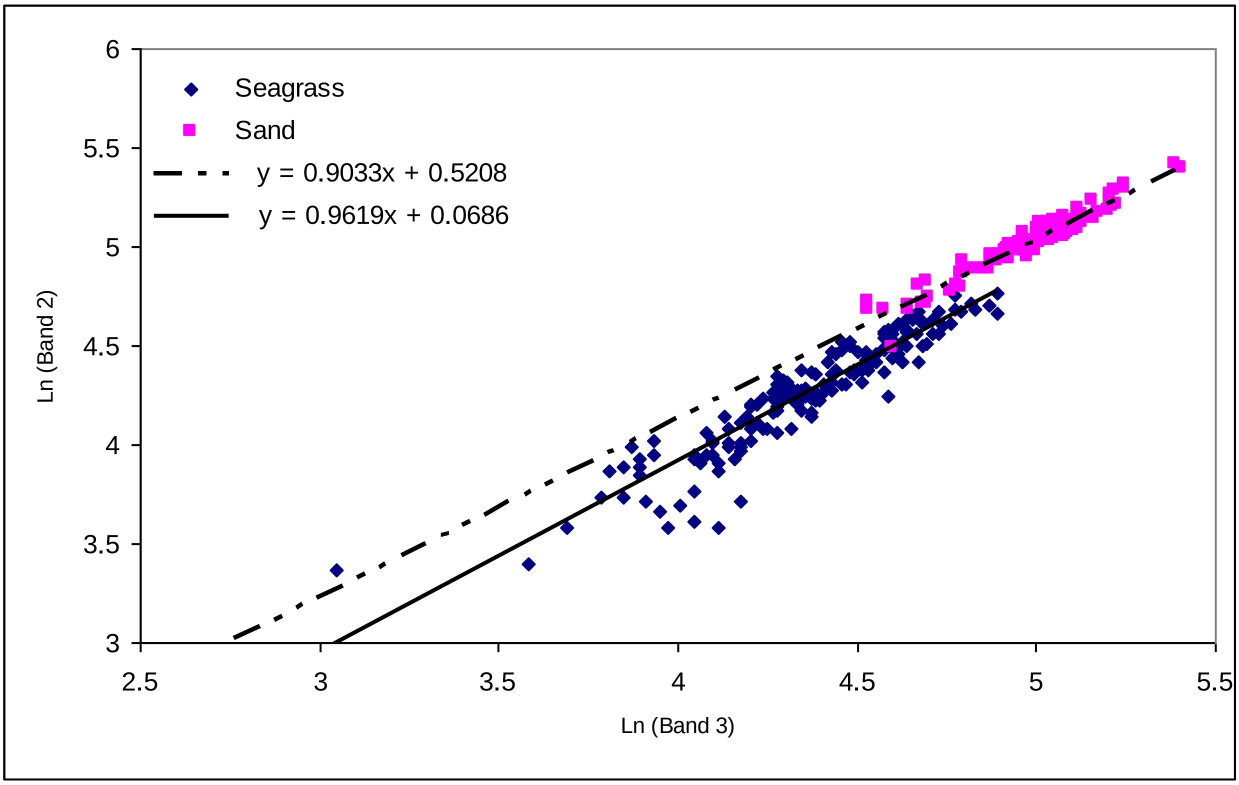
Depth decreases from left to right. Y intercept values provide unique depth invariant index of bottom type.

Figure 4 Bi plot of log transformed RGB bands 1 and 2 (seagrass n= 171, sand n= 99) for variable depths in the Isles of Scilly



Depth decreases from left to right. Y intercept values provide unique depth invariant index of bottom type.

Figure 5 Bi plot of log transformed RGB bands 1 and 3 (seagrass n= 171, sand n= 99) for variable depths in the Isles of Scilly



Depth decreases from left to right. Y intercept values provide unique depth invariant index of bottom type.

Figure 6 Bi plot of log transformed RGB bands 2 and 3 (seagrass n= 171, sand n= 99) for variable depths in the Isles of Scilly

3.22 Radiance values in each band are then transformed using natural logarithms (ln), to make the relationship with depth linear. For each substrate type the transformed irradiances of the different bands are plotted for each band combination (see examples in Figures 4-6). The gradient of the line represents the ratio of attenuation coefficients (this ratio should be the same regardless of what habitat type it is, see Figures 4-6). Also irrespective of depth each habitat type has a unique y-intercept which can be used as a depth-invariant index of bottom type (Green *et al.* 2000).

Phase 2 Supervised classification

3.23 Whilst unsupervised classification methods utilise statistical clustering techniques to identify the main spectral clusters within an image, supervised classification uses knowledge of the user to define the spectral groups (Green *et al.* 2000). Following ground identification of the unsupervised clusters, informational classes were chosen to meet the objectives of the study. These classes were seagrass (three levels of coverage), macro-algae (brown and green), unvegetated sand and unvegetated rock (split between intertidal and subtidal). Seabed was classified as drift algae where ground truthing identified bare sand, but the aerial photograph showed algae. In some cases, field validation identified clusters that either did not represent sufficiently certain classes or described two or more classes. Therefore, a hybrid classification method was adopted (Lillesand & Kiefer 2000) by augmenting the unsupervised with a supervised classification. The supervised classification was implemented using regions (training areas) confirmed during the ground truthing phase, which were representative of the different habitat classes. The relevant pixels were selected on the images and their spectral information used to specify 'signatures' (numerical descriptors for processing algorithms) of the different classes present in the image scene. Adhering to currently accepted protocol (Green *et al.* 2000), where possible a minimum of 10 training areas per class throughout the image was used to obtain a representative sample of the spectral range of each class.

3.24 The final signature set was entered into a maximum likelihood classification program, which assigned each pixel to a particular signature using a probability density function (Lillesand & Kiefer 2000). A threshold was conducted on the distance-image histogram of the classified image to eliminate pixels that are most likely to be classified incorrectly at a 95% level of probability.

Knowledge editing

3.25 Careful knowledge, or contextual, editing can significantly improve the accuracy of final classified images (Mumby & Green 2000, Irving *et al.* 2007). In this work we applied five different methods of knowledge editing to the supervised classified maps:

1) Where ground truth observations illustrated an incorrect classification of the seabed, (either as seagrass when seagrass was not present or as another habitat when seagrass was observed) the area of interest region growing select tool in Erdas Imagine v9.3 was used to select all adjoining pixels of that classification, and pixels were re-coded.
2) Based on the ground truthing and review of previous studies a maximum depth limit of seagrass of 5.3m was identified. Depth isobaths from the SeaZone digital bathymetric depths were only available for 5m and 10m. The 5m isobaths was chosen to remove areas of seagrass in depths greater than 5m c.d. unless they constituted the edge of a known shallower bed (see section 4.5).
3) RoxAnn habitat maps (Munro & Nunny 1998) were used to remove areas identified as substrates unsuitable for seagrass growth and help to recode misclassified . Within ArcGIS a spatial join was performed between the ground control positions of identified seagrass (and past records of seagrass) with the RoxAnn biotopes to identify which biotopes have no records of seagrass (Table). Seagrass was found on most of the sedimentary seabed types, with the exception of the deeper and wave exposed habitats. *Zostera marina* cannot grow on bedrock or boulders, however some of the records intersected these biotope types (Cobbles, boulders & bedrock outcrops and Infralittoral (or littoral) bedrock or boulders w. kelp/*Himanthalia*/fucoids-grazed bedrock), which may be due to inaccuracies or the resolution of the RoxAnn biotope maps (the data was interpolated between survey lines spaced at 200m, Munro & Nunny 1998). This method of knowledge editing was therefore taken with caution.
4) Depth invariant bottom index was used to examine the likelihood of a pixel being seagrass versus algae.
5) Finally, local knowledge was used to help validate the maps. Tim Allsop (Local dive operator and ground truthing surveyor for this project) and Kevan Cook (Natural England) were shown first drafts of the seagrass beds and asked to comment firstly on those areas classified as seagrass where they are confident from personal observations that no seagrass exists, and also on areas where they think due to local conditions seagrass growth is unlikely, but do not know that seagrass is absent.

Table 1 Occurrence of seagrass with RoxAnn seabed “Biotope” records

RoxAnn seabed “Biotope”	% of seagrass records occurring within “Biotope”
Zostera	75
Cobbles, boulders & bedrock outcrops	13.19
Shallow sheltered medium sand with variable or low gravel content	4.16
Shallow (<20m) sandy gravel, cobbles, sm. boulders or sand veneers over bedrock	3.47

RoxAnn seabed “Biotope”	% of seagrass records occurring within “Biotope”
No RoxAnn data	2.08
Infralittoral (or littoral) bedrock or boulders w. kelp/Himanthalia/fucoids-grazed bedrock	1.39
Shallow (<20m), sheltered fine sand	0.69
Circalittoral bedrock w. faunal turf	0
Deep (>20m) sandy gravels, cobbles, small boulders or sand veneer over bedrock	0
Deep (30m+) wave exposed, fine sand	0
Deep (45m+) circalitt. Bedrock faunal turf including dense Axinellids	0
Deep, exposed, moderately sorted medium sand with variable gravel content	0
Wave-exposed coarse shell sand, (mostly >20m)	0

Accuracy assessment

3.26 The overall accuracy of the final classification was assessed using error matrices, whereby each row and column represented each classification category (Mumby & Green, 2000). For the present study, accuracy assessment sites were randomly selected from each class per mosaic. A measure of accuracy of the whole image across all classes was calculated using the multivariate Khat statistics (K, otherwise known as the Kappa coefficient, for details see Mumby & Green, 2000) using the equation;

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_i + \cdot x_{+i})}{N^2 = \sum_{i=1}^{r}(x_i + \cdot x_{+i})}$$

3.27 Where ‘r’ is the number of rows in the matrix, ‘xii’ is the number of observations in the *i*th row of the *i*th column, ‘xi+’ and ‘x+i’ are the row and column totals and N is the total number of observations (ten per class) (Green & Mumby, 2000). The Khat statistic represents the proportion of error reduced by the classification compared to the image being classified completely at random (Erdas Inc., 1991).

4 Map outputs and discussion

Seagrass bed maps

4.1 Figure illustrates the steps in the classification process for part of one image mosaic showing the channel between Bryher and Tresco. The final classified images where edited to just show just the seagrass classes. These steps were applied to each of the image mosaics.

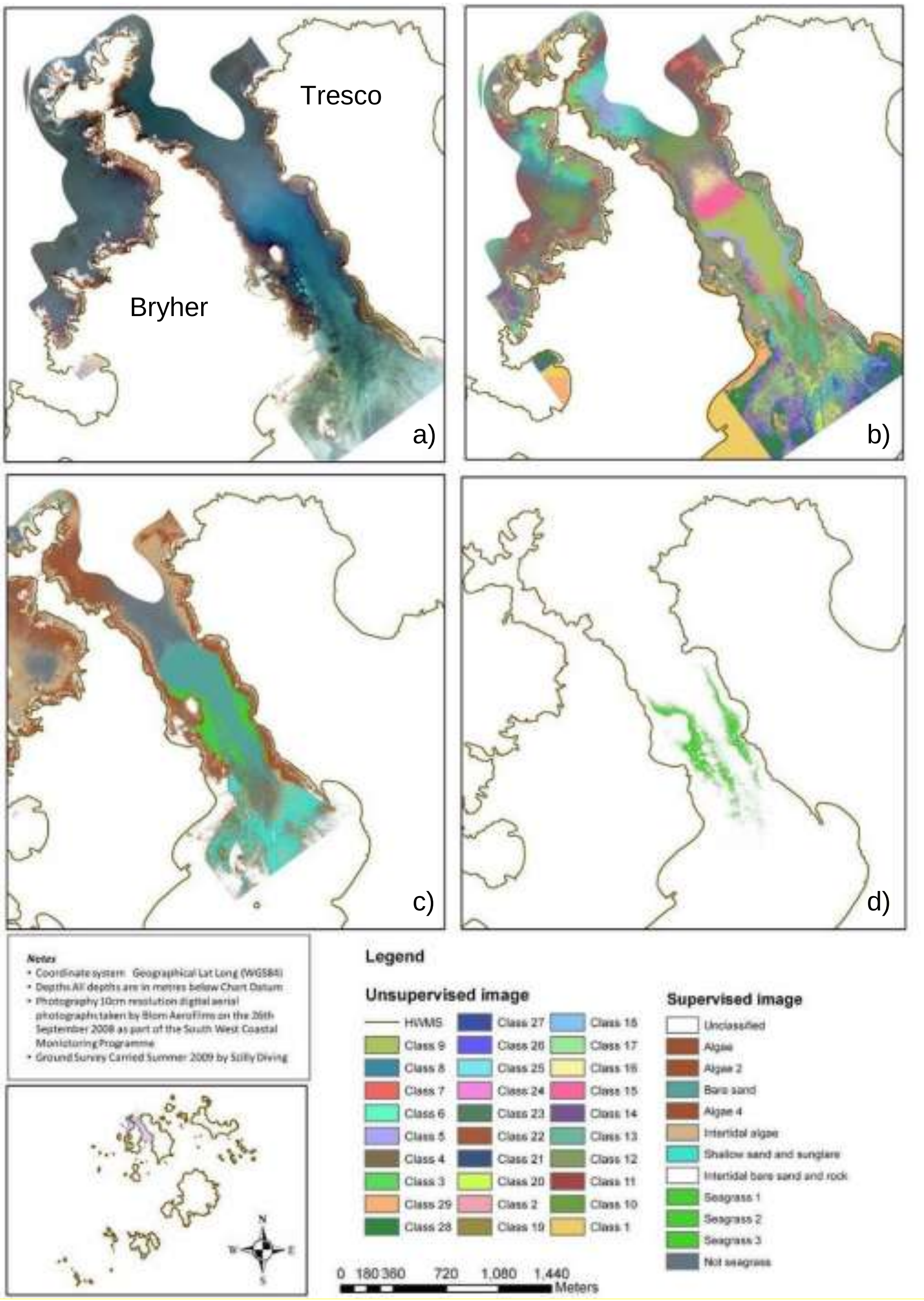


Figure 7 The four stages of the classification of *Zostera marina* between Bryher and Tresco, a) Raw aerial image mosaic; b) unsupervised image; c) supervised classification; d) supervised classification, seagrass only prior to knowledge editing

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4.3 **Figure** illustrates the initial supervised classification of the images, showing the location of signatures that most closely relate to seagrass, prior to any knowledge editing. No ground truthing positions or previous records of seagrass in the Isles of Scilly identified records for the Western Rocks area and therefore no seagrass could be identified for this region. Mosaics with known seagrass occurrence are illustrated in Shaded mosaics show those containing known seagrass beds (see Appendix 2 for details of constituent aerial images).

4.4 **Figure**. The supervised images were next subjected to a series of knowledge editing steps (see page 11).

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4.6 **Figure** shows seagrass from the supervised classification overlain on to those RoxAnn mapped biotopes (Munro & Nunny 1998) where seagrass was previously recorded (see **Table**). The majority of predicted seagrass overlap with these faces. Exceptions occur on the northerly coasts where possible seagrass has been identified through the supervised classification but the substrate is unsuitable. These northerly coasts receive little shelter from Northerly winds and are unlikely to be suitable sites for seagrass habitat. It is important to note that there is some lack of confidence in the current validity of these biotope maps, for example they failed to detect seagrass which occurs within St. Mary’s harbour. Also in Great Bay (St. Martin’s) there are a number of areas of soft sediment suitable for seagrass (obvious visually from the aerial photographs), which are not mapped as soft sediment by the biotope survey. There are also large areas of the *Zostera* biotope in the waters between St. Mary’s and Tresco, where seagrass has not been predicted to occur by the present study. There are a number of possible explanations for these inconsistencies. Firstly, the biotope survey was carried out in 1997 and as quite a dynamic habitat some seagrass distributions may have altered. Secondly the *Zostera* biotopes could not be differentiated by RoxAnn from algal covered rocks (Munro & Nunny 1998) and instead a classification of “potential seagrass” was given, which was then refined using depth data, wave exposure, ground truthing (see

Appendix 4), aerial photography and side scan sonar. However, examination of the ground truthing samples (grab and video, see

Appendix 4) used for this refinement shows that in many cases seagrass was identified at depths way in excess[2] of, not only any of the *Zostera* recorded by the GCPs of the current study (maximum depth 5.2m) but in excess of any UK records of seagrass.

The current study and an assessment of recent surveys (Cook 2004a, b, Cook & Foden 2005, Cook 2006, Wyn *et al.* 2006, Cook & Paver 2007, Cook *et al.* 2008), did not identify seagrass beyond 6m depth[3] (see page 8). Therefore, a second level of knowledge editing involved a 5m isobaths clip being applied to the seagrass map (see Please note bathymetric data is derived from © British Crown and SeaZone Solutions Limited, 2009. All Rights Reserved. Products Licence No. 062006.004. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (**www.ukho.gov.uk**). NOT TO BE USED FOR NAVIGATION.

4.7 **Figure**). The depth invariant bottom index (see page 8) was used to confirm the likelihood that these pixels had been misclassified as seagrass. The application of this depth clip removed areas of mapped seagrass from the East coasts, an area that was most likely misclassified as seagrass due to a combination of depth and wave reflection (as the pixels identified as seagrass were very sparse and there was a lot of noise in this region). The clip also removed a large area of mapped seagrass about 2km North West of St Mary's Harbour. This particular location of possible seagrass appears to be fairly contentious. In addition to being identified as seagrass by the supervised classification analysis of the current study, it was also identified as seagrass during the biotope survey (Munro & Nunny 1998) and previous aerial image analysis (ERICC site 26, Hocking & Tompsett 2002), however no GCP from the current study or local knowledge (**Figure**) confirms that seagrass occurs here. The pattern of the area is consistent with current swept seagrass meadows and the substrate is soft sediment, ruling out the occurrence of rocky algal habitat. Furthermore, the constancy of the feature between the 1997 survey (Munro & Nunny 1998), the 2000 image analysis (Hocking & Tompsett 2002) and the current analysis make the occurrence of green drift algae (commonly misclassified as seagrass by image analysis and able to occur over soft sediments) unlikely. Further survey is recommended for this location.

[2] For example Station 9 in Area 12 identified dense *Zostera* at a depth of 22.5m and a number of stations recorded seagrass at depths >10m.
[3] Only a few of the large meadows extended up to 6m depth, most of the beds were within the 5m isobaths.

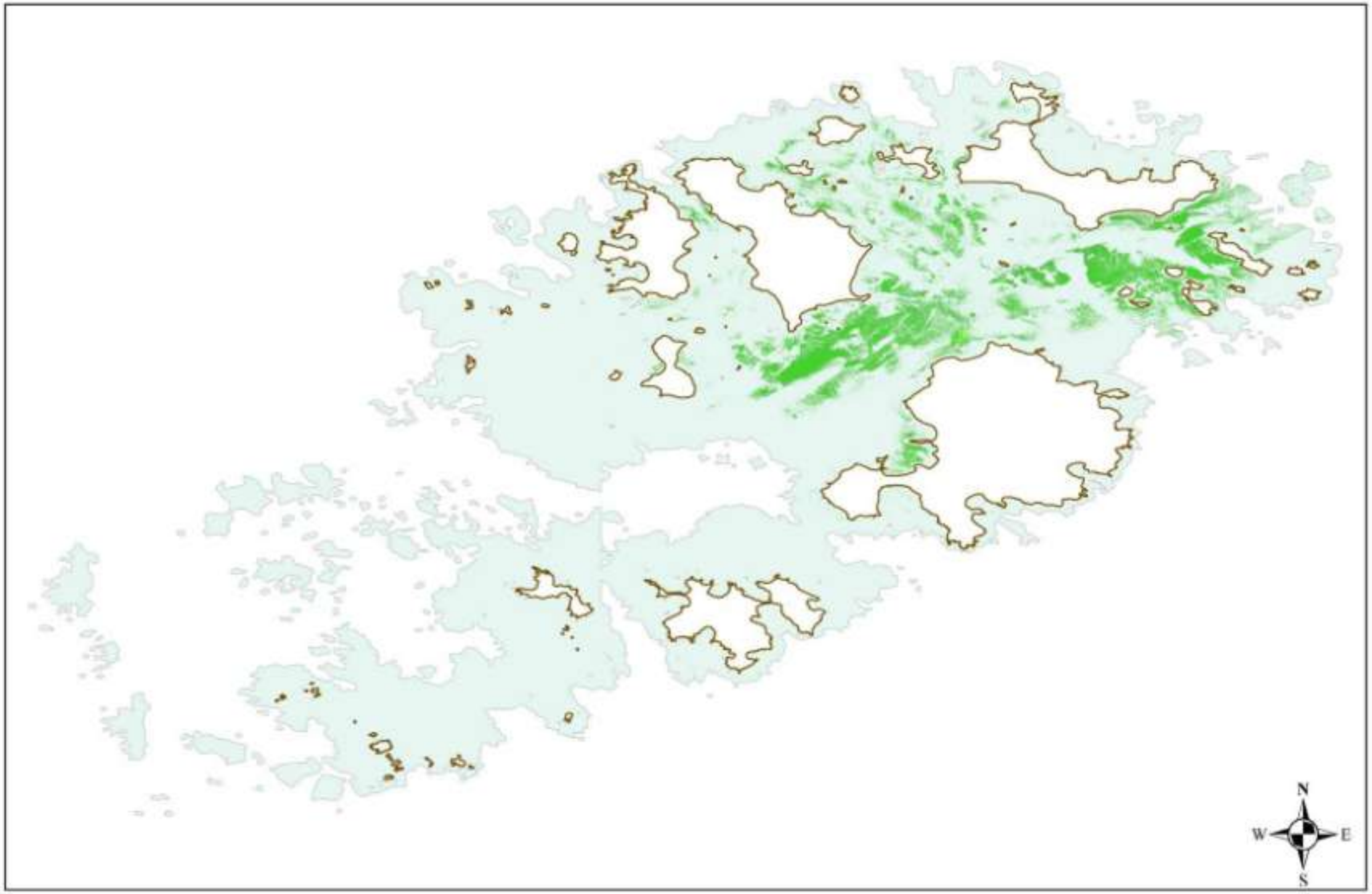

Figure 8 Initial map of seagrass distribution from the supervised classification, prior to knowledge editing

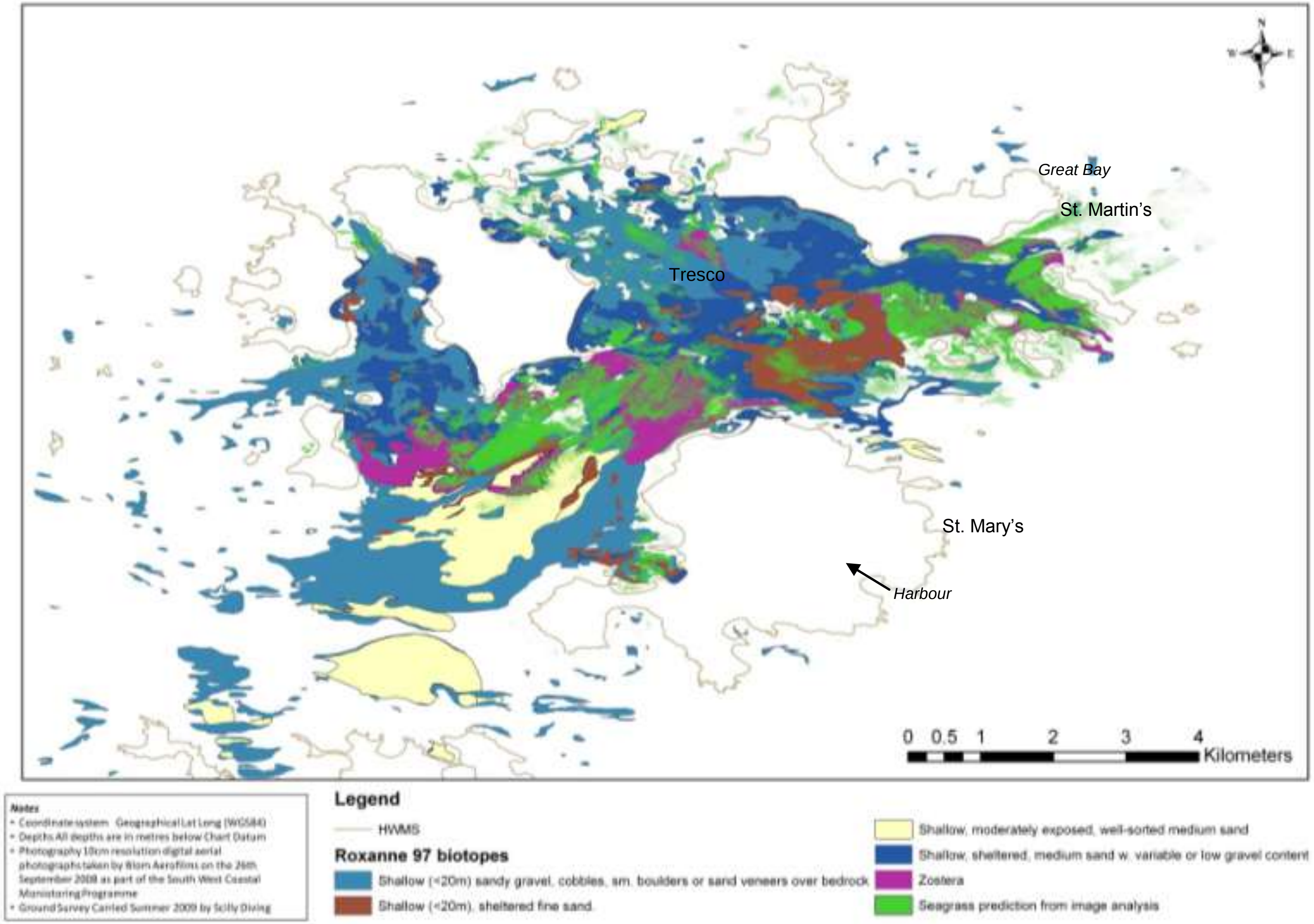

Figure 9 Predicted seagrass from supervised classification (prior to knowledge editing) overlain on to RoxAnn mapped biotopes were seagrass has been recorded (Munro & Nunny 1998)

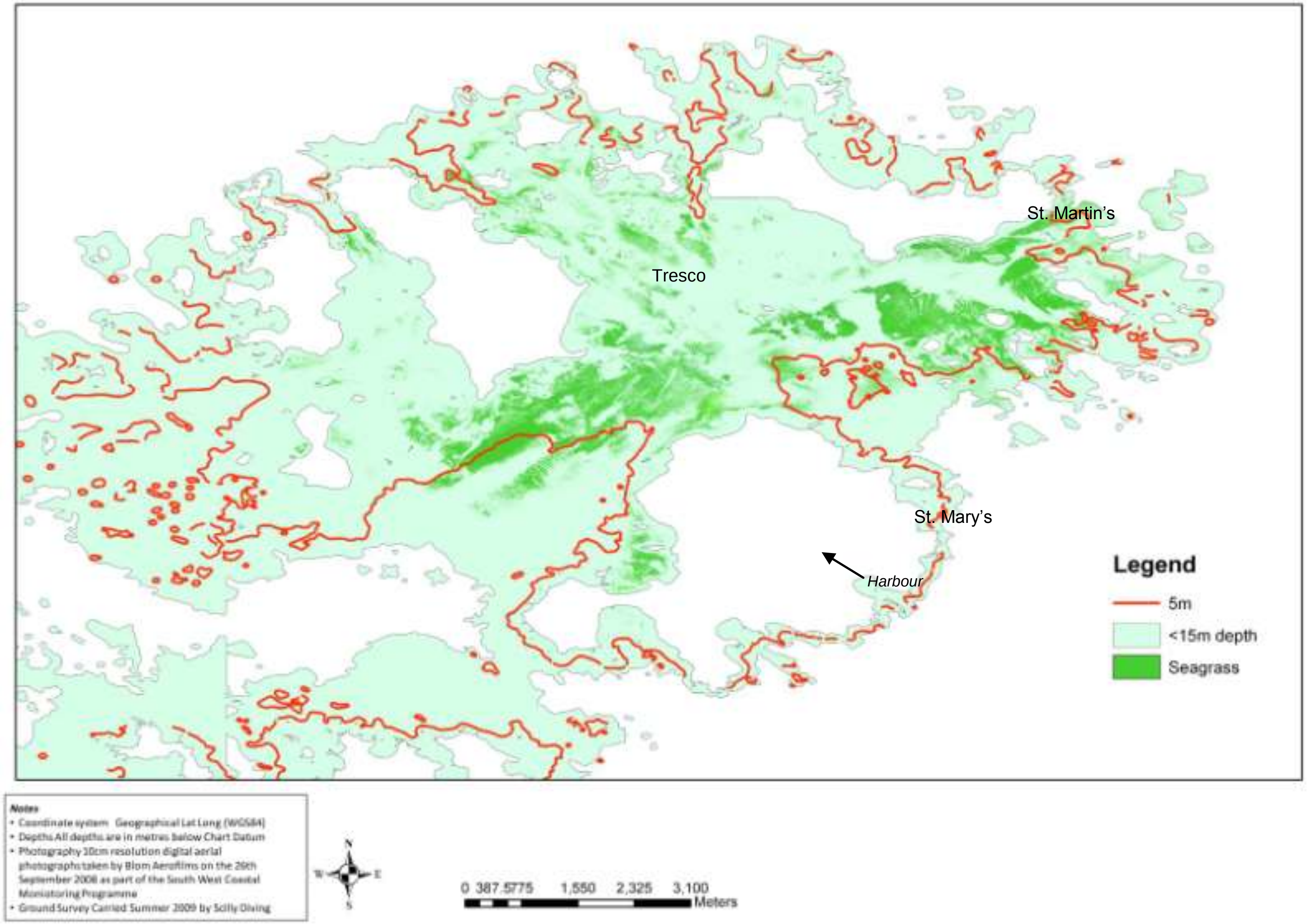

Figure 10 The 5m isobath overlain on to the map of predicted seagrass from supervised classification, prior to knowledge editing

4.8 As a final step in the knowledge editing, local knowledge and reports were consulted to identify areas of the map where seagrass could be confirmed, discounted or possible. **Figure** shows the edited maps provided by Tim Allsop (Scilly diving). Areas outlined in blue are sites were ground truthing from the current study was insufficient to confirm the occurrence of seagrass and need further survey. Some of the unconfirmed, but possible, areas of seagrass have been confirmed via other sources. For example, the two northerly patches of seagrass in Porth Cressa were visually confirmed by Angie Gall (Isles of Scilly Wildlife Trust). Also the ERCCIS report (Hocking & Tompsett 2002) suggests that there is seagrass west of Samson (Site S18) and dive surveys in 2008 confirmed isolated dense beds of *Zostera marina* in Rushy Bay off the south coast of Bryher (Kevan Cook, Natural England). There is also strong anecdotal evidence to suggest that there was once a large seagrass bed between the southern end of Bryher and Tresco, a dive survey in 1996 observed patchy sparse growth in agreement with the outputs of the current analysis (Kevan Cook, Natural England, pers. comm.).

4.9 Equally valuable from this exercise was the identification of known seagrass not predicted by the mapping (areas outline in purple on **Error! Reference source not found.**). In some instances it was possible to reclassify an area as seagrass by selecting a particular signature or changing the threshold (for example in Porth Moran on the south west coast of White Island). However, for some areas a distinct signature demarcating seagrass was not possible (for example in Wine Cove in Great Bay, St. Martin's and New Grimsby Harbour, Tresco) and these will require further survey. In reviewing the literature a report of seagrass occurring off Rat Island and to the west of St Mary's Harbour Quay (Halcrow Group Limited 2009) was found, this is a site unconfirmed by other surveys or records, or by the current studies ground control points.

4.10

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4.12 **Figure** shows the final map of seagrass post knowledge editing. These final maps are also available as ArcGIS shape files for each mosaic, as a whole region and in quarter regions (North East, South East, North West and South West). The final map estimates that there are approximately 196.5 ha of seagrass, with patch sizes ranging from 10cm (resolution of the images) to 46 ha (the area to the west of the Eastern Isles).

4.13 Figure illustrates the results of the accuracy assessment of this final map (the actual Kappa coefficient is provided for each mosaic in **Table** , along with a summary of each mosaic). The Kappa coefficient represents the proportion of error reduced by the classification compared to the image being classified completely at random (Erdas Inc., 1991), so a higher value equates to higher confidence in the classification for that mosaic. The lowest accuracies/ confidence (Kappa coefficient <0.4, i.e. where less than 40% of the error has been reduced by the classification) were evident for the north and south coasts of St Martin's, South Bryher and Porth Cressa, and caution should be used when utilising the maps here. The highest accuracies (Kappa coefficient >0.6) were found for the mosaics covering St. Mary's Harbour, the area between Tresco and St. Martin's, and the Eastern Isles, but also for Great Bay (St. Martin's) where according to local knowledge seagrass has not been effectively identified by the image analysis.

Finally, As surveyed using divers during 2008 (Cook *et al.*, 2009); GCPs which recorded seagrass within the current study, grab and video records of seagrass from the RoxAnn study (Munro & Nunny *et al.*, 1998) and diver observations incorporated from a survey carried out in August 2010 (Cook, in prep; provided during the final stages of the production of the current report and therefore not fully incorporated into knowledge editing).

Figure illustrates how this map matches up with GCPs of seagrass from the current study, data from Cook *et al.* (2009) demarcating the edges of the main meadows, and grab/video records from the biotope survey (Munro & Nunny 1998). The good correlation between the image analysis of the current study and the boundaries outlined by Cook *et al.* (2009) highlights the usefulness of the latter for monitoring the extent on an annual basis. However the method of Cook *et al.* (2009) only identifies the outer edge of a focal bed. This means that much of the inner configuration of the bed is missed, as are adjacent patches which may be beyond the view of the divers. These are, however, both picked up by the aerial image analysis, making this a valuable method for identifying internal fragmentation or re-colonisation within the bed and for predicting the locations of meadows beyond commonly surveyed areas. As surveyed using divers during 2008 (Cook *et al.*, 2009); GCPs which recorded seagrass within the current study, grab and video records of seagrass from the RoxAnn study (Munro & Nunny *et al.*, 1998) and diver observations incorporated from a survey carried out in August 2010 (Cook, in prep; provided during the final stages of the production of the current report and therefore not fully incorporated into knowledge editing).

4.14 **Figure** also illustrates data from diver observations carried out in August 2010 (Cook, in prep) Eastern Isles to the north east of Great Ganilly. These were provided during the final stages of the production of the current report and therefore could not be fully incorporated into knowledge editing. The positions illustrate that some of the patch of seagrass identified to the north of Great Ganilly is kelp and merging into an area of patchy seagrass/ kelp and then becomes a seagrass bed.

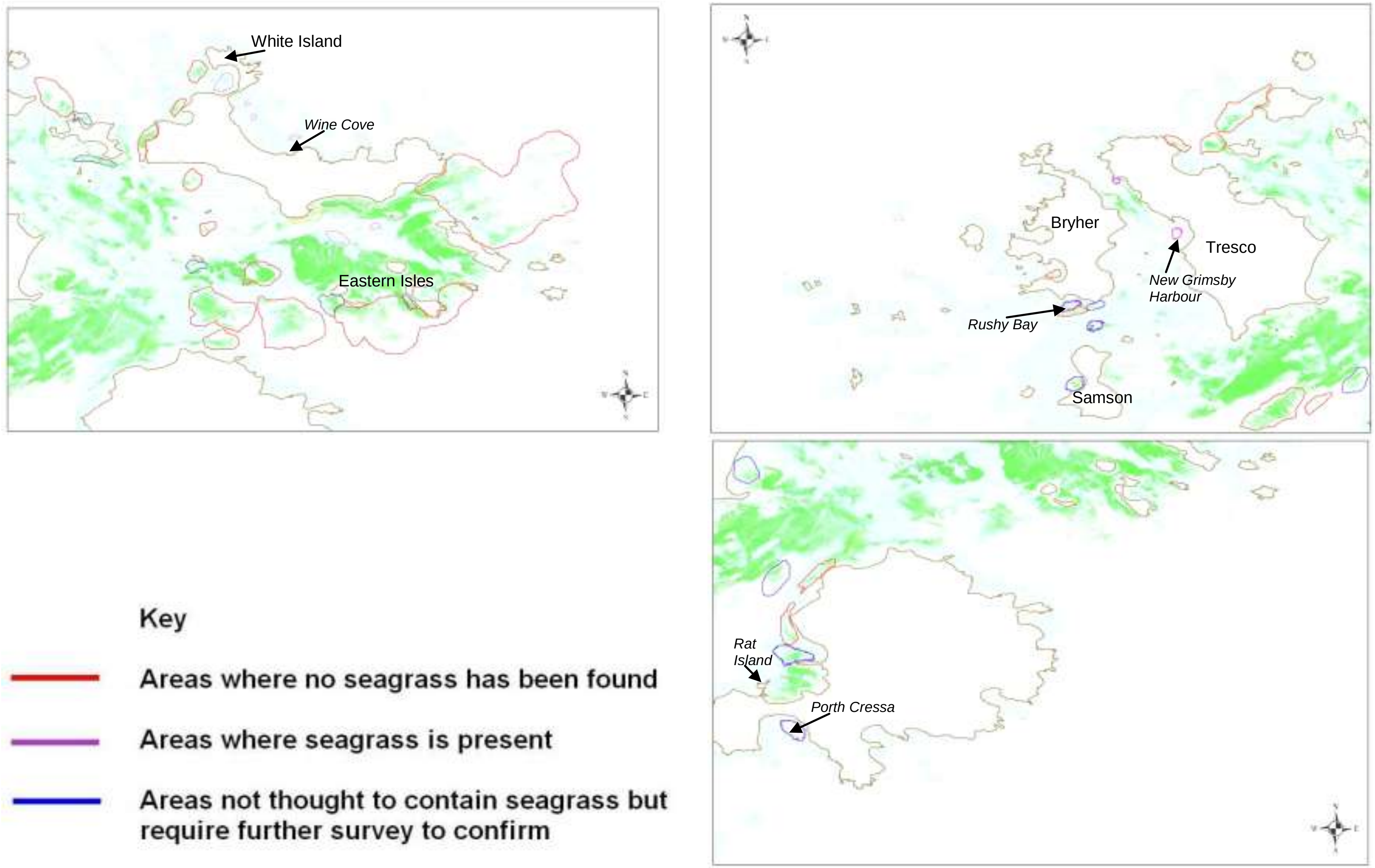


Figure 11 Identification of false positive and false negative areas of seagrass using local knowledge (Allsop et al., pers. comm.)

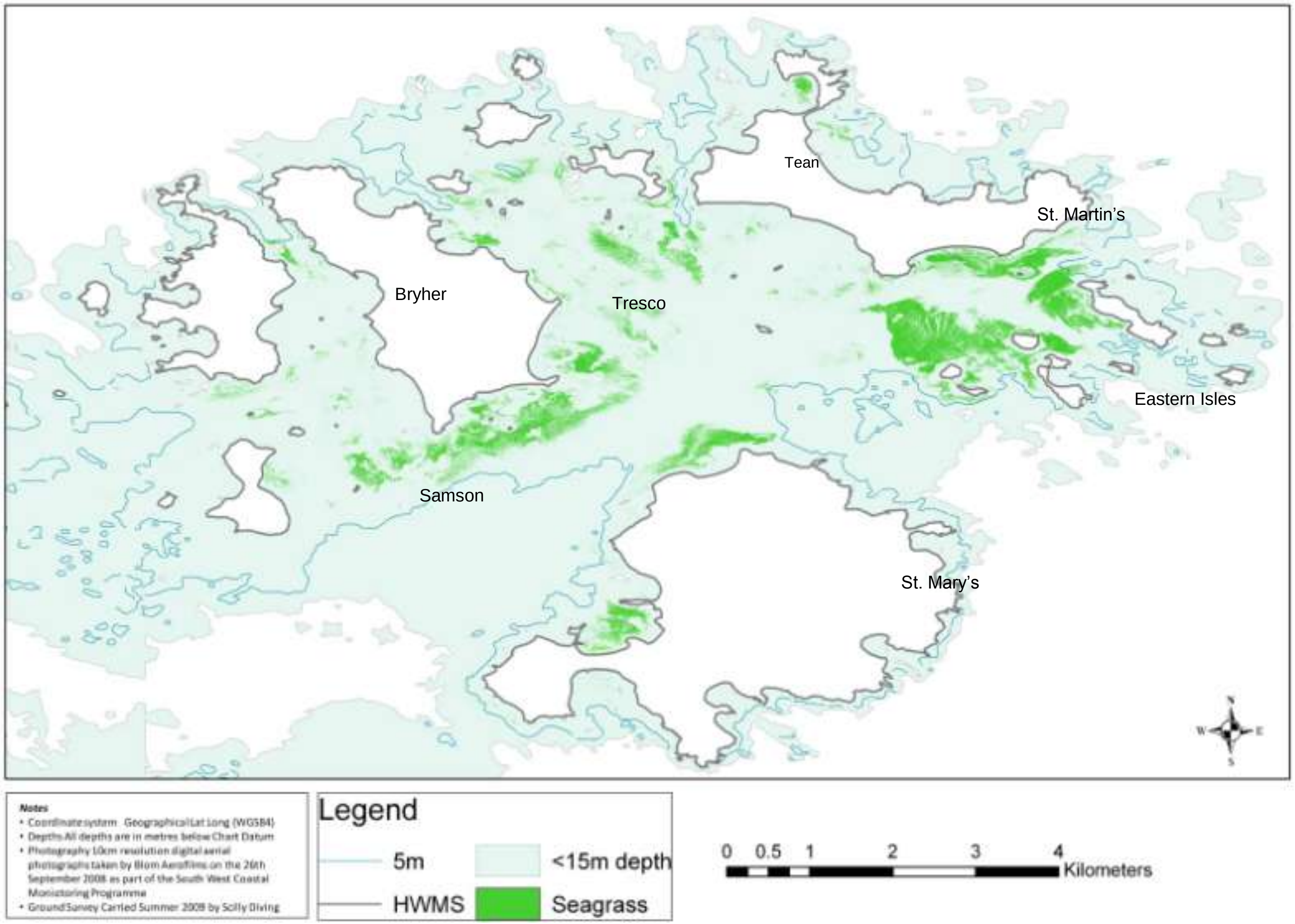
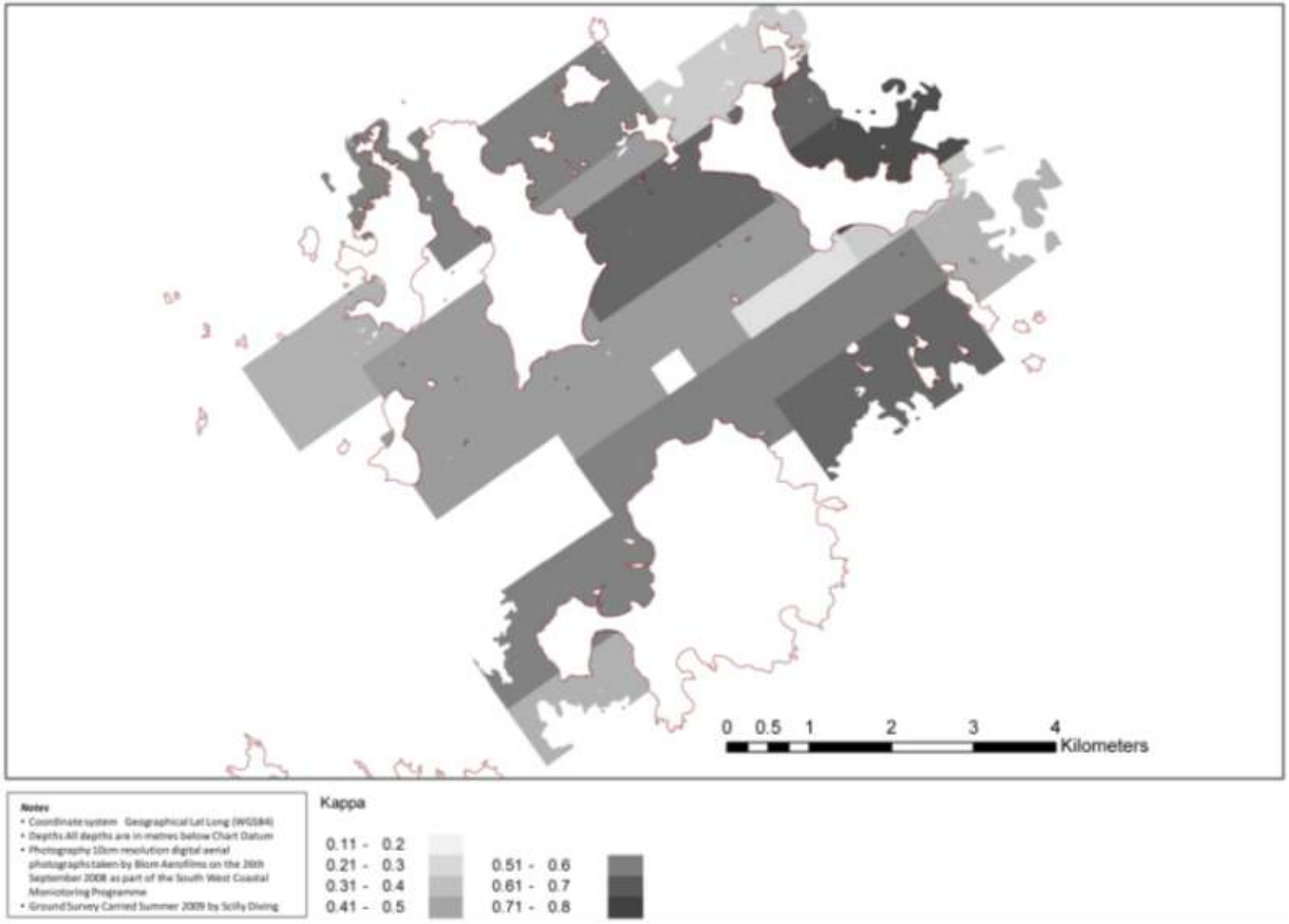


Figure 12 Final map of seagrass distribution post knowledge editing



Actual values are shown in Table 2.

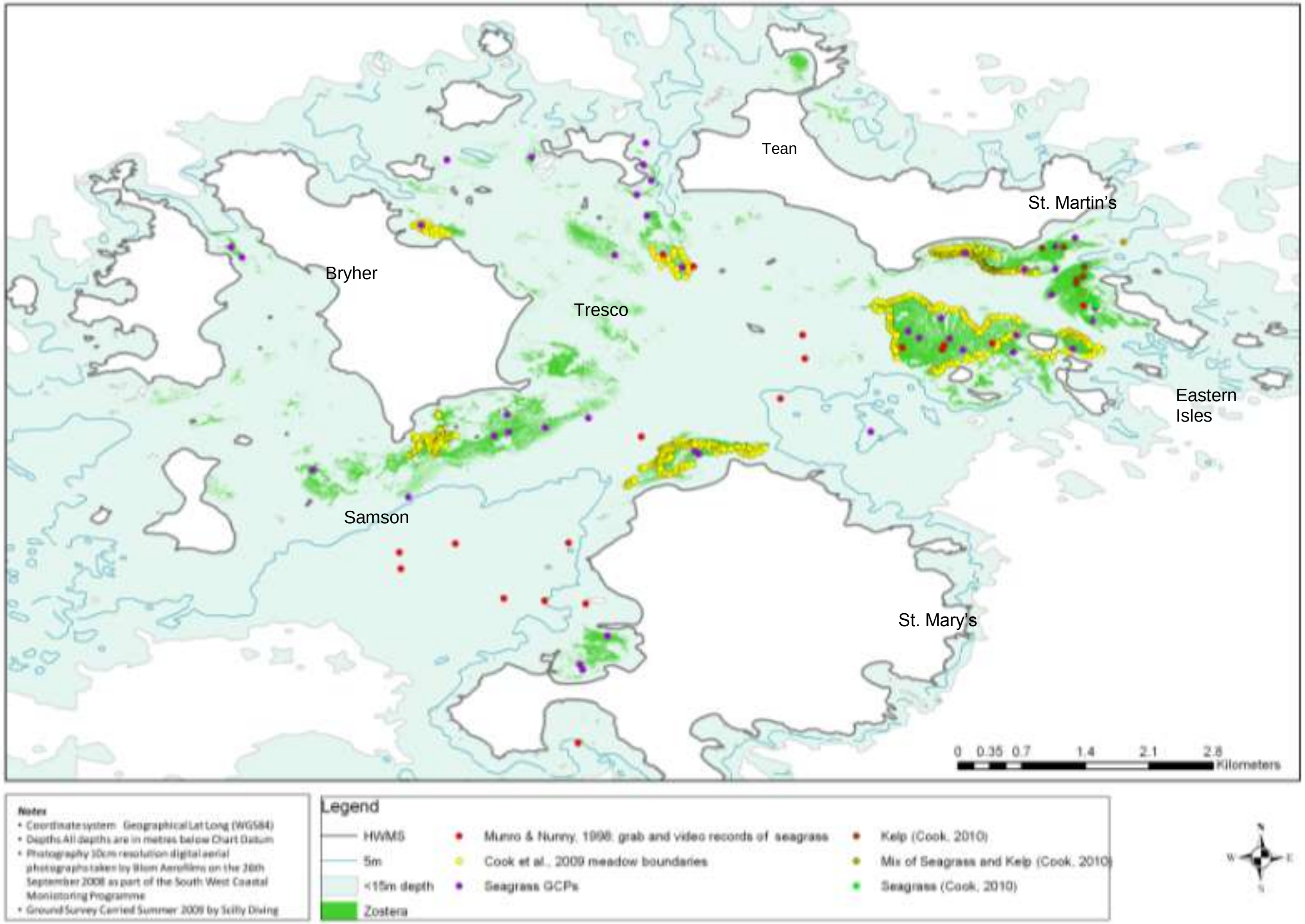
Figure 13 Accuracy assessment of individual mosaics using Kappa Analysis, shading indicates range of Kappa coefficient

Table 2 Summary of mosaics containing seagrass, including notes on the mosaics, number of GCPs within the mosaic and the output of the accuracy assessment

Zone (see Figure 2)	Mosaic name	Seagrass present in mosaic	Notes	No of Accuracy assessment positions	Overall accuracy	Kappa
Zone3	SouthBryher	Yes		11	45.45%	0.3125
Zone5	zone5run10+11	Yes	Anchor/ mooring damage evident and measurable from this image	19	57.89%	0.5113
Zone5	zone5run9	No	No seagrass from ground truthing or previous records to allow supervised classification, however, local knowledge states that seagrass present in New Grimsby Harbour			
Zone5	zone5run8	Yes		24	50.00%	0.4251
Zone5	zone5run7	Yes		15	57.58%	0.5027
Zone6	zone6run10	Yes		31	64.52%	0.517
Zone6	zone6run9	Yes		25	56.00%	0.4888
Zone6	zone6run8	Yes		35	71.43%	0.6747
Zone6	zone6run7	Yes		20	55.00%	0.4462
Zone6	zone6run7part2	Yes		20	50.00%	0.4429
Zone7	zone7run8	Yes		13	69.23%	0.6312
Zone7	zone7run7	Yes	No seagrass GCPs for Accuracy assessment	10	80.00%	0.7531

Table continued…

Zone (see Figure 2)	Mosaic name	Seagrass present in mosaic	Notes	No of Accuracy assessment positions	Overall accuracy	Kappa
Zone8	zone8run6	Yes		26	26.92%	0.222
Zone8	zone8run6part2	Yes	Significant amount of seagrass identified from previous records and GCPs, however large areas identified by supervised classification as being seagrass which local knowledge suggests is not, RoxAnn data suggests is.	20	35.00%	0.1419
Zone8	zone8run5	Yes		45	60.00%	0.5607
Zone8	zone8run5part2	Yes		25	60.00%	0.375
Zone8	zone8run4part2	Yes		24	66.67%	0.616
Zone9	zone9run6pt3	No	All false negatives for seagrass	10	40.00%	0.3023
Zone9	zone9run6	No	Green drift algae misclassified as seagrass	35	57.14%	0.4771
Zone9	zone9run5	Yes	Significant wave and sun glare in the south part of the image (some of which has been removed) and is not appropriate to use for measures of fragmentation	23	60.87%	0.551
Zone9	zone9run4	Yes		16	62.50%	0.5808
Zone9	zone9run3	Yes		14	57.14%	0.3636



As surveyed using divers during 2008 (Cook *et al.*, 2009); GCPs which recorded seagrass within the current study, grab and video records of seagrass from the RoxAnn study (Munro & Nunny *et al.*, 1998) and diver observations incorporated from a survey carried out in August 2010 (Cook, in prep; provided during the final stages of the production of the current report and therefore not fully incorporated into knowledge editing).

Figure 14 Knowledge edited map of seagrass distribution showing the locations of the main meadow boundaries

4.15 The fact that the image analysis can provide full coverage of individual beds means that the internal spatial structure can be measured and compared over time, to identify natural and anthropogenic change. Some of the fragmentation of the beds observed is natural, for example the mounding effects causing striations of seagrass are common in areas of strong currents (as observed in the Eastern Isles, and see cover photo), but the configuration can also be due to human pressures for example via mooring and anchor scarring of the beds, as visible in The Town (Bryher) and in St Mary's Harbour. Such changes caused by anthropogenic activity need to be identified and monitored in order that they can be managed through the SAC designation as required under the *Habitats Directive*, or any future Marine Protected Area designation.

Figure 15 Comparison of aerial photographs of St Mary's Harbour seagrass bed between 1996 and 2008

4.16 **Figure** illustrates the seagrass bed in St. Mary's Harbour visible in aerial photographs from 1996 and 2008. Damage to the seagrass bed due to mooring chain scarring is visible in both images; however despite these scars the meadow appears to be accreting along the north eastern edge and northern limit. Also mooring scars appear smaller but more numerous in 2008. In February 1996 the Duchy of Cornwall contracted Beckett and Rankine Ltd to install a new mooring system to allow a greater number of boats to moor in the harbour. A grid of ground chains fixed to buried anchors and riser chains allowed the installation of 200 new moorings (Beckett and Rankine pers. comm). Whilst further assessment (image analysis of the 1996 photographs and an accurate comparison with the 2008 images), comparisons of the two photographs suggests that this new system may have been advantageous in terms of increased coverage of seagrass, limiting the size of mooring scar, although fragmentation of the bed in terms of the number of scars may be greater.

5 Recommendations

Advice for future mapping

5.1 The use of aerial photography coupled with the resulting image processing of unsupervised and supervised classification followed by spatial configuration analysis, provides a cost-effective means of mapping the extent of *Zostera marina* beds, particularly when using data freely available from the South West Coastal Monitoring Programme. However if using this method for mapping other seagrass beds using the South West Coastal Monitoring Programme aerial photographs the following advice and recommendations are proposed see below.

Acquisition of aerial photos

5.1.1. The timings of the supply of the aerial photography are out of the control of Natural England, for example some South West Coastal Monitoring work was delayed by over a year due to bad weather. This can have a number of implications for using the photos for mapping the seagrass. Firstly, it can influence when the photographs are taken and mean that in the optimum conditions for seagrass mapping are not met. Natural England should be aware of this and try to guide the process. Secondly delays can be passed on to the image analysis contractor. Therefore prior to contract letting, it is recommend that Natural England liaise with BLOM (or other contractor), the Environment Agency and Channel Observatory in order to set priorities where other work is relying on the output.

5.1.2. It should also be noted that in the Isles of Scilly, the majority of seagrass beds are fairly shallow, the water clarity is high and there is high contrast between the white sands common in the region and the seagrass, all of which aid the remote mapping of seagrass beds. The method is still applicable to other regions; however in some sites (particularly those prone to periods of high turbidity) the time of taking the aerial photographs becomes more imperative in order to select the best conditions.

5.1.3. The availability of the aerial photographs to download via the World Wide Web has significant advantages in terms of making the data available to contractors, researchers and the wider public. However, in terms of image analysis the format supplied by the South West Coastal Monitoring Programme may not be appropriate as the images have already been mosaiced and "cut" into 500m x 500m tiles. Due to differences in the sun angle and crops of photos occurring across known seagrass beds, the current study used orthorectified photo files which had not been mosaiced or cut into tiles. Mosaicing of the images provided by Blom for the present study was carried out based on flight paths and appropriate cropping techniques employed to select areas of interest.

Ground truthing

5.1.4. Randomised primary ground-truthing (following the unsupervised classification) as carried out in this study, either in addition to, or instead of, transects, with some ground control positions retained for accuracy assessment is strongly recommended for future mapping. However we also advise that pre ground-truthing and post ground-truthing meetings with those directly involved in the field survey are imperative to clarify the details, in particular which measurements are to be made and more importantly why.

5.1.5. The amount of time required for adequate ground-truthing of each of the beds to be undertaken should not be underestimated and sufficient time should be allocated during planning. The number of ground control positions can be estimated by multiplying the number or images or mosaics by the number of classes to be used in the unsupervised classification and then multiplying by five. The number and distribution of ground control positions should be presented to field surveyors during initial planning, or ideally during the tendering phase, in order for an accurate time to be allowed. The latter requires providing potential contractors with details of the imagery prior to letting the contract.

5.1.6. We recommend that in future mapping projects a second session of ground truthing is planned for and implemented post supervised classification to aid knowledge editing. In the current study a number of low confidence areas have been identified which now require further survey (for example patches in Porth Cressa, the north western edge of the bed in St Mary's Harbour, south coast of Bryher, Wine Cove and little bay in St Martin's Bay, (see map of uncertain areas in Appendix) . Using methods used by Cook *et al.* (2008) to define the boundaries of the main seagrass beds would be a useful secondary ground truthing method, following the supervised classification to improve the accuracy of the maps and confirm the edges of the beds.

5.1.7. The current method was not able to distinguish density or cover levels of seagrass. Although the use of diving for ground truthing would provide definitive values for seagrass density categories the use of drop camera is recommended due to the large volume of ground truthing positions required to aid analysis and validate the classification. Use of diving to carry out ground truthing would be expensive and time consuming. Diving surveys assessing density should be carried out separately on the major beds.

Requirement for good depth data and depth correction techniques

5.1.8. It is strongly recommended that detailed bathymetric data are acquired prior to and during the mapping process (for example, from bathymetric LIDAR or acoustic survey). This data is very important for clipping areas prior to image analysis, thus greatly reducing image processing time and the acquisition of extraneous images. Depth data is also required for water column correction techniques and after the initial classification as part of the knowledge editing. Depth (corrected to chart datum) should be recorded for every seagrass GCP and past records to identify maximum depth of seagrass and apply knowledge based clips.

5.1.9. Despite the problems with applying depth correction techniques to the mosaics in the current study we recommend that they are used in the future. Depth correction techniques are relatively simple to carry out, however they can only be applied to small areas and to individual images (not mosaics), which may be more applicable to mapping seagrass in other SACs than it was to the Isles of Scilly SAC. Good depth data for the area and from ground truthing is a prerequisite for this technique.

Knowledge editing

5.1.10. The use of local knowledge was extremely useful for the interpretation of images within this project, and should be used along with other knowledge editing techniques detailed to further improve the accuracy of final images as part of future mapping. Prior to commencing the mapping work key experts and knowledgeable locals should be identified and approached to alert them to the work being carried out. They should be provided with supervised classified maps for them to mark areas they can authoritatively discount as seagrass or areas that they think are not seagrass but are not confident adding to the interpretation.

5.1.11. Whilst future remote sensing for monitoring should be carried out at a similar time of year and under similar tide and weather conditions, it would aid knowledge editing to analyse images taken during the winter when areas of drift algae are less prevalent and could be identified.

Advice on the acquisition of CASI Hyperspectral Information

5.1.12. Whilst the identification of subtidal seagrass edges in the Isles of Scilly is relatively straight forward when the contrast is between seagrass and white sand, but where the beds are adjacent to or heterogeneous with algae (and particular green drift algae) there are particular difficulties in distinguishing subtidal seagrass. The aerial photographs used in the present study were taken in

September, which is a time when algal coverage was at a peak and the accuracy assessment identified that in many cases it was difficult to distinguish seagrass from other algae of similar colour and character using only three bands available from the Aerial photographs (red, green and blue). There is little doubt that an increased number of spectral bands would improve the classification through the ability to distinguish between different subtidal flora, and there is greater scope for employing water correction techniques and calculating depth invariant bottom indices. One future option when mapping coastal seagrass beds, therefore, is the use of multispectral remote sensing techniques, which involves the acquisition of visible, near infrared, and short-wave infrared images in several broad wavelength bands.

5.1.13. The Compact Airborne Spectrographic Imager (CASI) is one of the most widely used commercial airborne spectrometers in the world; it acquires data in multiple spectral bands and also can be operated in a hyper-spectral acquisition mode[4]. A key advantage of CASI over other remote sensing systems is its ability to map seagrass, macroalgal and reef habitats with significantly greater accuracy than either satellite imagery or colour aerial photography (Mumby *et al.* 1997). It should be noted from previous studies that in order to map seagrass standing crop with the greatest accuracy the wavelength focus should be on the 580 to 650nm zone of the electromagnetic spectrum, particularly if the seagrass to be mapped extends deeper than 1m (Mumby *et al.* 1997).

5.1.14. CASI has many similarities with aerial photography remote sensing. For example, it is most accurate when incorporated with water column correction, contextual editing such as bathymetry; clear conditions are essential for CASI flights, and ground-truthing is still needed following the CASI survey, and the amount and location is directed by the CASI validation needs.

5.1.15. Colour aerial photography permits seagrass mapping with a poorer accuracy than CASI and if quotes for new image acquisition for mapping seagrass beds were examined, CASI imagery would be considerably more cost-effective than aerial photography for mapping seagrass (Mumby *et al.* 1997). However, since aerial photography is a standard medium for a variety of applications such as land-use mapping, the cost of data acquisition may be shared between users or avoided entirely, for example through the freely available SWCMP images. Under these circumstances aerial photography is a cost-effective means of mapping the *extent* of seagrass beds.

Using the maps for conservation management

The main advantage of aerial image analysis for mapping and monitoring seagrass beds over other methods (for example, diver other methods (for example, diver or acoustic survey) is that full coverage of the bed extent and configuration is provided. The configuration is provided. The current study identified a good correspondence between the image analysis of the current study analysis of the current study and the boundaries outlined by Cook *et al.* (2009) (see As surveyed using divers during 2008 (Cook *et al.*, 2009); GCPs which recorded seagrass within the current study, grab and video records of seagrass from the RoxAnn study (Munro & Nunny *et al.*, 1998) and diver observations incorporated from a survey carried out in August 2010 (Cook, in prep; provided during the final stages of the production of the current report and therefore not fully incorporated into knowledge editing).

5.2 **Figure**), which highlights the usefulness of the latter for monitoring the extent on an annual basis. However the method of Cook *et al.* (2009) only identifies the outer edge of a focal bed. This means that much of the inner configuration of the bed is missed, as are adjacent patches which may be beyond the view of the divers. These are, however, both picked up by the aerial image analysis, making this a valuable method for identifying internal fragmentation or recolonisation within the bed and for predicting the locations of meadows beyond commonly surveyed areas.

[4] Multispectral systems are characterized by fewer, wider bands (typically 100 nm or wider) were as hyperspectral systems, collect many, narrow bands, each one typically less than 10 nm wide.

5.3 Seagrass beds are highly dynamic and both the configuration of the bed and overall extent can change as the beds die back and re-colonise areas as part of a natural cycle and as a result of storms and currents. It may also be possible that the beds in the Isles of Scilly are still in a phase of recovery after losses which occurred during the 1930s due to the wasting disease (Den Hartog 1987). Therefore monitoring the health of the habitat based on an overall change extent of seagrass should be performed with caution (particularly where different methods of measuring extent have been used).

5.4 To aid monitoring individual seagrass landscapes should be identified, defined as a separate landscape where the shortest distance from the edge of one seagrass bed to another patch of seagrass is larger than the greatest distance from the epicentre of the bed to its furthest edge.

5.5 For each identified landscape, total landscape metrics could be calculated using the layer created during the current study to describe the configuration of the seagrass meadow, thus allowing comparisons of configurations between meadows. The same metrics could also be calculated for pre-defined equal areas, which can act as permanent reference regions for future monitoring (see methods in Irving *et al.* 2007). We recommend the use of a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns, such as the freeware software Fragstats (McGarigal et al, 2002).

5.6 Identifying accretion and/erosion of the beds which is due to anthropogenic versus natural change can be difficult in some areas, but in others, where known pressures occur the assessment can be more straight forward. Mooring and anchor scars are easy to identify as they create halos of bare sand in the seagrass bed in sheltered locations (unlikely to be the result of storm damage) as illustrated in Figure , and using landscape metrics to examine changes in predefined reference polygons within these sites is strongly advised.

5.7 In order to link any changes in seagrass cover to human pressures requires measurement of the latter. Records of mooring and anchoring activity should be part of any monitoring. Similarly it is strongly recommended that other environmental measurements are taken, such as nutrient concentrations, light attenuation in the water column (the two most important water quality parameters affecting seagrass growth), salinity and water temperature, rainfall or freshwater run-off and wind exposure. The latter could be evaluated at relatively little expense and provide information on the vulnerability of the beds and their ability to recover.

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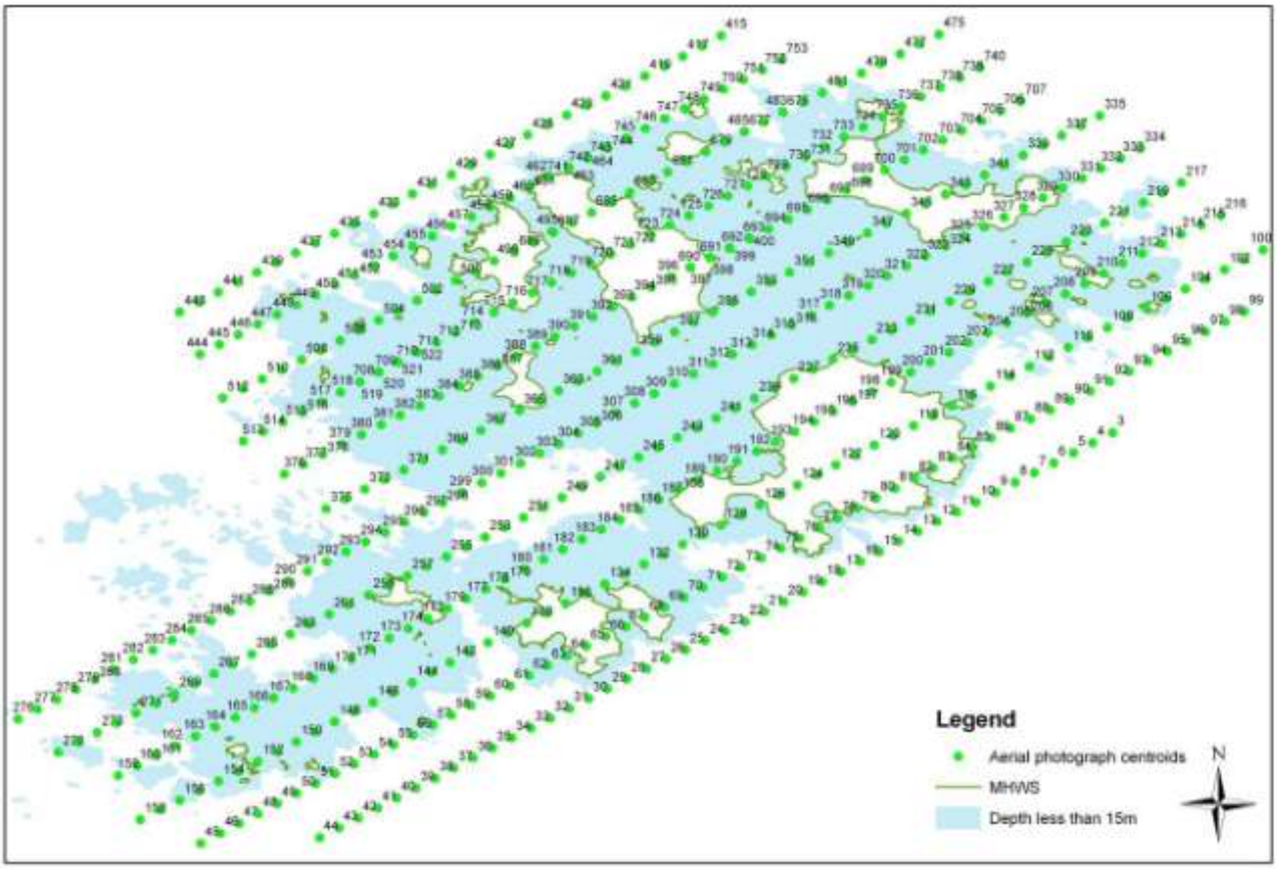
Appendix 1 Aerial survey area

Figure A Aerial photograph centroid positions provided by BLOM aerofilms



Appendix 2 Mosaic details

Table A Details of aerial photographs used in each mosaic and which zone the cover

Zone (see Map)	Area (Name given to help locate mosaic)	image 1	image 2	image 3	image 4	image 5	image 6
Zone1	NorthMuncoyLedges	4_0167	4_0168	4_0170			
Zone1	SouthMuncoyLedges	3_0149	3_0148	3_0146			
Zone1	NorthWesternRocks	5_0270	5_0269	5_0267			
Zone1	WesternRocks						
Zone2	FarNorthAnnet	6_0292	6_0294	6_0296			
Zone2	NorthAnnet	5_0261	5_0259	5_0257	5_0255	5_0254	
Zone2	MidAnnet	4_0176	4_0174	4_0172			
Zone2	SouthAnnet	3_0141	3_0142	3_0144			
Zone3	10NorthTreh2	10_0678	10_0680	10_0681	10_0683		
Zone3	11NorthTreh1	11_0743	11_0745	11_0747	11_0748		
Zone3	11NorthWestFirst2	11_0448	11_0450				
Zone3	11NorthWestLast3	11_0452	11_0454	11_0456			
Zone3	10NorthWest2	10_0500	10_0502	10_0504	10_0506		
Zone3	9NorthWest3	9_0519	9_0517	9_0520			
Zone3	8NorthWest4	8_0380	8_0382	8_0384	8_0386	8_0387	
Zone3	7NorthWest5	7_0365	7_0367	7_0369	7_0371		
Zone3	SouthBryher	9_0711	9_0713	9_0715			
Zone4	zone4run4	4_0184	4_0182	4_0180	4_0178		
Zone4	zone4run3	3_0132	3_0134	3_0136	3_0138	3_0139	
Zone4	zone4run2	2_0072	2_0070	2_0068	2_0066	2_0064	2_0062
Zone4	zone4run1	1_0021	1_0023	1_0025	1_0027	1_0029	1_0031
Zone5	zone5run10+11	11_0460	11_0458	10_0495			
Zone5	zone5run9	9_0718	9_0720				
Zone5	zone5run8	8_0389	8_0391	8_0393			

Table continued…

Zone (see Map)	Area (Name given to help locate mosaic)	image 1	image 2	image 3	image 4	image 5	image 6
Zone5	zone5run7	7_0363	7_0361	7_0359	7_0357		
Zone6	zone6run11	11_0748	11_0746	11_0744	11_0742		
Zone6	zone6run10	10_0685	10_0683	10_0681	10_0679		
Zone6	zone6run9	9_0728	9_0726	9_0724			
Zone6	zone6run8	8_0697	8_0695	8_0693	8_0691		
Zone6	zone6run7	7_0346	7_0348	7_0350			
Zone6	zone6run7part2	7_0352	7_0354	7_0256			
Zone7	zone7run11	11_0744	11_0746	11_0748		11_0751	
Zone7	zone7run10	10_0479	10_0481	10_0483	10_0485		
Zone7	zone7run9	9_0736	9_0734	9_0732	9_0730		
Zone7	zone7run8	8_0700	8_0702				
Zone7	zone7run7	7_0339	7_0341	7_0343			
Zone8	zone8run6	6_0332	6_0330	6_0328	6_0326		
Zone8	zone8run6part2	6_0324	6_0322	6_0320			
Zone8	zone8run5	5_0231	5_0229	5_0227	5_0225		
Zone8	zone8run5part2	5_0223	5_0221	5_0219			
Zone8	zone8run4	4_0214	4_0212	4_0210			
Zone8	zone8run4part2	4_0208	4_0206	4_0204	4_0202		
Zone8	zone8run3	3_0114	3_0112	3_0110	3_0108	3_0106	3_0104
Zone9	zone9run6	6_0318	6_0316	6_0314	6_0312		
Zone9	zone9run6part2	6_0310	6_0308	6_0306	6_0304	6_0302	
Zone9	zone9run5	5_0233	5_0235	5_0237	5_0239		
Zone9	zone9run5part2	5_0241	5_0243	5_0245	5_0247		
Zone9	zone9run4	4_0186	4_0188	4_0190	4_0192		
Zone9	zone9run3	3_0130	3_0128	3_0126			
Zone9	zone9run2	2_0075	2_0077	2_0079	2_0081	2_0083	2_0085
Zone9	zone9run1	1_0015	1_0013	1_0011	1_0009		

Figure 1.

Appendix 3 List of ground truth positions

Table B List of ground truth positions

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
9northwest8	3	6	49.93451	-6.38179			>15m		
9northwest10	3	8	49.93471	-6.38313	Algae brown		No data	Algae brown	Algae brown
9northwest12	3	10	49.93358	-6.38802	Algae brown		No data	Algae brown	Algae brown
9northwest15	3	13	49.93573	-6.38130	Algae brown		No data	Algae brown	Algae brown
9northwest17	3	15	49.92911	-6.37922	Algae brown		No data	Algae brown	Algae brown
9northwest21	3	19	49.93264	-6.38942	Algae brown		No data	Algae brown	Algae brown
9northwest22	3	20	49.92933	-6.38718			>15m		
9northwest24	3	22	49.93535	-6.38106	Algae brown		No data	Algae brown	Algae brown
9northwest25	3	23	49.92935	-6.38448			>15m		
9northwest27	3	25	49.93420	-6.38419	Algae brown		No data	Algae brown	Algae brown
9northwest28	3	26	49.93249	-6.37511	Algae brown		No data	Algae brown	Algae brown
9northwest31	3	29	49.93485	-6.38581	Algae brown		No data	Algae brown	Algae brown
9northwest34	3	32	49.93320	-6.38144	Algae brown		No data	Algae brown	Algae brown
9northwest37	3	35	49.93621	-6.37833			>15m		
7northwest5	3	40	49.92646	-6.35171	Algae brown		4	Algae brown	Algae brown
7northwest5	3	41	49.92494	-6.35486	Algae brown		1.3	Algae brown	Algae brown
7northwest5	3	46	49.92759	-6.34890	Algae brown		2.5	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
7northwest5	3	48	49.92418	-6.34926	Algae brown		4.2	Algae brown	Algae brown
7northwest5	3	55	49.92525	-6.34781	Algae brown		4.8	Algae brown	Algae brown
7northwest5	3	60	49.92331	-6.35542	Algae brown		8	Algae brown	Algae brown
7northwest5	3	61	49.92336	-6.36475	Algae brown		8.1	Algae brown	Algae brown
7northwest5	3	62	49.92805	-6.35776	Algae brown		5	Algae brown	Algae brown
7northwest5	3	63	49.91544	-6.37274			>15m		
7northwest5	3	65	49.92632	-6.34979	Algae brown		2.8	Algae brown	Algae brown
7northwest5	3	69	49.92124	-6.37818	Algae brown		No data	Algae brown	Algae brown
7northwest5	3	70	49.92886	-6.36089	Bare sand		6.8	Bare sand	Bare sand
7northwest5	3	71	49.92361	-6.35100	Algae brown		4.3	Algae brown	Algae brown
7northwest5	3	73	49.92414	-6.36739	Algae brown		No data	Algae brown	Algae brown
7northwest5	3	76	49.92172	-6.37413			>15m		
7northwest5	3	82	49.92849	-6.36223	Algae brown		8	Algae brown	Algae brown
7northwest6	3	83	49.92386	-6.36559	Algae brown		No data	Algae brown	Algae brown
7northwest7	3	84	49.92083	-6.36538	Algae brown		No data	Algae brown	Algae brown
northannet	2	86	49.89808	-6.36659			>15m		
northannet	2	87	49.90226	-6.35804	Algae brown		No data	Algae brown	Algae brown
northannet	2	88	49.89518	-6.38174	Algae brown		No data	Bare rock	Bare rock
northannet	2	89	49.90002	-6.37796	Algae brown		No data	Algae brown	Algae brown
northannet	2	92	49.90302	-6.36507			>15m		
northannet	2	104	49.89561	-6.37835	Algae brown		No data	Algae brown	Algae brown
northannet	2	105	49.89544	-6.38806	Algae brown		No data	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
northannet	2	106	49.89548	-6.37886	Algae brown		No data	Algae brown	Algae brown
northannet	2	107	49.89125	-6.38493			>15m		
northannet	2	108	49.89901	-6.37897	Algae brown		No data	Algae brown	Algae brown
northannet	2	109	49.89457	-6.39003	Algae brown		No data	Algae brown	Algae brown
northannet	2	110	49.89205	-6.37789	Algae brown		No data	Algae brown	Algae brown
northannet	2	111	49.89020	-6.38238			>15m		
northannet	2	113	49.90664	-6.36730			>15m		
northannet	2	115	49.90360	-6.37711			>15m		
northannet	2	118	49.90863	-6.36150			>15m		
northannet	2	120	49.90855	-6.36420	Algae brown		No data	Algae brown	Algae brown
northannet	2	121	49.90008	-6.37740	Algae brown		No data	Algae brown	Algae brown
northannet	2	122	49.90115	-6.37898			>15m		
northannet	2	123	49.89769	-6.38575	Algae brown		No data	Bare sand	Algae brown
northannet	2	125	49.89997	-6.35811			>15m		
northannet	2	128	49.89714	-6.37711	Algae brown		No data	Algae brown	Algae brown
midannet	2	134	49.88617	-6.38096			>15m		
midannet	2	136	49.88943	-6.37859	Algae brown		No data	Algae brown	Algae brown
midannet	2	138	49.88362	-6.37940			>15m		
midannet	2	140	49.89162	-6.37033	Algae brown		No data	Algae brown	Algae brown
midannet	2	141	49.89651	-6.36951	Other (and state in next column)	Ashore	No data		
midannet	2	142	49.88969	-6.37932	Algae brown		No data	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
midannet	2	145	49.89340	-6.37483	Algae brown		No data	Algae brown	Algae brown
midannet	2	147	49.89065	-6.37185	Algae brown		No data	Algae brown	Algae brown
midannet	2	149	49.89550	-6.36813	Algae brown		No data	Algae brown	Algae brown
midannet	2	150	49.89520	-6.36608	Algae brown		No data	Algae brown	Algae brown
midannet	2	152	49.89226	-6.36621	Algae brown		No data	Algae brown	Algae brown
midannet	2	159	49.88774	-6.37059	Algae brown		No data	Algae brown	Algae brown
midannet	2	163	49.89515	-6.36028	Bare sand		No data	Algae brown	Bare sand
midannet	2	165	49.88978	-6.37538	Algae brown		No data	Algae brown	Algae brown
midannet	2	167	49.89144	-6.37774			>15m		
midannet	2	168	49.88943	-6.36437	Algae brown		No data	Algae brown	Algae brown
midannet	2	169	49.88764	-6.37100	Algae brown		No data	Algae brown	Algae brown
midannet	2	171	49.89136	-6.37568	Algae brown		No data	Algae brown	Algae brown
midannet	2	172	49.89243	-6.36401	Algae brown		No data	Algae brown	Algae brown
midannet	2	173	49.89134	-6.36333	Algae brown		No data	Algae brown	Algae brown
midannet	2	174	49.89070	-6.36582	Bare sand		No data	Bare sand	Bare sand
midannet	2	175	49.88802	-6.36503	Bare sand		No data	Algae brown	Bare sand
midannet	2	176	49.88723	-6.36785	Algae brown		No data	Algae brown	Algae brown
midannet	2	177	49.88857	-6.37214	Algae brown		No data	Algae brown	Algae brown
midannet	2	178	49.89091	-6.37428	Algae brown		No data	Algae brown	Algae brown
midannet	2	179	49.89124	-6.37894	Algae brown		No data	Algae brown	Algae brown
Southannet	2	180	49.88566	-6.36216	Algae brown		No data	Algae brown	Bare sand
Southannet	2	182	49.88512	-6.36519	Algae brown		No data	Bare sand	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Southannet	2	183	49.88287	-6.36378	Algae brown		No data	Algae brown	Algae brown
Southannet	2	185	49.88756	-6.36699	Algae brown		No data	Algae brown	Algae brown
Southannet	2	186	49.88473	-6.36448	Algae brown		No data	Algae brown	Algae brown
Southannet	2	188	49.88395	-6.36480	Algae brown		No data	Algae brown	Algae brown
Southannet	2	191	49.88453	-6.36829			>15m		
Southannet	2	192	49.88400	-6.36446	Algae brown		No data	Algae brown	Algae brown
Southannet	2	198	49.88254	-6.36017	Algae brown		No data	Algae brown	Algae brown
Southannet	2	201	49.88381	-6.37663			>15m		
Southannet	2	202	49.89079	-6.36591	Algae brown		No data	Algae brown	Algae brown
Southannet	2	203	49.88156	-6.37127			>15m		
Southannet	2	204	49.88212	-6.37760			>15m		
Southannet	2	205	49.88260	-6.36838	Algae brown		No data	Algae brown	Algae brown
Southannet	2	208	49.88119	-6.37133			>15m		
Southannet	2	216	49.88618	-6.36458	Algae brown		No data	Algae brown	Algae brown
Southannet	2	217	49.88515	-6.36452	Algae brown		No data	Algae brown	Algae brown
zone4run4	4	220	49.89957	-6.35095	Algae brown		No data	Algae brown	Algae brown
zone4run4	4	227	49.89965	-6.34825	Algae brown		No data	Algae brown	Algae brown
zone4run4	4	233	49.90875	-6.34590			>15m		
zone4run4	4	235	49.90013	-6.34436	Algae brown		No data	Algae brown	Algae brown
zone4run4	4	244	49.89642	-6.36262			>15m		
zone4run4	4	247	49.90363	-6.35764	Algae brown		No data	Algae brown	Algae brown
zone5run7	5	264	49.93356	-6.33732	Algae brown		3.8	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone5run7	5	265	49.93534	-6.34344	Bare sand		0.5	Bare sand	Bare sand
zone5run7	5	266	49.93761	-6.33279	Algae brown		3.2	Bare sand	Bare sand
zone5run7	5	267	49.93682	-6.34084	Bare sand		3.3	Bare sand	Bare sand
zone5run7	5	268	49.93353	-6.33792	Algae brown		4	Algae brown	Algae green
zone5run7	5	269	49.93648	-6.32427	Algae brown		3.1	Algae brown	Algae brown
zone5run7	5	271	49.93638	-6.34089	Seagrass (note %cover in next column)	15	1.8	Algae brown	10
zone5run7	5	272	49.93940	-6.32420	Algae brown		2.7	Algae brown	Algae brown
zone5run7	5	273	49.94012	-6.32150	Algae brown		4	90	90
zone5run7	5	274	49.93698	-6.33612	Bare sand		2.3	Bare sand	Algae brown
zone5run7	5	275	49.93092	-6.34607	Algae brown		3.1	Algae brown	Algae brown
zone5run7	5	276	49.93369	-6.33142	Seagrass (note %cover in next column)	40	5	Algae brown	15
zone5run7	5	277	49.93219	-6.33822	Algae brown		2.5	Algae brown	Algae brown
zone5run7	5	282	49.93669	-6.32231	Bare sand		3.1	Algae brown	Algae brown
zone5run7	5	283	49.93526	-6.33239	Bare sand		3.6	Bare sand	Bare sand
zone5run7	5	284	49.92942	-6.33905	Bare sand		6	Bare sand	Bare sand
zone5run7	5	285	49.92755	-6.34093	Bare sand		8.2	Bare sand	Bare sand
zone5run7	5	288	49.93543	-6.32492	Algae brown		4.5	Algae brown	Bare sand
zone5run7	5	289	49.94303	-6.32304	Bare sand		0.5	Bare sand	Bare sand
zone5run7	5	291	49.93972	-6.33882	Bare sand		0.9	Bare sand	Bare sand
zone5run9	5	387	49.94804	-6.34744	Bare sand		1.2	Bare sand	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone5run9	5	389	49.94516	-6.34858	Algae brown		2	Algae brown	Algae brown
zone5run9	5	391	49.95167	-6.34578	Bare sand		0.9	Bare sand	Algae brown
zone5run9	5	392	49.95408	-6.34550	Bare sand		0.7	Bare sand	Bare sand
zone5run9	5	395	49.94986	-6.33940	Bare sand		0.5	Bare sand	Bare sand
zone5run9	5	397	49.94592	-6.34831	Bare sand		1.5	Bare sand	Algae green
zone5run9	5	400	49.94613	-6.34248	Bare sand		0.5	Bare sand	Bare sand
zone5run9	5	401	49.95244	-6.34677	Bare sand		0.5	Bare sand	Bare sand
zone5run9	5	403	49.94838	-6.34160	Bare sand		1	Bare sand	Bare sand
zone5run9	5	404	49.94481	-6.34658	Bare sand		1.8	Bare sand	Bare sand
zone5run9	5	406	49.94924	-6.34474	Bare sand		0.5	Bare sand	Bare sand
zone5run9	5	407	49.94954	-6.35050	Bare sand		0.5	Bare sand	Bare sand
zone5run9	5	408	49.94643	-6.34127	Bare sand		1.2	Bare sand	Bare sand
zone5run9	5	409	49.95082	-6.34900	Bare sand		0.5	Bare sand	Bare sand
zone5run9	5	410	49.95538	-6.34650	Bare sand		1	Bare sand	Bare sand
zone5run9	5	412	49.95449	-6.34437	Bare sand		0.7	Bare sand	Bare sand
zone5run9	5	413	49.94610	-6.34612	Bare sand		3.1	Algae green	Bare sand
zone6run7	6	415	49.95493	-6.30612	Bare sand		3.9	Bare sand	Bare sand
zone6run7	6	417	49.95936	-6.30001	Algae brown		1.5	Bare sand	Algae brown
zone6run7	6	424	49.96141	-6.29585	Bare sand		2.9	Algae brown	Bare sand
zone6run7	6	426	49.95391	-6.30153	Bare sand		4	Algae green	Bare sand
zone6run7	6	428	49.95298	-6.30647	Bare sand		3.8	Bare sand	Algae green
zone6run7	6	432	49.95956	-6.28996	Bare sand		2.3	Bare sand	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone6run7	6	434	49.95816	-6.29608	Bare sand		2.6	Algae green	Bare sand
zone6run7	6	435	49.96017	-6.30035	Bare sand		3.4	Bare sand	Bare sand
zone6run7	6	436	49.95568	-6.30447	Algae green		4.1	Bare sand	Algae green
zone6run7	6	439	49.96037	-6.30156	Bare sand		4.3	Bare sand	Bare sand
zone6run7	6	440	49.94961	-6.29930	Bare sand		1.2	Bare sand	Bare sand
zone6run7	6	442	49.95620	-6.29297	Bare sand		2.5	Bare sand	Bare sand
zone6run7	6	444	49.96143	-6.29376	Bare sand		3.2	Bare sand	Bare sand
zone6run7	6	445	49.95535	-6.31073	Bare sand		3.9	Bare sand	Algae green
zone6run7	6	448	49.95319	-6.30106	Bare sand		2.8	Bare sand	Bare sand
zone6run7	6	449	49.95654	-6.28855	Bare sand		3.9	Algae brown	Bare sand
zone6run7	6	453	49.95982	-6.30169	Bare sand		4.3	Algae green	Bare sand
zone6run7	6	454	49.96001	-6.29554	Bare sand		2.4	Bare sand	Bare sand
zone6run7	6	455	49.95944	-6.29911	Algae green		3.6	Bare sand	Bare sand
zone6run7	6	456	49.95797	-6.30317	Bare sand		5.2	Algae green	Algae green
zone6run7	6	457	49.95631	-6.30272	Algae green		3.8	Bare sand	Algae green
zone6run7	6	459	49.95647	-6.30433	Seagrass (note %cover in next column)	100	3.5	Bare sand	100
zone8run5	8	460	49.95704	-6.26685	Bare sand		3.4	Bare sand	Bare sand
zone8run5	8	461	49.95013	-6.28198	Seagrass (note %cover in next column)	40	4.6	70	95
zone8run5	8	462	49.94191	-6.28673	Algae brown		8.5	Algae brown	Algae brown
zone8run5	8	463	49.94601	-6.28010	Algae brown		5.6	Bare sand	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone8run5	8	464	49.94975	-6.27127	Seagrass (note %cover in next column)	90	1.8	80	60
zone8run5	8	465	49.95618	-6.27338	Bare sand		1.5	Bare sand	Bare sand
zone8run5	8	466	49.94099	-6.28922	Bare sand		10	Bare sand	Bare sand
zone8run5	8	468	49.95374	-6.26777	Bare sand		3.2	80	80
zone8run5	8	469	49.94510	-6.28056	Algae brown		5.8	Algae brown	Algae brown
zone8run5	8	471	49.94789	-6.27092	Algae green		3.9	Algae brown	Algae brown
zone8run5	8	472	49.95366	-6.26620	Bare sand		2.7	Bare sand	Algae brown
zone8run5	8	473	49.95239	-6.26171	Algae brown		1	Algae brown	Algae brown
zone8run5	8	475	49.94940	-6.27785	Seagrass (note %cover in next column)	100	3.5	100	100
zone8run5	8	476	49.94944	-6.28087	Seagrass (note %cover in next column)	95	4.4	85	Bare sand
zone8run5	8	477	49.94878	-6.27000	Algae brown		1.1	Algae brown	Algae brown
zone8run5	8	479	49.94689	-6.27049	Algae brown		3.8	Algae brown	Algae brown
zone8run5	8	480	49.94278	-6.27730	Algae brown		5.2	Algae brown	Algae brown
zone8run5	8	481	49.95622	-6.27048	Seagrass (note %cover in next column)	70	1.8	Bare sand	70
zone8run5	8	483	49.94827	-6.27653	Seagrass (note %cover in next column)	90	3.2	90	90
zone8run5	8	485	49.95139	-6.27870	Seagrass (note %cover in next column)	85	3.7	Bare sand	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone8run5	8	488	49.94407	-6.28136	Bare sand		9.5	Bare sand	Bare sand
zone8run5	8	489	49.95247	-6.26722	Bare sand		1.9	Bare sand	Bare sand
zone8run5	8	490	49.94559	-6.29056	Bare sand		7	Bare sand	Bare sand
zone8run5	8	491	49.95566	-6.27054	Bare sand		2.2	Bare sand	Bare sand
zone8run5	8	496	49.94280	-6.27537	Algae brown		5.1	Algae brown	Algae brown
zone8run5	8	499	49.95053	-6.25912	Algae brown		4.6	Algae brown	Algae green
zone8run5	8	501	49.95625	-6.26741	Algae brown		3.8	60	40
zone8run5	8	505	49.94838	-6.26566	Seagrass (note %cover in next column)	85	1.2	85	85
farnorthannet	2	509	49.90646	-6.37200			>15m		
farnorthannet	2	512	49.90004	-6.38630			>15m		
farnorthannet	2	514	49.89893	-6.38472			>15m		
farnorthannet	2	515	49.90910	-6.37570			>15m		
farnorthannet	2	518	49.90997	-6.37640			>15m		
farnorthannet	2	519	49.90435	-6.38768			>15m		
farnorthannet	2	525	49.90764	-6.37078			>15m		
farnorthannet	2	526	49.89969	-6.37990			>15m		
farnorthannet	2	527	49.90436	-6.37073			>15m		
farnorthannet	2	529	49.90717	-6.38571			>15m		
farnorthannet	2	530	49.90409	-6.39097			>15m		
farnorthannet	2	532	49.89985	-6.37740	Algae brown		No data	Algae brown	Algae brown
zone6run7pt2	6	551	49.95095	-6.31884	Bare sand		3.5	Bare sand	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone6run7pt2	6	554	49.94151	-6.31362	Seagrass (note %cover in next column)	90	3.5	Bare sand	Bare sand
zone6run7pt2	6	559	49.95153	-6.31519	Algae green		4.1	Bare sand	Algae green
zone6run7pt2	6	561	49.94058	-6.31786	Seagrass (note %cover in next column)	25	2.5	Algae brown	Bare sand
zone6run7pt2	6	562	49.94717	-6.31673	Bare sand		4.3	Bare sand	Algae brown
zone6run7pt2	6	564	49.94188	-6.32166	Seagrass (note %cover in next column)	25	0.8	25	Bare sand
zone6run7pt2	6	566	49.94313	-6.32688	Algae brown		9.5	Algae brown	Algae brown
zone6run7pt2	6	568	49.94767	-6.31400	Bare sand		4.5	Bare sand	Bare sand
zone6run7pt2	6	571	49.94538	-6.31107	Bare sand		3.5	Bare sand	Algae brown
zone6run7pt2	6	572	49.93974	-6.32292	Seagrass (note %cover in next column)	80	1.5	30	60
zone6run7pt2	6	573	49.95245	-6.31196	Bare sand		5	Algae green	Algae green
zone6run9	6	575	49.95897	-6.32443	Bare sand		2.8	Algae green	Bare sand
zone6run9	6	576	49.96139	-6.32019	Bare sand		1.9	Algae green	Bare sand
zone6run9	6	584	49.96330	-6.31640	Algae brown		2.8	Bare sand	Algae brown
zone6run9	6	590	49.96127	-6.32993	Algae green		3	Bare sand	Bare sand
zone6run9	6	593	49.96238	-6.32412	Bare sand		1.8	Bare sand	Bare sand
zone6run9	6	599	49.96076	-6.32868	Bare sand		3.1	Bare sand	Bare sand
zone6run9	6	600	49.96170	-6.32136	Bare sand		1.8	Algae green	Algae green
zone6run9	6	603	49.96723	-6.31546	Algae brown		Dry	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone6run9	6	604	49.96251	-6.31317	Bare sand		0.8	Bare sand	Bare sand
zone6run9	6	606	49.96326	-6.31220	Bare sand		1.1	Algae green	Algae green
zone6run9	6	607	49.95779	-6.32362	Bare sand		2	Bare sand	Bare sand
zone6run9	6	608	49.96600	-6.32396	Bare sand		3.5	Algae green	Bare sand
zone6run9	6	609	49.96099	-6.31941	Algae green		2.5	Bare sand	Bare sand
zone6run9	6	616	49.96542	-6.31297	Algae green		1.6	Algae green	Algae green
zone6run9	6	617	49.96507	-6.30739	Seagrass (note %cover in next column)	100	3.9	100	100
zone6run9	6	619	49.96359	-6.31645	Algae green		2.6	Algae brown	Algae brown
zone6run9	6	621	49.96159	-6.32711	Algae green		2.3	Algae green	Bare sand
zone6run10	6	623	49.96934	-6.33332	Algae brown		5.6	Algae brown	Algae brown
zone6run10	6	624	49.97655	-6.32337	Algae brown		8.8	Algae brown	Algae brown
zone6run10	6	625	49.97181	-6.33324	Algae brown		3.2	Algae brown	Algae brown
zone6run10	6	626	49.96491	-6.33670	Algae brown		5.6	Algae brown	Bare sand
zone6run10	6	628	49.97358	-6.31860			>15m		
zone6run10	6	633	49.96910	-6.33448	Algae brown		5.1	Algae brown	Algae brown
zone6run10	6	634	49.96636	-6.33450	Algae brown		5.5	Algae brown	Algae brown
zone6run10	6	637	49.96989	-6.33087	Algae brown		3.7	Algae brown	Algae brown
zone6run10	6	639	49.97437	-6.32876	Algae brown		4.6	Algae brown	Algae brown
zone6run10	6	642	49.97242	-6.33007	Algae brown		4.8	Algae brown	Algae brown
zone6run10	6	645	49.96864	-6.32529	Algae brown		7	Algae brown	Algae brown
zone6run10	6	647	49.96993	-6.31906	Algae brown		5.9	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone6run10	6	650	49.97080	-6.33497	Algae brown		7.2	Algae brown	Algae brown
zone6run10	6	651	49.97488	-6.32500	Algae brown		6.5	Algae brown	Algae brown
zone6run10	6	654	49.96159	-6.32844	Bare sand		4.9	Algae brown	Bare sand
zone6run10	6	655	49.96895	-6.32146	Algae green		2	Bare sand	Algae green
zone6run10	6	656	49.96487	-6.32090	Bare sand		5.2	Bare sand	Bare sand
zone6run10	6	658	49.97137	-6.31804	Algae brown		8	Algae brown	Algae brown
zone6run10	6	660	49.97010	-6.31997	Algae brown		5	Bare sand	Algae brown
zone6run10	6	661	49.96711	-6.32759	Bare sand		1.8	100	80
zone6run10	6	662	49.96981	-6.32009	Bare sand		7.6	Bare sand	Bare sand
zone6run10	6	663	49.96736	-6.31922	Seagrass (note %cover in next column)	100	1.5	100	100
zone6run10	6	667	49.96066	-6.33015	Seagrass (note %cover in next column)	5	0.8	5	Bare sand
zone6run11	6	670	49.97253	-6.33479	Bare sand		4.5	Algae brown	Algae brown
zone6run11	6	671	49.97415	-6.33190	Algae brown		4.8	Algae brown	Algae brown
zone6run11	6	674	49.97396	-6.33024	Algae brown		8.5	Algae brown	Algae brown
zone6run11	6	675	49.97599	-6.32997			16		
zone6run11	6	677	49.96869	-6.33944			11		
zone6run11	6	679	49.97380	-6.32907	Algae brown		4.8	Algae brown	Algae brown
zone6run11	6	682	49.96673	-6.34059	Algae brown		3.2	Algae brown	Algae brown
zone6run11	6	683	49.97266	-6.33088	Algae brown		3.4	Bare rock	Algae brown
zone6run11	6	684	49.96811	-6.34087			11		

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone6run11	6	687	49.97675	-6.32429			16		
zone6run11	6	688	49.97388	-6.33747	Algae brown		8.3	Algae brown	Algae brown
zone6run11	6	690	49.96957	-6.33270	Algae brown		4.2	Algae brown	Algae brown
zone6run11	6	691	49.97401	-6.33069	Algae brown		9.5	Algae brown	Algae brown
zone6run11	6	693	49.97593	-6.32125	Algae brown		6.8	Algae brown	Algae brown
zone6run11	6	694	49.97086	-6.34465			>15m		
zone6run11	6	696	49.97024	-6.32970	Algae brown		4.8	Algae brown	Algae brown
zone6run11	6	699	49.97232	-6.34342	Algae brown		8.3	Algae brown	Algae brown
zone6run11	6	700	49.97154	-6.34450			13		
zone6run11	6	702	49.97131	-6.33036	Algae brown		2	Algae brown	Algae brown
zone6run11	6	704	49.96483	-6.33980	Bare sand		3.2	Bare sand	Algae green
zone7run8	7	707	49.97622	-6.28744			16		
zone7run8	7	709	49.96910	-6.28197	Algae brown		3.5	Algae brown	Algae brown
zone7run8	7	711	49.96630	-6.28745	Bare rock		2.5	Bare rock	Bare rock
zone7run8	7	712	49.96684	-6.28355	Algae brown		6.8	Algae brown	Algae brown
zone7run8	7	713	49.96978	-6.27504			16		
zone7run8	7	718	49.97433	-6.28953	Algae brown		2.1	Algae brown	Algae brown
zone7run8	7	719	49.97164	-6.28755	Algae brown		3.5	Algae brown	Algae brown
zone7run8	7	723	49.97222	-6.28735	Algae brown		2.5	Algae brown	Algae brown
zone7run8	7	724	49.97118	-6.28315			16		
zone7run8	7	725	49.97128	-6.28440			11		
zone7run8	7	726	49.96619	-6.28670	Algae brown		2.2	Bare rock	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone7run8	7	728	49.96965	-6.28901	Algae brown		3.7	Algae brown	Algae brown
zone7run8	7	729	49.96820	-6.28243			12		
zone7run8	7	732	49.97075	-6.28263			12		
zone8run4part2	8	748	49.94806	-6.27156	Seagrass (note %cover in next column)	90	3.2	70	80
zone8run4part2	8	752	49.94339	-6.27162			10		
zone8run4part2	8	755	49.94061	-6.27095			10		
zone8run4part2	8	758	49.95119	-6.26376	Seagrass (note %cover in next column)	70	2.4	80	90
zone8run4part2	8	759	49.93993	-6.28047			14		
zone8run4part2	8	760	49.93950	-6.27041			15		
zone8run4part2	8	765	49.94017	-6.28567	Seagrass (note %cover in next column)	15	1.5	20	5
zone8run4part2	8	766	49.93801	-6.27810			14		
zone8run4part2	8	767	49.94871	-6.25846	Algae brown		5.8	Algae brown	Algae brown
zone8run4part2	8	769	49.93580	-6.28343			14		
zone8run4part2	8	770	49.93328	-6.28000			16		
zone8run4part2	8	783	49.93962	-6.28864			10		
zone8run4part2	8	784	49.94232	-6.28401			10		
zone8run4part2	8	786	49.95011	-6.26242	Algae brown		4.5	Algae brown	Bare sand
zone8run4part2	8	787	49.95242	-6.26345	Bare sand		2.7	80	60
zone8run4part2	8	789	49.94690	-6.25689	Algae brown		4.3	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone8run4part2	8	790	49.94508	-6.26501	Algae brown		2.8	Algae green	Algae brown
zone8run4part2	8	791	49.94527	-6.26353	Algae brown		3.5	Algae brown	Algae brown
zone8run4part2	8	793	49.94295	-6.28034	Algae brown		9.3	Bare sand	Algae brown
11northwest1	3	794	49.94569	-6.39092	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	795	49.94513	-6.39677			>15m		
11northwest1	3	796	49.94643	-6.38978	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	797	49.94421	-6.39740			>15m		
11northwest1	3	798	49.94484	-6.38578	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	799	49.94476	-6.38850			>15m		
11northwest1	3	800	49.94291	-6.38999	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	801	49.94603	-6.39753			>15m		
11northwest1	3	803	49.94402	-6.39081	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	805	49.94340	-6.38721	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	806	49.94656	-6.38694			>15m		
11northwest1	3	808	49.94567	-6.38511			>15m		
11northwest1	3	810	49.94292	-6.38319	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	813	49.94738	-6.39101	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	816	49.94671	-6.38366			>15m		
11northwest1	3	817	49.94225	-6.38714	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	818	49.95197	-6.36616			>15m		
11northwest1	3	820	49.95591	-6.38105			>15m		
11northwest1	3	824	49.95671	-6.38161	Algae brown		No data	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
11northwest1	3	827	49.95836	-6.36835			>15m		
11northwest1	3	830	49.95168	-6.37273			>15m		
11northwest1	3	831	49.95696	-6.36850	Algae brown		No data	Algae brown	Algae brown
11northwest1	3	832	49.95432	-6.37703			>15m		
11northwest1	3	835	49.95470	-6.37946			>15m		
11northwest1	3	836	49.95409	-6.37304			>15m		
11northwest1	3	837	49.95550	-6.37722			>15m		
11northwest1	3	843	49.95776	-6.37667			>15m		
11northwest1	3	845	49.95482	-6.36712	Algae brown		4	Algae brown	Algae brown
11northwest1	3	847	49.95850	-6.36983			>15m		
11northwest1	3	848	49.94963	-6.38096			>15m		
11northwest1	3	849	49.95488	-6.36505			>15m		
8northwest4	3	850	49.92740	-6.36852	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	852	49.92860	-6.36782	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	853	49.92479	-6.36866	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	855	49.93451	-6.36100	Algae brown		5.3	Algae brown	Algae brown
8northwest4	3	858	49.93148	-6.36719	Algae brown		8	Algae brown	Algae brown
8northwest4	3	860	49.92794	-6.37273	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	861	49.92548	-6.37365			>15m		
8northwest4	3	862	49.93205	-6.37137	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	863	49.93000	-6.36272	Algae brown		4.3	Algae brown	Algae brown
8northwest4	3	865	49.93844	-6.35680	Algae brown		2.1	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
8northwest4	3	867	49.92387	-6.37190	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	868	49.92714	-6.37109	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	870	49.94029	-6.35720	Algae brown		4.8	Algae brown	Bare sand
8northwest4	3	871	49.92536	-6.36304	Algae brown		3.5	Algae brown	Algae brown
8northwest4	3	873	49.93290	-6.37436	Algae brown		9.8	Algae brown	Algae brown
8northwest4	3	874	49.93698	-6.36089	Algae brown		No data	Algae brown	Algae brown
8northwest4	3	877	49.93588	-6.36630			>15m		
zone5run10+11	5	880	49.95485	-6.34218	Bare sand		1.1	Bare sand	Bare sand
zone5run10+11	5	881	49.95527	-6.34687	Bare sand		0.9	Bare sand	Bare sand
zone5run10+11	5	885	49.95432	-6.34278	Bare sand		1.1	Bare sand	Bare sand
zone5run10+11	5	886	49.96346	-6.36198			>15m		
zone5run10+11	5	887	49.96410	-6.35095	Algae brown		3.5	Algae brown	Algae brown
zone5run10+11	5	888	49.96310	-6.35645	Algae brown		1.6	Algae brown	Algae brown
zone5run10+11	5	892	49.95691	-6.34682	Algae brown		2.3	Bare sand	Algae brown
zone5run10+11	5	893	49.95706	-6.36126	Algae brown		6.5	Algae brown	Algae brown
zone5run10+11	5	894	49.96541	-6.35322			16		
zone5run10+11	5	896	49.95881	-6.36176	Algae brown		5	Algae brown	Algae brown
zone5run10+11	5	898	49.95816	-6.34609	Bare sand		3.2	Bare sand	Algae brown
zone5run10+11	5	899	49.95845	-6.34895	Seagrass (note %cover in next column)	30	1.4	40	30
zone5run10+11	5	901	49.96128	-6.35027	Algae brown		3.5	Algae brown	Algae brown
zone5run10+11	5	903	49.95679	-6.34486	Bare sand		3.4	Bare sand	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone5run10+11	5	905	49.95998	-6.35071	Algae brown		3.4	Algae brown	Algae brown
zone5run10+11	5	907	49.95744	-6.34790	Seagrass (note %cover in next column)	30	0.6	30	20
zone5run10+11	5	908	49.95542	-6.34648	Bare sand		0.8	Bare sand	Bare sand
zone5run8	5	909	49.94266	-6.34841	Bare sand		2.4	Bare sand	Bare sand
zone5run8	5	910	49.93795	-6.33883	Bare sand		0.8	Algae brown	Algae green
zone5run8	5	912	49.94443	-6.35032	Algae brown		2.5	Algae brown	Algae green
zone5run8	5	914	49.94261	-6.33814	Bare sand		1.8	Bare sand	Bare sand
zone5run8	5	916	49.94044	-6.35281	Bare sand		4.2	Bare sand	Algae brown
zone5run8	5	919	49.93610	-6.34401	Bare sand		1	Bare sand	Bare sand
zone5run8	5	920	49.94298	-6.35436	Bare sand		3.8	Algae brown	Bare sand
zone5run8	5	923	49.93927	-6.35278	Algae brown		2.2	Algae brown	Bare sand
zone5run8	5	924	49.93848	-6.33818	Bare sand		0.8	Bare sand	Algae brown
zone5run8	5	925	49.93469	-6.34524	Bare sand		0.9	Bare sand	Bare sand
zone5run8	5	926	49.94461	-6.33979	Bare sand		1.3	Bare sand	Bare sand
zone5run8	5	931	49.94137	-6.35513	Bare sand		4.5	Bare sand	Algae brown
zone6run8	6	950	49.96144	-6.29950	Bare sand		2.5	Bare sand	Algae green
zone6run8	6	951	49.96051	-6.31806			>15m		
zone6run8	6	952	49.95838	-6.30982	Bare sand		2.4	Bare sand	Bare sand
zone6run8	6	955	49.95766	-6.31100	Seagrass (note %cover in next column)	80	3.3	80	90

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone6run8	6	959	49.96363	-6.30881	Seagrass (note %cover in next column)	100	3.8	100	80
zone6run8	6	960	49.95409	-6.31658	Bare sand		4.2	Bare sand	Algae green
zone6run8	6	961	49.96266	-6.30456	Bare sand		3.9	Bare sand	Bare sand
zone6run8	6	968	49.95680	-6.30925	Bare sand		3.8	Algae green	Algae green
zone6run8	6	969	49.95364	-6.31490	Bare sand		4	Bare sand	Bare sand
zone6run8	6	970	49.96088	-6.31925	Bare sand		2.9	Algae green	Bare sand
zone6run8	6	973	49.95997	-6.32028	Algae green		3.5	Bare sand	Algae brown
zone6run8	6	974	49.95993	-6.30876	Bare sand		2.3	Bare sand	Bare sand
zone6run8	6	983	49.96153	-6.30779	Seagrass (note %cover in next column)	100	4.2	90	100
zone8run6part2	8	984	49.94799	-6.29791	Algae brown		5.8	Bare sand	Bare sand
zone8run6part2	8	985	49.94744	-6.29084	Bare sand		6.8	Bare sand	Algae brown
zone8run6part2	8	987	49.95467	-6.27429	Bare sand		1.8	Bare sand	Bare sand
zone8run6part2	8	988	49.94527	-6.29242	Bare sand		7.5	Bare sand	Bare sand
zone8run6part2	8	989	49.95121	-6.28887	Bare sand		5.2	Bare sand	Bare sand
zone8run6part2	8	992	49.95110	-6.28301	Algae brown		3.2	Algae brown	Algae brown
zone8run6part2	8	996	49.95148	-6.29968	Bare sand		2.8	Bare sand	Algae green
zone8run6part2	8	997	49.94810	-6.29185	Algae brown		6.2	Algae brown	Algae brown
zone8run6part2	8	998	49.94958	-6.29411	Algae brown		5.8	Algae brown	Algae brown
zone8run6part2	8	999	49.96693	-6.30610			10		
zone8run6part2	8	1000	49.96508	-6.30738	Bare sand		3.6	Bare sand	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone8run6part2	8	1005	49.94864	-6.28768	Bare sand		5.8	Bare sand	Bare sand
Zone9run2	9	1006	49.92116	-6.27532			>15m		
Zone9run2	9	1007	49.90789	-6.30141	Algae brown		2	Algae brown	Algae brown
Zone9run2	9	1008	49.90321	-6.30215			>15m		
Zone9run2	9	1009	49.90894	-6.30982	Algae brown		1.5	Algae brown	Algae brown
Zone9run2	9	1010	49.92202	-6.27556			>15m		
Zone9run2	9	1011	49.90462	-6.30054	Algae brown		8	Algae brown	Algae brown
Zone9run2	9	1012	49.91003	-6.29989	Algae brown		2	Algae brown	Algae brown
Zone9run2	9	1013	49.90587	-6.30672	Algae brown		2	Algae brown	Algae brown
Zone9run2	9	1014	49.90974	-6.29256			>15m		
Zone9run2	9	1015	49.91367	-6.28284	Algae brown		8.5	Algae brown	Algae brown
Zone9run2	9	1016	49.92383	-6.27783	Algae brown		5.5	Algae brown	Algae brown
Zone9run2	9	1017	49.90432	-6.30140	Algae brown		8	Algae brown	Algae brown
Zone9run2	9	1018	49.91937	-6.27601			>15m		
Zone9run2	9	1019	49.92498	-6.27536			>15m		
Zone9run2	9	1020	49.92651	-6.27692	Algae brown		1.2	Algae brown	Algae brown
Zone9run2	9	1021	49.90823	-6.29940	Algae brown		7.2	Algae brown	Algae brown
Zone9run2	9	1022	49.90524	-6.30040	Algae brown		8	Algae brown	Algae brown
Zone9run3	9	1023	49.90697	-6.32389	Algae brown		6	Algae brown	Algae brown
Zone9run3	9	1024	49.90712	-6.32192	Algae brown		3	Algae brown	Algae brown
Zone9run3	9	1025	49.90813	-6.31169	Algae brown		7.5	Algae brown	Algae brown
Zone9run3	9	1026	49.90611	-6.32248			>15m		

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone9run3	9	1027	49.90607	-6.32158			>15m		
Zone9run3	9	1028	49.90749	-6.31031	Algae brown		9.2	Algae brown	Algae brown
Zone9run3	9	1029	49.90793	-6.32179	Algae brown		1.5	Algae brown	Algae brown
Zone9run3	9	1030	49.90903	-6.32436	Algae brown		1.5	Algae brown	Algae brown
Zone9run3	9	1031	49.91197	-6.31615	Algae brown		2.2	Algae brown	Algae brown
Zone9run3	9	1032	49.90801	-6.31527	Algae brown		7	Algae brown	Algae brown
Zone9run3	9	1033	49.90551	-6.31650			>15m		
Zone9run3	9	1034	49.90676	-6.32052			>15m		
Zone9run3	9	1035	49.90671	-6.31756	Algae brown		7.8	Algae brown	Algae brown
Zone9run3	9	1036	49.91658	-6.31418	Seagrass (note %cover in next column)	30	1.8	30	50
Zone9run3	9	1037	49.91709	-6.31444	Seagrass (note %cover in next column)	40	2.5	30	50
Zone9run4	9	1038	49.91945	-6.30932	Bare sand		1.8	Bare sand	Algae brown
Zone9run4	9	1041	49.92004	-6.32346			>15m		
Zone9run4	9	1042	49.92443	-6.31545	Algae brown		7.2	Algae brown	Bare sand
Zone9run4	9	1043	49.91849	-6.32531			>15m		
Zone9run4	9	1044	49.92066	-6.32026	Algae brown		4.8	Algae brown	Algae brown
Zone9run4	9	1045	49.90968	-6.33053			>15m		
Zone9run4	9	1046	49.92096	-6.32222			>15m		
Zone9run4	9	1047	49.91994	-6.31174	Seagrass (note %cover in next column)	70	3.2	70	40

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone9run4	9	1050	49.91674	-6.32439	Algae brown		3.5	Algae brown	Algae brown
Zone9run4	9	1051	49.92392	-6.31574	Algae brown		7	Algae brown	Algae brown
Zone9run4	9	1052	49.91989	-6.31007	Bare sand		2.1	Algae brown	Bare sand
Zone9run4	9	1053	49.91721	-6.31231	Algae brown		2.3	Bare sand	Rock
Zone9run5	9	1054	49.93936	-6.30471	Algae brown		4.2	Bare sand	Algae brown
Zone9run5	9	1055	49.93027	-6.31562	Bare sand		7.8	Bare sand	Algae brown
Zone9run5	9	1056	49.94196	-6.29543	Bare sand		7.5	Bare sand	Bare sand
Zone9run5	9	1059	49.92681	-6.31441	Algae brown		4	Algae brown	Algae brown
Zone9run5	9	1060	49.93826	-6.30311	Seagrass (note %cover in next column)	70	3.5	70	100
Zone9run5	9	1061	49.93800	-6.28739			>15m		
Zone9run5	9	1062	49.94213	-6.29234	Bare sand		9.8	Bare sand	Bare sand
Zone9run5	9	1063	49.94246	-6.29109	Bare sand		9.8	Algae brown	Bare sand
Zone9run5	9	1064	49.92828	-6.31436	Algae brown		4.2	Algae brown	Algae brown
Zone9run5	9	1065	49.93793	-6.30266	Seagrass (note %cover in next column)	100	5.2	20	Algae brown
Zone9run5	9	1068	49.93724	-6.30978	Bare sand		8	Bare sand	Bare sand
Zone9run5	9	1069	49.93934	-6.30168	Bare sand		6.2	Algae green	Bare sand
Zone9run5	9	1070	49.93108	-6.31654	Algae brown		8	Algae brown	Algae brown
Zone9run5	9	1071	49.92819	-6.31623	Algae brown		7.5	Algae brown	Algae brown
Zone9run5	9	1072	49.94053	-6.28777			>15m		
Zone9run5	9	1073	49.93699	-6.29367	Algae brown		5.6	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone9run5	9	1074	49.93814	-6.29617	Algae brown		5.2	Algae green	Algae brown
Zone9run5	9	1077	49.93729	-6.30789	Bare sand		6.5	Algae green	Bare sand
Zone9run5	9	1078	49.93840	-6.29124			>15m		
Zone9run5	9	1079	49.91298	-6.28282			>15m		
Zone9run5	9	1080	49.90443	-6.29857	Algae brown		8	Algae brown	Algae brown
Zone9run5	9	1081	49.90895	-6.29150	Algae brown		4.8	Algae brown	Algae brown
Zone9run5	9	1082	49.90710	-6.29633			>15m		
Zone9run5	9	1083	49.90412	-6.29182			>15m		
Zone9run5	9	1086	49.91637	-6.27795	Algae brown		7.8	Algae brown	Algae brown
Zone9run5	9	1087	49.91794	-6.27642			>15m		
Zone9run5	9	1088	49.91370	-6.28245	Algae brown		8.7	Algae brown	Algae brown
Zone9run5	9	1089	49.90585	-6.29390			>15m		
Zone9run5	9	1090	49.90387	-6.29440	Algae brown		4.5	Algae brown	Algae brown
Zone9run5	9	1091	49.91569	-6.27900	Algae brown		5.4	Algae brown	Algae brown
Zone9run5	9	1092	49.90688	-6.29456	Algae brown		7	Algae brown	Algae brown
Zone4run2	4	1095	49.89760	-6.32881	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1096	49.89977	-6.32278	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1097	49.88688	-6.34746	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1098	49.88613	-6.35136	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1099	49.90039	-6.32024			>15m		
Zone4run2	4	1100	49.88400	-6.34526	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1104	49.88392	-6.34415	Algae brown		No data	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone4run2	4	1105	49.88931	-6.32820	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1106	49.88740	-6.35069	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1107	49.88639	-6.35250	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1108	49.89039	-6.33527	Bare sand		No data	Algae brown	Bare sand
Zone4run2	4	1109	49.88667	-6.34743	Algae brown		No data	Algae brown	Bare sand
Zone4run2	4	1113	49.89544	-6.32833	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1114	49.89855	-6.31945	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1115	49.89562	-6.32586	Algae brown		No data	Bare sand	Algae brown
Zone4run2	4	1116	49.88938	-6.34736	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1117	49.88313	-6.34892	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1118	49.88907	-6.34711	Algae brown		No data	Algae brown	Algae brown
Zone4run2	4	1122	49.89120	-6.33548	Bare sand		No data	Bare sand	Bare sand
Zone4run3	4	1123	49.88881	-6.35384	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1124	49.89656	-6.35218	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1125	49.89777	-6.34395	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1126	49.89796	-6.33651	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1127	49.89378	-6.35651	Algae brown		No data	Algae brown	Bare sand
Zone4run3	4	1131	49.89856	-6.34224	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1132	49.88749	-6.34997	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1133	49.88748	-6.35266	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1134	49.89948	-6.34620	Algae brown		No data	Algae brown	Algae brown
Zone4run3	4	1135	49.89844	-6.34628	Algae brown		No data	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone4run3	4	1136	49.89053	-6.35693			>15m		
Zone4run3	4	1140	49.89376	-6.35184	Algae brown		No data	Algae brown	Algae brown
Zone4run1	4	1141	49.89312	-6.32226	Algae brown		No data	Algae brown	Algae brown
Zone4run1	4	1142	49.89196	-6.32057			>15m		
Zone4run1	4	1143	49.89200	-6.32106			>15m		
Zone4run1	4	1144	49.88284	-6.33798	Algae brown		No data	Algae brown	Algae brown
Zone4run1	4	1145	49.88811	-6.33518	Algae brown		6	Algae brown	Algae brown
Zone4run1	4	1149	49.88362	-6.34491	Algae brown		No data	Algae brown	Algae brown
Zone4run1	4	1150	49.88544	-6.33749	Algae brown		No data	Algae brown	Algae brown
Zone7run11	7	1151	49.97620	-6.32049	Algae brown		8.5	Algae brown	Algae brown
Zone7run11	7	1152	49.97091	-6.34212	Algae brown		11	Algae brown	Algae brown
Zone7run11	7	1153	49.97304	-6.34082	Algae brown		11	Algae brown	Algae brown
Zone7run11	7	1154	49.97007	-6.34061	Algae brown		9.3	Algae brown	Algae brown
Zone7run11	7	1155	49.97070	-6.33869	Algae brown		5.2	Algae brown	Algae brown
Zone7run11	7	1158	49.97401	-6.33278	Algae brown		4.5	Algae brown	Algae brown
Zone7run11	7	1159	49.98000	-6.31200	Algae brown		No data	Algae brown	Algae brown
Zone7run11	7	1160	49.97600	-6.32527			>15m		
Zone7run11	7	1161	49.97085	-6.33350	Algae brown		5.5	Algae brown	Algae brown
Zone7run11	7	1162	49.97222	-6.33926	Algae brown		6.3	Algae brown	Algae brown
Zone7run11	7	1163	49.97256	-6.33400	Algae brown		4.5	Algae brown	Algae brown
Zone7run11	7	1164	49.97293	-6.33046	Algae brown		5.3	Algae brown	Algae brown
Zone8run6	8	1167	49.96797	-6.26622	Algae brown		8.8	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone8run6	8	1168	49.96651	-6.26312	Algae brown		2.8	Algae brown	Algae brown
Zone8run6	8	1169	49.96776	-6.26681	Algae brown		6.5	Algae brown	Algae brown
Zone8run6	8	1170	49.95825	-6.26692	Algae brown		3.8	Algae brown	Algae brown
Zone8run6	8	1171	49.96151	-6.25790			>15m		
Zone8run6	8	1172	49.95833	-6.27438	Algae brown		1.7	Bare sand	Algae brown
Zone8run6	8	1173	49.96763	-6.26112	Algae brown		6.5	Algae brown	Algae brown
Zone8run6	8	1176	49.96040	-6.26478	Algae brown		3.8	Algae brown	Algae brown
Zone8run6	8	1177	49.95989	-6.26442	Algae brown		3.8	Algae brown	Algae brown
Zone8run6	8	1178	49.95784	-6.27626	Seagrass (note %cover in next column)	95	1.4	Bare sand	Bare sand
Zone8run6	8	1179	49.95937	-6.26544	Seagrass (note %cover in next column)	100	2.8	80	100
Zone8run6	8	1180	49.96179	-6.25936	Algae brown		8.4	Algae brown	Algae brown
Zone8run6	8	1181	49.96616	-6.27164	Algae brown		6.4	Algae brown	Algae brown
Zone8run6	8	1182	49.96909	-6.26033			>15m		
Zone8run6	8	1185	49.95856	-6.26744	Seagrass (note %cover in next column)	100	3.2	80	10
Zone8run6	8	1186	49.96144	-6.26171	Bare sand		8.8	Bare sand	Bare sand
Zone8run6	8	1187	49.96498	-6.27028	Algae brown		6	Algae brown	Algae brown
Zone8run6	8	1188	49.95797	-6.27409	Bare sand		1.7	Algae brown	20
Zone9run6	9	1189	49.93417	-6.31527	Bare sand		7	Bare sand	Bare sand
Zone9run6	9	1190	49.93945	-6.31546	Bare sand		6.6	Algae green	Bare sand

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
Zone9run6	9	1191	49.93380	-6.31495	Bare sand		7.2	Bare sand	Bare sand
Zone9run6	9	1194	49.93585	-6.32308	Algae brown		7.2	Algae brown	Algae brown
Zone9run6	9	1195	49.93707	-6.31171	Algae green		7.8	Bare sand	Bare sand
Zone9run6	9	1196	49.93692	-6.31203	Algae green		7.6	Algae green	Bare sand
Zone9run6	9	1197	49.93631	-6.32059	Algae brown		5.5	Algae brown	Algae brown
Zone9run6	9	1198	49.94190	-6.31293	Bare sand		7.2	Algae green	Bare sand
Zone9run6	9	1199	49.94666	-6.30374	Bare sand		2.6	Bare sand	Bare sand
Zone9run6	9	1200	49.93578	-6.31527	Bare sand		6.5	Bare sand	Bare sand
Zone9run6	9	1203	49.93564	-6.32385	Algae brown		7.5	Algae brown	Algae brown
Zone9run6	9	1204	49.94549	-6.29687	Bare sand		4	Bare sand	Bare sand
Zone9run6	9	1205	49.94618	-6.30648	Bare sand		2.6	Bare sand	Bare sand
Zone9run6	9	1206	49.94534	-6.29483	Bare sand		5.3	Bare sand	Bare sand
Zone9run6	9	1207	49.93538	-6.32315	Algae brown		8	Algae brown	Algae brown
Zone9run6	9	1208	49.93570	-6.32590	Algae brown		7.4	Algae brown	Algae brown
Zone9run6	9	1209	49.93918	-6.32140	Algae brown		1.2	Algae brown	Algae brown
Zone9run6	9	1212	49.93890	-6.31473	Bare sand		7.2	Algae brown	Algae brown
Zone9run1	9	1227	49.90521	-6.30018	Algae brown		7.4	Algae brown	Algae brown
zone8run5pt2	8	1230	49.95585	-6.26071	Algae brown		4.6	Algae brown	Algae brown
zone8run5pt2	8	1231	49.96600	-6.24614	Algae brown		8	Algae brown	Algae brown
zone8run5pt2	8	1232	49.96102	-6.25981	Bare sand		7.8	Bare sand	Algae brown
zone8run5pt2	8	1233	49.95951	-6.25706			>15m		
zone8run5pt2	8	1234	49.95412	-6.25647	Algae brown		5	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone8run5pt2	8	1235	49.95633	-6.26217	Algae brown		9.6	Algae brown	Algae brown
zone8run5pt2	8	1236	49.95130	-6.26095	Algae brown		3.2	Algae brown	Algae brown
zone8run5pt2	8	1239	49.95696	-6.26283	Bare sand		9.6	Algae brown	Algae brown
zone8run5pt2	8	1240	49.95520	-6.25757	Algae brown		4.2	Algae brown	Algae brown
zone8run5pt2	8	1241	49.96492	-6.24714			>15m		
zone8run5pt2	8	1242	49.96315	-6.24975			>15m		
zone8run5pt2	8	1243	49.95966	-6.26004	Algae brown		7.2	Algae brown	Algae brown
zone8run5pt2	8	1244	49.96238	-6.24570			>15m		
zone8run5pt2	8	1245	49.95900	-6.26123	Algae brown		5.3	Algae brown	Algae brown
zone8run4	8	1248	49.94692	-6.25261	Algae brown		7.2	Algae brown	Algae brown
zone8run4	8	1249	49.95415	-6.25558	Algae brown		5.2	Algae brown	Algae brown
zone8run4	8	1250	49.94952	-6.25148	Algae brown		4.5	Algae brown	Bare sand
zone8run4	8	1251	49.95414	-6.25963	Rock		0	Rock	Algae green
zone8run4	8	1252	49.95119	-6.24538	Algae brown		7.7	Algae brown	Algae brown
zone8run4	8	1253	49.95241	-6.24344	Algae brown		4.4	Algae brown	Algae brown
zone8run4	8	1254	49.95916	-6.24413			>15m		
zone8run4	8	1257	49.95257	-6.25175	Algae brown		7.9	Algae brown	Algae brown
zone8run4	8	1258	49.95488	-6.25725	Bare sand		5.3	Bare sand	Algae brown
zone8run4	8	1259	49.95140	-6.25274	Algae brown		5.5	Algae brown	Algae brown
zone8run4	8	1260	49.95519	-6.25423	Algae brown		5	Algae brown	Algae brown
zone8run4	8	1261	49.94857	-6.25018	Algae brown		3.5	Algae brown	Algae brown
zone8run4	8	1262	49.95350	-6.24986	Algae brown		8.7	Algae brown	Algae brown

Table continued…

MBA_REF	Zone	Label on map	LatDD (WGS84)	Long DD (WGS84)	Reference	Percentage cover of seagrass	Depth*	Adjacent site 1 Reference (Numbers = % cover seagrass)	Adjacent site 2 Reference (Numbers = % cover seagrass)
zone8run4	8	1263	49.95200	-6.24891	Algae brown		5.5	Algae brown	Algae brown
zone7run9	7	1266	49.96642	-6.30796	Algae brown		3.7	Bare sand	Algae brown
zone7run9	7	1267	49.97188	-6.30834	Algae brown		6.8	Algae brown	Algae brown
zone7run9	7	1268	49.96572	-6.30724	Algae brown		1.5	Algae brown	Algae brown
zone7run9	7	1269	49.97005	-6.30621	Algae brown		9	Algae brown	Algae brown
zone7run9	7	1270	49.97404	-6.29039	Algae brown		2.9	Algae brown	Algae brown
zone7run9	7	1271	49.96875	-6.30792	Bare sand		8.3	80	40
zone7run9	7	1272	49.97423	-6.30530	Algae brown		7.5	Algae brown	Algae brown
zone7run9	7	1275	49.97808	-6.29868			>15m		
zone7run9	7	1276	49.96661	-6.30816	Bare sand		4.3	30	Algae brown
zone7run9	7	1277	49.97216	-6.30154	Algae brown		6	Algae brown	Algae brown
zone7run9	7	1278	49.97726	-6.29767	Algae brown		8.5	Algae brown	Algae brown
zone7run9	7	1279	49.97675	-6.29500	Algae brown		3.7	Algae brown	Algae brown
zone7run9	7	1280	49.97680	-6.29684	Algae brown		4.8	Algae brown	Algae brown
zone7run9	7	1281	49.96790	-6.30332	Rock		2.7	Rock	Algae brown
zone7run9	7	1284	49.97300	-6.29134	Algae brown		4.2	Algae brown	Bare sand
zone7run9	7	1285	49.97081	-6.29119	Bare sand		2.8	Bare sand	Bare sand

*Depth was recorded in situ by ground truthing team but could not be corrected to chart datum due to date and time of observation not being recorded.

Appendix 4 Grab and Video records containing seagrass from Munro & Nunny 1998

Table C Grab and Video records containing seagrass

Station	Area	Biotope code	Depth (sea level)	Video description	Lat	Long
1	7	ims.zmar	4.9	sand with stones, dense *Zostera*, fucoids	49.94831	-6.27861
3	4	mir.sedk? / ims.zmar	6	sand and stones with much foliose algae protruding through sand	49.93966	-6.30839
4	6	ims zmar	7.9	level clean sand, shells with attached green algae, occasional large rounded boulders	49.92909	-6.32676
1	11	ims zmar	2.1	v. silty, steep bedrock	49.95266	-6.26463
3	3	igs	9.3		49.94346	-6.2946
4	4	IGS	13.1		49.92657	-6.33215
4	5	IGS	10	Dense *Zostera marina* bed on clean	49.92915	-6.31558
9	12	igs / cgs	22.5	dense *Zostera*	49.90931	-6.31462
transect	1 north	igs / ims.zmar	5	dense patches of *Zostera*	49.9577	-6.30622
transect	1 south	igs / ims.zmar	5		49.95655	-6.30319
transect	2 west	mir.sedk > mir.lhyp.ft	12	dense *Zostera*	49.92363	-6.322
transect	2 mid		12	patchy *Zostera*	49.92342	-6.31793
transect	2 east		12	sparse to dense *Zostera*	49.92313	-6.31388

Table continued…

Station	Area	Biotope code	Depth (sea level)	Video description	Lat	Long
transect	3 west	ims zmar	6		49.9485	-6.28253
transect	3 mid	ims zmar	6		49.94891	-6.27364
transect	3 east	ims zmar	6		49.94874	-6.27837
transect	4 north	igs > elr.him/ mir.kr > ims z.mar > elr.him/ mirkr	5		49.94975	-6.2924
transect	4 south	igs > elr.him/ mir.kr > ims z.mar > elr.him/ mirkr	5		49.94742	-6.2922
transect	5 south	ims zmar	10		49.9282	-6.3323

Source: Munro & Nunny 1998

Appendix 5 Areas requiring more survey

Figure B Areas requiring more survey