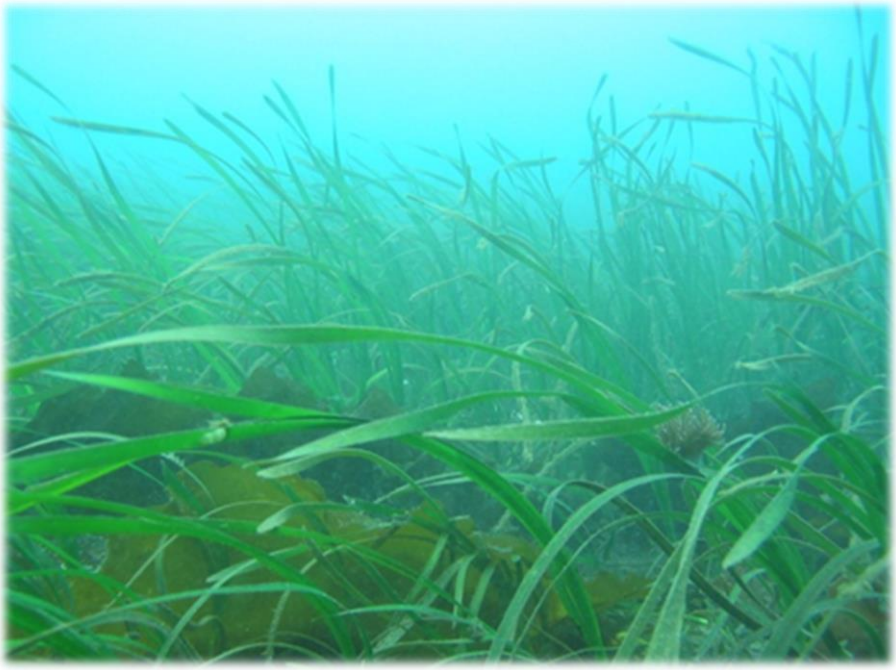
Plymouth Sound and Estuaries SAC Seagrass Condition Assessment 2012

Report Number: ER12-185



Performing Company:

Ecospan Environmental Ltd
Unit 8 Strashleigh View
Lee Mill
Devon
PL21 9GS

Tel: 01752 897198
Email: info@ecospan.co.uk
www.ecospan.co.uk

Sponsor: Natural England

Framework Agreement No. 22643/04
Ecospan Project No: 12-222

Author: LA Curtis

Approved By: M D R Field

Date of Approval: December 2012

Circulation

1. Gavin Black — Natural England
2. Mike Field — Ecospan Environmental Ltd

Contents

EXECUTIVE SUMMARY

A combination of drop-down/towed video (DDTV) and diver surveys were carried out on the seagrass beds within Plymouth Sound SAC. The DDTV surveys were carried out by Ecospan Environmental Ltd, and the diver surveys by Natural England. The results and conclusions drawn from both survey methods are reported here together.

The principal aim of the surveys was to obtain standardised biological information for the seagrass beds within the SAC, and to compare these data with previous studies (where possible) for the purpose of condition monitoring of the seagrass sub-feature. An additional objective was to review DDTV and diving methods in order to assess the feasibility of using only one method in future condition assessments. The study was also intended as a pilot for a standardised monitoring protocol for assessing the density of *Zostera marina* under the requirements of the Water Framework Directive.

A number of difficulties and limitations were experienced when comparing the data collected in this study with previous studies because of different methods and sampling locations employed. Despite this, it has been possible to draw a number of recommendations regarding the condition of the seagrass feature, though the confidence in the assessment is variable depending on the attribute considered.

An apparent extension in extent at a number of the seagrass beds since 2006 is thought to be largely due to seagrass not being detected in the aerial images that were used as a basis for the previous assessment, particularly in deeper water. Furthermore a number of the 2006 aerial images did not encompass the full extent of seagrass that was mapped during this study. However, it is probable that the area of dense seagrass cover has extended at Drakes Island.

The cause of apparent temporal differences in the number of plants per m^2 observed between 2009 and 2012 at Cawsand Bay and Cellars Cove (where numbers decreased and increased respectively) is not known, but may be due to different recording methods, survey months, sampling locations or natural fluctuations. Different methods applied in determining epiphyte and infection scores as well as percentage of leaves infected between this study and previous studies made it impossible to usefully make temporal comparisons. Consequently the recommended condition of plant/shoot density and epiphyte cover has been based on the absence of evidence of anthropogenic impact. It was not possible to make a recommendation for the condition of the infection score and infection percentage cover attributes. There was no confirmed presence of *Labyrinthula sp*.

Mean maximum plant lengths appear to have decreased at Drakes Island since 2009. However, given the limitations in the data, the value in making these comparisons is limited and should be treated with caution. The variation observed is likely to be as a result of natural variation between the different sampling locations that were applied between years.

The presence of drift and attached macroalgae are largely consistent with that recorded previously.

The condition of the seagrass sub-feature within Plymouth Sound SAC has been recommended to be assessed as being in a **Favourable Condition**.

It has been concluded that there is scope for using DDTV methods only as a measure of seagrass density (using percentage cover as a measure), which would provide a broad scale assessment at relatively low cost. However diving methods are still necessary for a full condition assessment as not all attributes can be measured using DDTV techniques alone (i.e. mean maximum leaf length, infection and epiphyte scores).

The benefits of using DDTV for measuring extent are clear. The methods employed during this study are by far the most efficient and accurate methods used to measure the extent of seagrass in the Plymouth Sound SAC to date.

A number of recommendations have been made to improve the quality and usefulness of data in future condition assessments. In particular, to ensure that more meaningful and rigorous temporal statistical analysis can be carried out on any future data collected, the diving survey design should be altered to increase the number of replicates per bed. A triangular lattice design should also be applied within DDTV survey (rather than the 20m square grid design that was used here) so that the distance between stations can be reduced for the same sampling effort. This would enable 'patchiness' within beds to be better detected and more accurately mapped.

1 INRODUCTION

Plymouth Sound and its associated tributaries hold a number of national and international designations. The areas within European Sites (Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)), which are covered by tidal waters at any time are collectively referred to as a European Marine Site (EMS) and protected by national and international legislation.

The Plymouth Sound and Estuaries SAC has a rich diversity of southern flora and fauna and a variety of different habitats due to the variations in wave exposure, water depth, rock and sediment types, salinity and tidal streams. Plymouth Sound and Estuaries qualifies as a SAC for the following Annex 1 habitats as listed in the EU Habitats Directive:

- Large shallow inlets and bays
- Estuaries
- Sandbanks which are slightly covered by seawater all the time.
- Reefs
- Atlantic salt meadows

Annex I habitats present as a qualifying feature within the SAC, but not a primary reason for its selection include mudflats and sandflats not covered by seawater at low tide.

The sub-littoral sediment areas within Plymouth Sound and its adjacent areas include: 'tide-swept sandbanks in estuarine habitats' and 'muds and muddy sands'. A sub-feature of the sandbanks feature in Plymouth Sound, and one of the reasons for the SAC designation, are seagrass (*Zostera marina*) bed communities. The primary areas of sub-tidal sandbanks are found at the mouth of the River Yealm (Cellars Cove and Red Cove, though Tomb Rock is now also known to be significant in extent). There are also known seagrass beds at Cawsand Bay and Drake's Island with more ephemeral beds at Firestone Bay and Jennycliff Bay. Intertidal *Zostera noltii* beds also exist but are not part of this seagrass sub-feature. A newly identified seagrass bed has been located off Tomb Rock recently, the extent and condition of which was unknown prior to this survey.

Natural England has a statutory duty to periodically assess the condition of the SAC and consequently, since the seagrass beds are a sub-feature, these are incorporated within the process. The relevant part of Natural England's advice under Regulation 33 (1) that relates to the seagrass is shown in the Favourable Condition Table (Table 1).

Table 1. Plymouth SAC seagrass favourable condition table

Sub-feature	Attribute	Source	Measure	Method	Baseline data
Eelgrass bed communities	*Extent	Reg. 33 document	Area (ha) of eelgrass bed communities measured twice during peak growth period twice during reporting cycle.	Towed video	Irving et al, 2007
Eelgrass bed communities	Characteristic species density of *Zostera marina*	Reg. 33 document	Average density measured during peak growth period twice during reporting cycle.	Towed video and NE dive survey	Irving 2010
Eelgrass bed communities	Characteristic species epiphytic community	Reg. 33 document	Presence and abundance of epiphytic species measured during summer twice during reporting cycle.	NE dive survey	Irving 2010
Eelgrass bed communities	Maximum leaf length	-	Maximum length of seagrass blades within quadrats.	NE dive survey	Irving 2010
Eelgrass bed communities	Presence of wasting disease, *Labyrinthula sp.*	-	Proportion of leaves showing blackening as a proxy for presence of *Labyrinthula sp*.	NE dive survey	Irving 2010
Eelgrass bed communities	*Presence of macroalgae including drift macroalgae within seagrass beds.	Adapted from Reg. 33 document for nutrient status.	Percentage cover and species of macroalgae.	Towed video	None

The seagrass sub-feature last underwent condition assessment in 2009 [2] and extent mapping in 2006 [3]. Natural England commissioned Ecospan Environmental Ltd to update the condition assessment of some of the attributes of the seagrass beds (those marked with an asterisk in Table 1 above) within the SAC before the end of September 2012. Natural England carried out diving surveys to assess the remaining attributes the results of which are also reported within this document.

The principal aim of the combined surveys was to obtain standardised biological information for the seagrass beds within the Plymouth Sound and Estuaries SAC, and to assess the condition of the seagrass sub-feature against previous survey data. An additional objective was to provide a pilot study for a standardised monitoring protocol for assessing the density of *Zostera marina* under the requirements of the Water Framework Directive.

2 OBJECTIVES

The objectives of the overall project were:

- To develop a cost effective sampling strategy to allow the condition of all known subtidal seagrass beds in Plymouth Sound to be assessed against the relevant attributes whilst allowing for comparison with previous survey data. These attributes are:
    - Extent
    - Presence of macroalgae including drift macroalgae within seagrass beds.
    - Density of *Zostera marina* (% cover, number of plants and number of flowering plants).
    - Number of leaves per plant
    - Maximum plant length
    - Amount of infection with the slime mould *Labyrinthula*
    - Amount and type of epiphyte cover
- To provide an assessment of the direction of ecological change by the integration of data collected by Ecospan Environmental Ltd (using drop down video methods) with that collected by Natural England (using diving methods), and comparing both sets of data with relevant historical data where possible.
- To provide an ecological baseline of attribute condition (from which to assess future change) where one does not exist (i.e. for the bed at Tomb Rock).
- To identify as far as possible anthropogenic influences that are impacting on the ability of the sub-feature to achieve Favourable Condition.
- To record the presence of the non-native algal species *Sargassum muticum* across the survey area.
- To critically review the two methods of measuring seagrass bed density in order to elucidate the feasibility of using only one method in future.
- To provide an overall assessment of the condition of seagrass within the SAC.

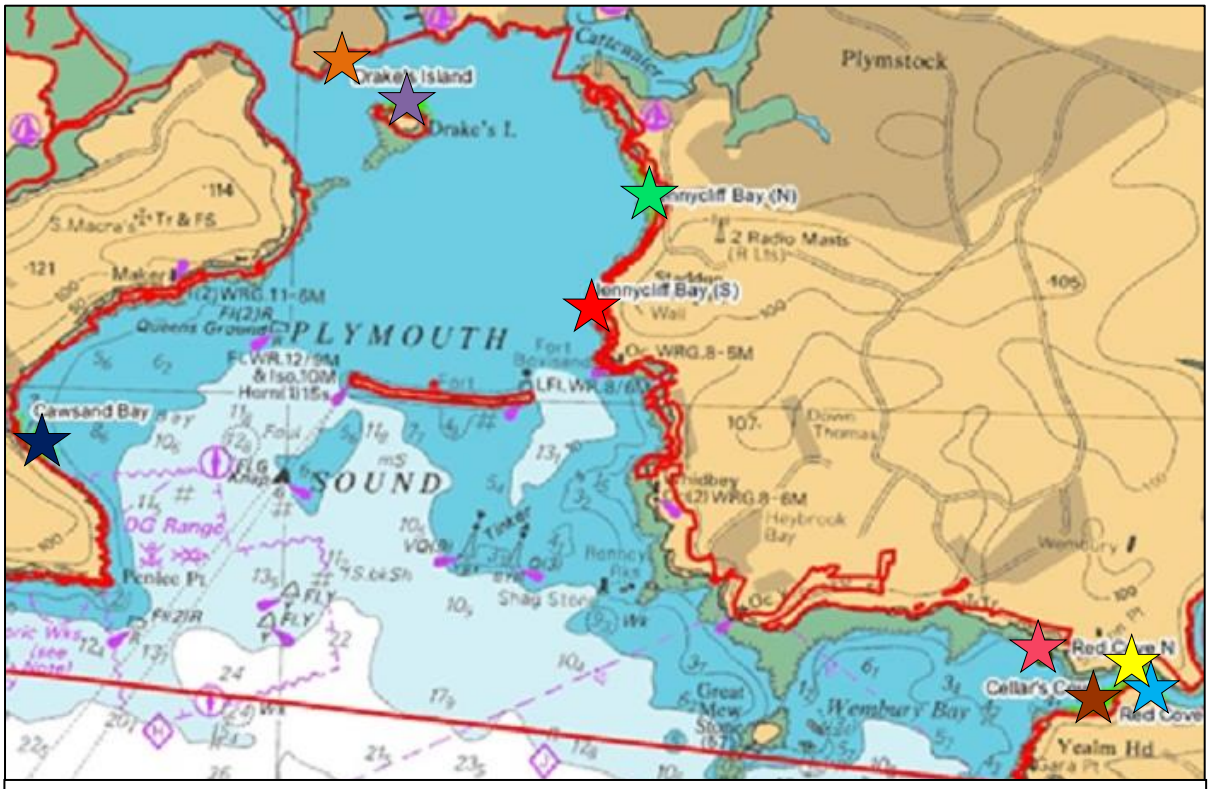
An additional objective to gather bathymetric data was met by Ecospan Environmental Ltd to enable the relationship between seagrass extent and depth to be explored in each bed.

3 METHODS

3.1 Survey Areas

The seagrass beds surveyed by one or both methods outlined in Sections 3.2, 3.3 and 3.4 are listed as follows and their location shown in Figure 1:

- Drakes Island
- Firestone Bay
- Cawsand Bay
- Jennycliff North
- Jennycliff South
- Tomb Rock
- Cellars Cove
- Red Cove North and Red Cove South



Plymouth Sound and Estuaries SAC Seagrass Beds - Key

SAC Boundary		
Drakes Island	**Jennycliff North**	**Cellars Cove**
Firestone Bay	**Jennycliff South**	**Tomb Rock**
Cawsand Bay	**Red Cove North**	**Red Cove South**

Figure 1. Location of the seagrass beds within the Plymouth Sound and Estuaries SAC

3.2 Drop-Down/Towed Video (DDTV) Survey

All of the known seagrass beds were surveyed using drop-down/towed video (DDTV) methods. The surveys were undertaken using an adaptation of the towed video technique. In this technique an underwater video camera and lights were attached under a heavy lead 'fish' in such a way that the camera pointed just forward of the vertical. The fish was then towed slowly (< 1 knot) above the seabed at the required depth principally to determine the percentage cover of seagrass. The percentage cover was assessed at the greatest possible resolution, but to facilitate spatial and temporal comparisons of the data, percentage cover data was subsequently aggregated into broader categories (see Table 4). The presence of macroalgae, anthropogenic influences and invasive species (*Sargassum muticum*) was also determined. The height of the camera above the seabed was adjusted according to the underwater visibility. The camera was deployed from Ecospan's 7.9m MCA Cat. 3 coded catamaran *Coastal Surveyor*. The position of the camera was determined using standard survey software linked to a survey quality differential GPS (Hemisphere R320) which gives sub-metre accuracy.

The survey area delineating the expected maximum extent of the seagrass beds (derived from previous studies) was divided into 20m survey transects which were drawn and transferred onto electronic charting software (Seapro) to enable positioning of the survey vessel. Each area of seagrass was methodically surveyed, with survey stations visited sequentially every 20m. Where possible, observations were continued between stations and target notes were made for notable observations i.e. presence of litter, patchiness in percentage cover etc. Given the uncertainty of historical data and the previously unmapped Tomb Rock bed, expert judgement was used to try and ensure that the survey areas encompassed the entirety of each seagrass bed. The survey areas were extended in the field where seagrass % cover of greater than 5% was observed at the edge of the delineated survey area. Where percentage cover of <5% was observed expert judgement combined with the use of previous extent data was used to decide if transects should be continued or extended, or whether the edge of the bed had been reached. The 5% threshold was based on the OSPAR definition of a '*Zostera spp*. bed' which states that plant densities should provide at least 5% cover to qualify [4].

The following data was gathered in real-time from each station on a pro-forma survey sheet:

- % Cover of seagrass per field of view (to enable both extent and % cover to be determined).
- Presence of macroalgae including drift macroalgae within seagrass beds.
- Presence of the invasive species *Sargassum muticum*.
- Observed anthropogenic influences such as litter, debris, mooring and anchoring would be noted (and quantified wherever possible).
- Station number

The surveys were carried out between the 29th of August and 17th of September 2012. Survey data was collected over a total of five days during this period with a further three days where surveys were attempted but had to be aborted due to poor underwater visibility which resulted from the high winds and exceptionally heavy rain that occurred in the preceding days. The continuation of strong winds on these dates also prevented safe manoeuvring of the boat close to shore.

Underwater visibility was variable from site to site and was also dependant on the state of tide, with better visibility generally encountered on the flooding tide. Although underwater visibility

generally improved over the survey period, it continued to be poorer than expected for the time of year. These conditions made surveying techniques more challenging as it meant the camera had to be operated closer to the seabed. This was particularly difficult in beds which fringed rocky areas where depth changed rapidly (e.g. Jennycliff North and South). In these areas the camera had to be 'dropped down' between stations rather than towed, resulting in fewer possible observations between stations.

Initially a high definition (HD) Delta Vision Industrial Underwater Camera was used and 10 second clips at those stations with seagrass present were recorded in MP4 format to enable quality control to be subsequently carried out. However, due to technical failure of the recording hardware associated with the HD underwater camera, a standard definition camera had to be employed. The standard definition camera (a Kongsberg OE14-366) had been intended to continuously record directly to DVD. The time was recorded in the boat book at each station where seagrass was present to enable the station and video footage to be linked for subsequent quality control. However, there was a subsequent failure in DVD recording equipment. As such, less data was available for secondary verification and quality assessment, but twenty data points (equating to 1.2% of all data points) were recovered from the original HD recording.

3.3 Dive Survey

3.3.1 Locations and Settings of Sample Stations

The four most substantial beds were surveyed using diving methods and these were:

- Drake's Island
- Cawsand Bay
- Cellars Cove
- Red Cove North and Red Cove South

Tomb Rock was also surveyed as an extra site but given that the diving surveys were carried out prior to the extent surveys, and no historical data existed for the bed, the main area of bed was missed and provided only very limited data. The ephemeral seagrass beds at Jennycliff North, Jennycliff South and Firestone Bay were not subject to diving surveys.

The dive surveys were undertaken by buddy pairs who collected samples at pre-defined but randomly determined locations for surface analysis and recording.

Natural England decided to vary the method from that used by Irving *et al* in 2010. As the aim of the diver survey was to measure the health of the bed (and not specifically the extent of the bed which was measured at a later date using DDTV), the methods used by Natural England to determine the randomised sample locations were intended to maximise the chance of those locations being within the extent of the bed. Therefore, where the expected extent of the bed was broad, a central datum marker and random vector technique was used. Where the extent and/or shape of the bed was more restricted, Natural England used a fixed transect. Although this amended approach meant that methodologies within the survey varied, it was assumed that the similar number of randomised samples gathered allowed comparable data to be collected.

Each of the two methods of randomly determining survey point locations are described as follows:

1. Central Datum Marker

A central datum line was lowered to the sea floor from which all bearings and distances were measured. The position of the datum was determined from previous mapping of the various bed extents. Once the central line was correctly positioned, sample points were located at randomly selected distances (between 0 and 30m), and bearings (between 0° and 359°), from the central line. Bearings were measured using a standard diver's compass and the distances from the central line using a marked tape.

2. Transect Marker

A weighted transect line of either 50 or 100m was used and survey points were then placed at 5 or 10m intervals respectively.

At each of the survey points, a 0.25m^2 quadrat (0.5m by 0.5m) was positioned such that the bottom left hand corner of the quadrat lay against the right hand edge of the tape at the indicated sample point. Once at the indicated position, all the plants within the bottom left hand quarter were then cut above the rhizomes and stored in a marked plastic bag for post dive analysis. Care was taken to ensure that all leaves were traced to the base and that only the plants with their rhizomes directly under the quarter square were taken. By taking plants only from the bottom left-hand corner of the quadrat the destructiveness of the sampling strategy was minimised. The pre-determined strategy also removed the potential for diver bias when selecting the area within the quadrat to be sub-sampled.

All diving fieldwork was undertaken by Natural England staff over a total of 3 days from the 8th to the 10th of August 2012. The coordinates of the central datum markers and transects, and the sampling interval distances are outlined in Table 2.

Table 2. Coordinates of the dive site central datum markers and transects

Site	Latitude (N)	Longitude (W)	Date Surveyed	Sample Point Location Notes
Drake's Island 1	50 21.414	4 09.144	8th August	Samples at random 30m vectors from Central Datum Marker
Drake's Island 2	50 21.398	4 09.070	8th August	Samples at random 30m vectors from Central Datum Marker
Drake's Island 3	50 21.411	4 09.283	8th August	Samples at random 30m vectors from Central Datum Marker
Cawsand Bay 1	50 19.685	4 11.785	8th August	Samples at random 30m vectors from Central Datum Marker
Cawsand Bay 2	50 18.710	4 11.803	8th August	Samples at random 30m vectors from Central Datum Marker
Cawsand Bay 3	50 19.752	4 11.914	9th August	Samples at random 30m vectors from Central Datum Marker
Cellars Cove 1	50 18.596	4 04.012	9th August	Samples at random 30m vectors from Central Datum Marker
Cellars Cove 2	50 18.616	4 03.971	9th August	Samples at random 30m vectors from Central Datum Marker
Cellars Cove Transect Start	50 18.660	4 03.865	9th August	Surveys at 10m intervals along 100m transect
Cellars Cove Transect End	50 18.700	4 03.804		
Red Cove North Transect Start	50 18.761	4 03.613	10th August	Surveys at 5m intervals along 50m transect
Red Cove North Transect End	50 18.762	4 03.661		
Red Cove South Transect Start	50 18.696	4 03.583	10th August	Surveys at 5m intervals along 50m transect
Red Cove South Transect End	50 18.677	4 03.553		
Tomb Rock	50 18.822	4 04.398	10th August	Surveys at 50m vectors from Central Datum Marker

3.3.2 Metrics analysed

At each sample point, Diver 1 collected the *Zostera* samples, whilst Diver 2 recorded the substrate type. Diver 2 also recorded the presence of any large amounts of drift algae.

- **Post Dive Analysis**

The *Zostera* plants were analysed post-dive at the end of each diving day (to ensure no degradation of the samples) for:

- Maximum leaf length
- Degree of infection with *Labyrinthula sp.*
- Amount of epiphytes
- Number of shoots
- Presence of invertebrate eggs
- Presence of flowering plants

Following training in order to ensure consistency, divers took each shoot collected and measured the longest leaf in that shoot using a tape measure, and recorded the length in centimetres as the maximum leaf length. Divers then assessed each intact leaf on the shoot to estimate the % cover of browning and epiphyte cover and, using the scoring system outlined in Table 3, this was then recorded as a value between 0 and 5. In 2010 Irving considered just the top 10cm of leaves to assess browning and epiphyte cover, however, in this study the entire leaf was considered as it is thought that the data produced would be more accurate.

Table 3. Scoring system for Leaf Infection and Epiphyte cover

Score	Description	% Infection
0	Uninfected/uncovered leaf	0
1	Minimal infection/cover apparent	0 - 2
2	Up to a quarter of leaf infected/covered	3 - 25
3	Up to half the leaf infected/covered	26 - 50
4	Over half all of leaf infected/covered	51 - 75
5	Almost all of leaf infected/covered	76 - 100

Figure 2. *Zostera* Plant Showing both Clean leaves, Infection and Epiphyte Cover

3.4 Bathymetric Survey

A bathymetric survey was carried out on the 10th and 11th of October 2012, following the collection of seagrass extent data. This survey was undertaken from Ecospan's vessel *Coastal Surveyor* using a Hemisphere R320 RTK GPS (typically accurate to 4cm in vertical plane and

2cm in the horizontal plane) for positioning, and a Sonarmite high frequency 200 KHz single beam echosounder following Ecospan's Standard Operating Procedure (SOP HS-04). The full extent of each bed was traversed following the same 20m transects as those used for DDTV survey. The water depth relative to chart datum was recorded, producing a 20 m grid of bathymetric data which was presented in the form a contour plot using SURFER 10 software. This data was then used to examine the relationship between water depth and seagrass extent.

4 RESULTS

All raw data and data plots are available in the GIS files which accompany this report.

4.1.1 Attributes Measured Using DDTV

To qualify as a *Zostera* spp. 'bed', the OSPAR definition states that plant densities should provide at least 5% cover [4]. Given this threshold value, the percentage cover data at each bed have been plotted and all percentage cover above 5% contoured. In order to make the percentage cover data easier to compare with future studies, the data has been categorised (and described) as follows:

Table 4. Percentage Cover Categories

% Cover	Description
5-25	Very Sparse
26-50	Sparse
51-75	Moderate
76-100	Dense

The total area of seagrass with a percentage cover of 5% or greater has been calculated for each bed and specified as the total area of seagrass bed at each location. The area for each category of percentage cover has also been calculated (using SURFER 10) for each bed. The raw data (percentage cover and OSGB 1936 British Uniform Grid) from each target station that was used to create the contours has been plotted spatially for each bed and is presented Appendix 1. The mean percentage cover has been determined for each bed by taking the percentage cover recorded at each station, and using all values of 5% cover or greater to calculate the mean.

HD recordings of seagrass at twenty stations were subjected to secondary verification for quality control purposes. The secondary verification was carried out by a second surveyor who analysed the recorded video footage post-survey. The data collected in real-time was compared to the results produced by the secondary verification using the Bray-Curtis similarity index in the statistical software package PRIMER [7]. The similarity of the analysis between the surveyor was determined to be 82% (see Appendix 2). It should be noted however that this similarity was determined on the percentage cover data before categorisation (i.e. to the nearest 1%). The data has been categorised for inclusion within this report. The categorised data was also analysed using the Bray-Curtis similarity index, resulting in 96% similarity (see Appendix 2). It was originally planned to carryout secondary verification on data collected at 5% of all stations (which would have equated to 85 separate video clips). However, given the equipment failure previously discussed, video clips from just 20 stations were recovered that equated to 1.8% of all data points. Consequently, although the results of the quality assessment remain valid, they are less robust than if data from 5% of stations had been secondary verified.

The FRAGSTATS [6] spatial analysis software package has not been used to analyse the data as it was not within the scope of this assessment.

4.1.2 Bathymetry

The results of the bathymetric survey are represented as contour plots and the bathymetric contours relative to the seagrass percentage cover contours are presented for each bed. The boat tracks recorded during the collection of the bathymetric data are presented in Appendix 3.

4.1.3 Attributes Measured Using Diving Methods

The mean and range of each of the attributes measured using diving techniques (number of plants per m^2, % leaves infected, infection scores, epiphyte scores and mean maximum plant length) have all been provided for each dive site (central datum marker or transect) to enable variability within beds to be gauged. An overall mean value and range for each attribute at each bed has also been calculated to simplify temporal comparisons within beds.

To determine the density the raw data of plants per 0.0625 m^2 has been multiplied by 16 to give a density per m^2.

The range of values for all attributes have been taken from the raw data. The mean number of plants per m^2 at each dive site has been calculated by taking the mean of the values measured from each quadrat within each dive site. To calculate the mean value for the entire bed, the mean of the mean values for each dive site has been calculated (i.e. where three dive sites were surveyed within a seagrass bed, the mean value for each site has been summed and divided by three). This approach to calculating the mean values was applied to each of the attributes measured.

The method of calculating mean values has been used because of the inherent biology and observed patchy nature of the attributes within beds which indicates that the data from quadrats within each dive site is not totally independent i.e. quadrats *between* transects/central datum sites are not considered to be replicates of the same population. This is demonstrated by comparing the mean and range of % of leaves infected and maximum plant lengths at two dive sites within Cawsand Bay, see Figures 3 and 4. These figures show that the ranges for these measured attributes do not overlap and therefore the attributes between dive sites are clearly different. T-tests on the attribute data from each dive site produced p values of <0.0001 for both % leaves infected and mean max plants lengths, indicating that data from different dive sites at Cawsand Bay are in fact significantly different.

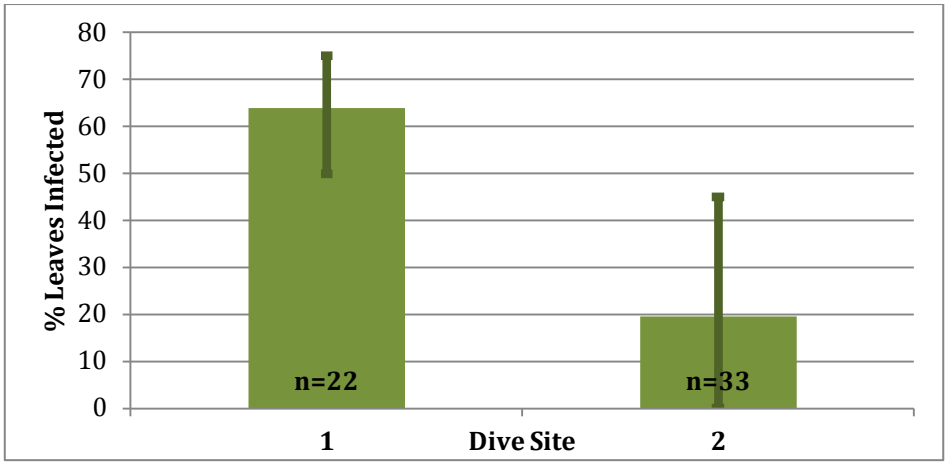


Figure 3. Mean (and range) of % leaves infected at Cawsand Bay dive sites where

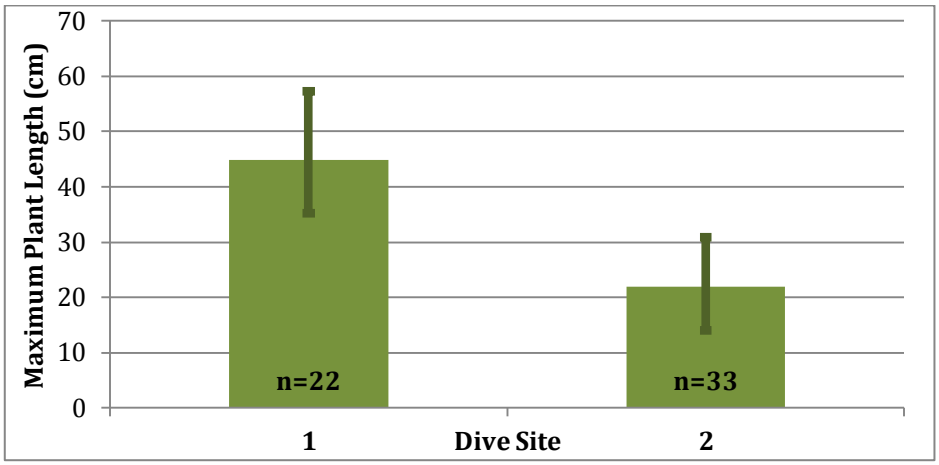


Figure 4. Mean (and range) of maximum plant length at Cawsand Bay dive sites where

A summary of the raw data from each of the seagrass beds dived is presented in Appendix 4.

4.2 Drakes Island

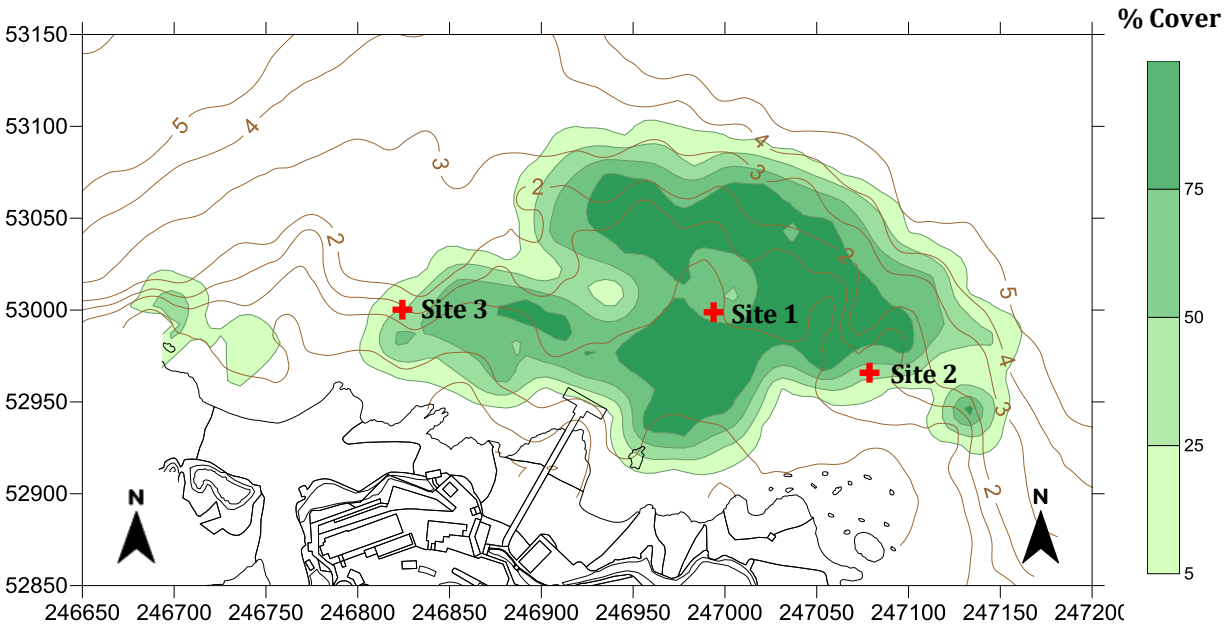


Figure 5. Contour plots of % cover of seagrass, bathymetry (brown contours represent depth in metres below chart datum (C.D)) and locations of dive site central datum markers at Drakes Island.

4.2.1 Attributes Measured Using DDTV

The mean percentage of seagrass cover at Drakes Island is 66%.

The total area of seagrass which qualifies as a bed at Drakes Island is 44,207 m². The total area of seagrass in each category of percentage cover is presented in Table 5 below:

Table 5. Area of seagrass in each Percentage Cover Category

% Cover	Area (m²)
5-25 (Very Sparse)	11,206
26-50 (Sparse)	8,713
51-75 (Moderate)	11,785
76-100 (Dense)	12,503
5-100	44,207

28% of the total area of bed is considered to be 'dense' (76-100% seagrass cover). The greatest cover of seagrass reached 90-95% (see percentage cover raw data plot in Appendix 1). As might be expected the seagrass cover was patchier at the periphery of the bed. The bed is relatively compact but a reduction in percentage cover is apparent to the west where an area of low percentage cover protrudes in to the main area of seagrass from the west. This area of low percentage seagrass cover appears to be matched by an absence of other algae species (see accompanying GIS files).

Drift algae (mainly kelp) was common at stations where seagrass was present and was occasionally abundant. Red algae species were also common, though in low abundance.

There was no evidence of anthropogenic activity within the extent of the bed at Drakes Island. However, a Small Craft Anchorage area does exist within the extent of the bed, see Figure 6.

Small Craft Moorings are also present within 20 m of the bed to the north. These moorings are owned by the Ministry of Defence and are not for public use. The Small Craft Moorings as marked adjacent to the jetty are no longer present.

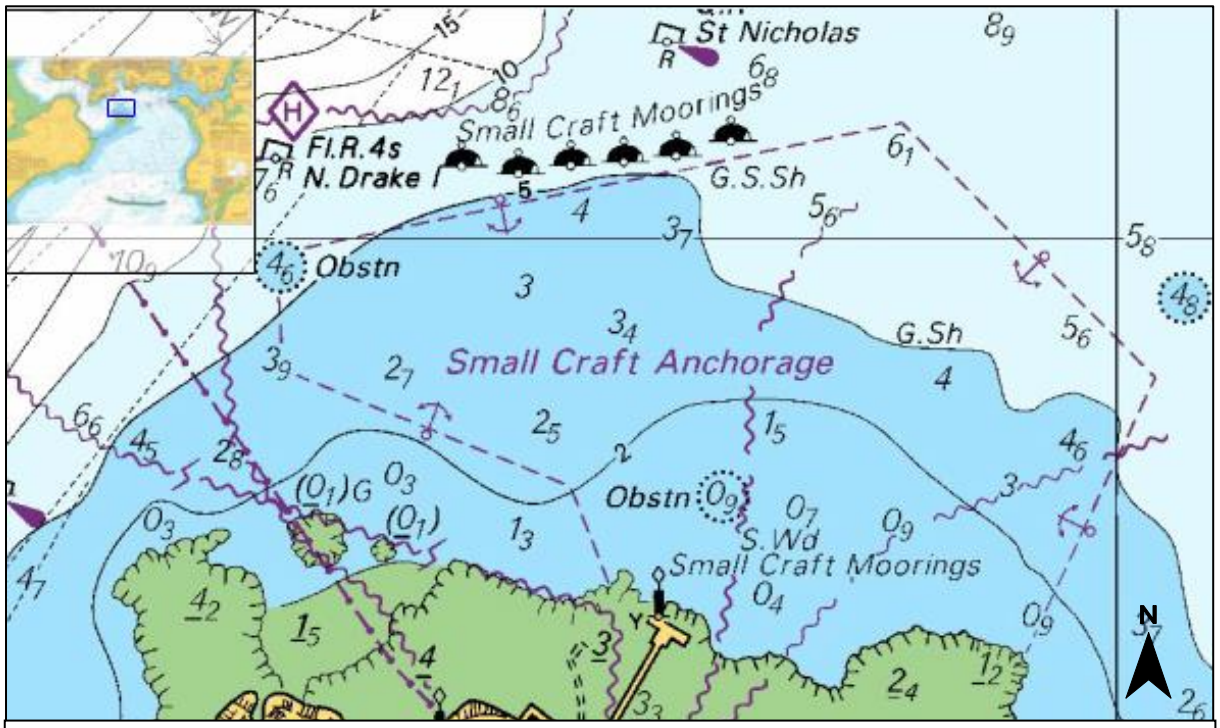


Figure 6. Map showing designated Small Craft Anchorage to the north of Drakes Island

4.2.2 Bathymetry

The seagrass bed at Drakes Island extends from extreme low water (chart datum) to a lower depth limit of 5m below C.D which is at the north-eastern and eastern extent of the bed (190-230m to from the head of the jetty). The greatest percentage cover of seagrass (90-95% cover) was found mainly between the 1m and 2m depth contours within the eastern extent of the bed.

4.2.3 Attributes Measured Using Diving Methods

The attribute data which was collected using diving techniques is summarised in Table 6. Data is presented using mean values and ranges for each dive site. Two of the dive quadrats did not fall directly within the extent of the bed at Drakes Island but were within 5 m of the edge; given the accuracy of differential GPS (within 5 m) the data from these quadrats has been included within the mean and range values.

Table 6. Mean and range values for each attribute measured using diving methods

		Mean and Range Values				
Central Datum/ Transect	**n**	**Number of Plants (per M²)**	**% Leaves Infected**	**Infection Score**	**Epiphyte Score**	**Max Plant Length (Cm's)**
1	8	134 (0-256)	59 (0-100)	0.9 (0-3)	2.1(0-5)	56 (11-111)
2	8 (*1)	108 (0-208)	55 (0-100)	0.8 (0-4)	2.6 (0-5)	49 (13-86)
3	8 (*1)	50 (0-96)	51 (0-80)	1.0 (0-4)	2.3 (0-5)	56 (21-114)
Mean	**-**	**97 (0-256)**	**55 (0-100)**	**0.9 (0-3)**	**2.3 (0-5)**	**54 (11-114)**

* Number of quadrats in which no *Zostera marina* was recorded

Most of the mean attribute values are comparable between sites with the exception of number of plants per m^2 at Site 3, which is roughly half of that of the remaining two sites.

One flowering plant and one plant with attached eggs was observed at Site 1, and no flowering plants or attached eggs were observed at Site 2. At Site 3 a total of six plants were observed to have eggs attached, five of the plants were within the same quadrat. No flowering plants were found at Site 3.

4.3 Cawsand Bay

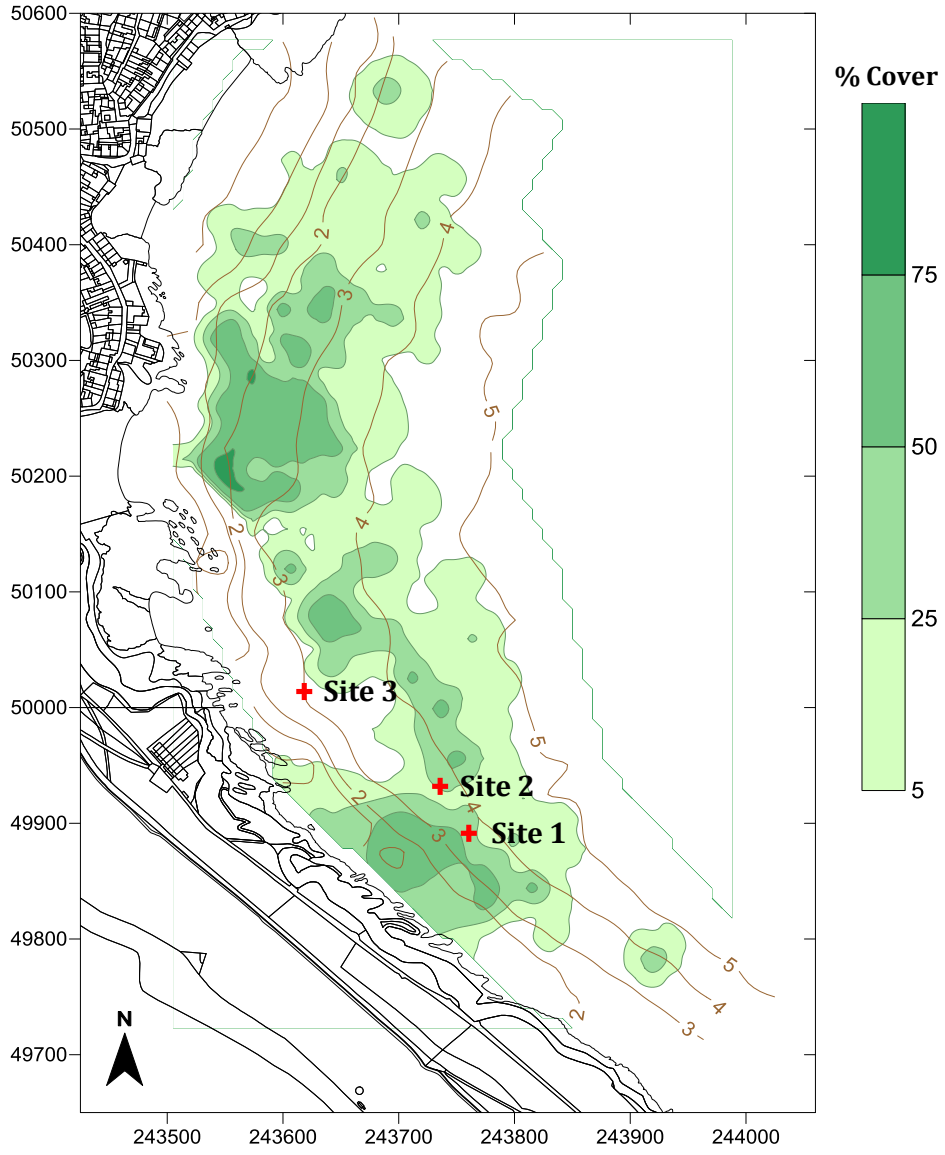


Figure 7. Contour plots of % cover of seagrass, bathymetry (brown contours represent depth in metres below chart datum (C.D)) and locations of dive site central datum markers at Cawsand Bay.

4.3.1 Attributes Measured Using DDTV

The mean percentage of seagrass cover within the extent of the bed at Cawsand Bay is 30%.

The total area of seagrass which qualifies as a bed at Cawsand Bay is 119,739 m^2. The total area of seagrass in each category of percentage cover is presented in Table 7.

Table 7. Area of seagrass in each Percentage Cover Category

% Cover	Area (m^2)
5-25 (Very Sparse)	72,541
26-50 (Sparse)	29,560
51-75 (Moderate)	17,141
76-100 (Dense)	497
5-100	119,739

61% of the total bed area falls within the 'very sparse' category (5-25%). It stretches approximately 700m in length from north to south-southeast and extends to 250m wide in parts. The bed was found to be very patchy in some areas and is somewhat fragmented overall. The greatest percentage cover of seagrass was found just off Cawsand beach where up to 85% cover was recorded, but most of this patch was of moderate percentage cover (50-75%). A second relatively large patch of moderate percentage cover was found at the southern extent of the bed where the seagrass is found closer to the shore.

Occasionally large patches of drift algae were observed, as well as dense abundances of foliose red algae species mainly at the northern and southern ends of the bed.

In terms of anthropogenic activity; netting and mooring were observed within the extent of the bed during the course of the survey. Netting was being carried out over the eastern extent of the bed off Kingsand beach. The nets were visible in the underwater camera footage but did not appear to be interfering with the seagrass itself. Although two moorings were observed within the extent of the bed, definitive evidence of scarring was not apparent. A third mooring chain was observed in seagrass that was <5% cover, but again no definitive evidence of scarring of the seabed was identified. Although Cawsand Bay is known to be a very popular anchoring area for yachts (as the bay provides shelter from prevailing south-westerly winds), no anchored boats were observed during the survey (probably as a result of the poor weather and it being a week-day) and again no definitive evidence of anchor scarring was identified.

No anchor scarring was identified during the survey. However the identification of such impacts was difficult; the bed at Cawsand Bay was large and patchy and given the multiple tasks and observations required by the DDTV operator it was not possible to identify whether all of the patches of low seagrass density were due to natural variability. Although no definitive evidence of negative effects from anchoring activity was apparent, this may not necessarily be the case, further targeted studies would be required in order to make a conclusion.

There were a small number of moorings within the large extent of the bed but no mooring chain scars were observed. It is thought that if present these scars would have been detected during the DDTV survey as the search for such scars can be more targeted aided by the presence of surface markers.

4.3.2 Bathymetry

Seagrass is present in depths from extreme low water (C.D) to a lower depth limit of 5 m below C.D at the southern end, and approximately 4m below C.D. at the northern end. The greatest % cover of seagrass are in depths of 1.5m to 2m below C.D.

4.3.3 Attributes Measured Using Diving Methods

The attribute data which was collected using diving techniques is summarised in Table 8. Data is presented using mean values and ranges for each dive site. Dive Site 3 has no data as the central datum point was not within the extent of the bed.

Table 8. Mean and range values for each attribute measured using diving methods

		Mean and Range Values				
Central Datum/ Transect	**n**	**Number of Plants (per M^2)**	**% Leaves Infected**	**Infection Score**	**Epiphyte Score**	**Max Plant Length (Cm's)**
1	10 (*2)	35 (0-112)	64 (25-100)	0.9 (0-3)	1.9 (0-5)	45 (25-62)
2	16 (*8)	33 (0-144)	20 (0-80)	0.3 (0-3)	1.7 (0-5)	22 (9-50)
Mean	**-**	**34 (0-144)**	**42 (0-100)**	**0.6 (0-3)**	**1.8 (0-5)**	**34 (9-62)**

* Number of quadrats in which no *Zostera marina* was recorded

The number of plants per m^2 and the epiphyte scores at Sites 1 and 2 are comparable, but the remaining mean attribute values are different between the sites. The mean percentage of leaves infected, the infection score and maximum plant length are considerably higher at Site 1. It was thought likely that the infection score and percentage of leaves infected would be correlated with the longer leaf length, as longer leaves tend to be older. However, no significant correlation was detected between these attributes.

One flowering plant was observed at Site 1, but no attached eggs were observed at any of the Cawsand Bay sites.

4.4 Cellars Cove

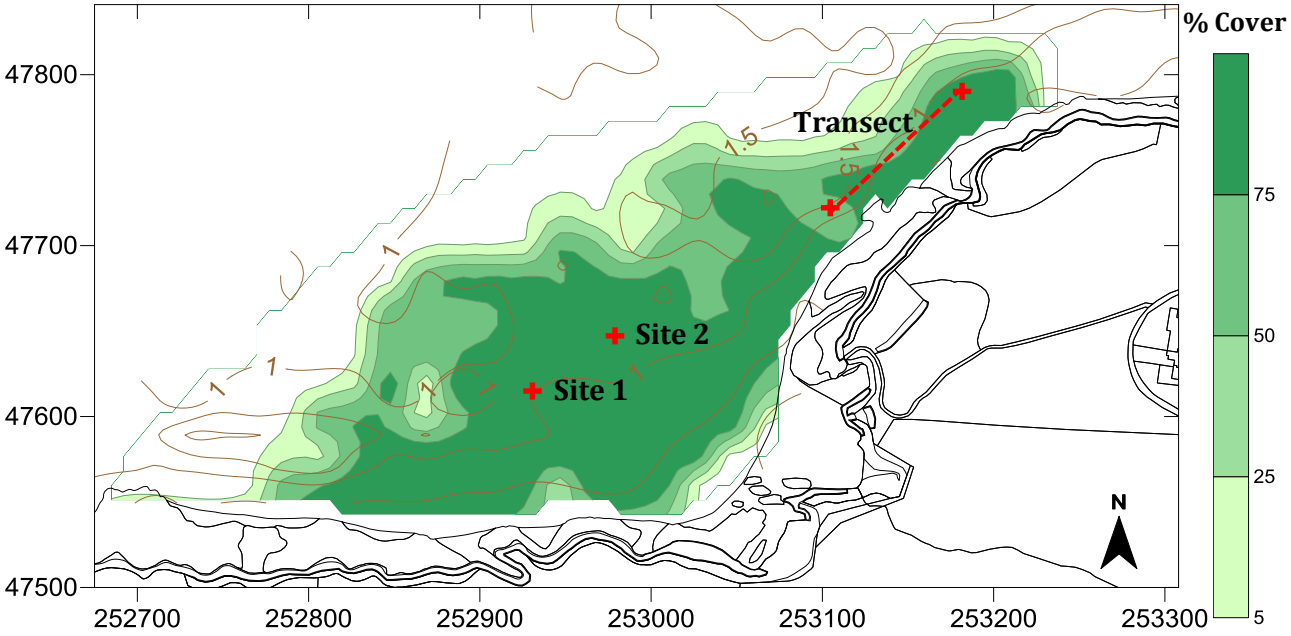


Figure 8. Contour plots of % cover of seagrass, bathymetry (brown contours represent depth in metres below chart datum (C.D)) and locations of dive site central datum markers and the dive transect at Cellars Cove.

4.4.1 Attributes Measured using DDTV

The mean percentage seagrass cover within the extent of the bed at Cellars Cove is 74%.

The total area of seagrass which qualifies as a bed at Cellars Cove is 64171 m². The total area of seagrass in each category of percentage cover is presented in Table 9:

Table 9. Area of seagrass in each Percentage Cover Category

% Cover	Area (m²)
5-25 (Very Sparse)	7,673
26-50 (Sparse)	6,585
51-75 (Moderate)	12,936
76-100 (Dense)	29,815
5-100	57,009

53% of the total area of bed is considered to be 'dense' (76-100% seagrass cover). The highest percentage cover is found within the southern half of the bed where 100% cover is common (See raw data plot in Appendix 1).

Very occasional drifts of algae were observed within the western extent of the bed. At the inshore extent of the bed adjacent to Cellars Cove beach, the seagrass cover quickly declines as *Ulvae spp* and red algae species become dominant. Other algae species were common throughout the bed but not in any abundance.

A small amount of plastic litter that was being carried in the strong tidal current was seen at two target stations. It was however transient and was not effecting the seagrass in any way.

4.4.2 Bathymetry

Cellars Cove is a shallow embayment which does not exceed depths of 2m C.D. The extent of seagrass is mainly between 0 and 1.5m below C.D. The bed is well defined but, as may be expected more patchy seagrass cover is found on the peripheries.

4.4.3 Attributes Measured Using Diving Methods

The attribute data which was collected using diving techniques is summarised in Table 10 below, data is presented using mean values and ranges for each dive site.

Table 10. Mean and range values for each attribute measured using diving methods

		Mean and Range Values				
Central Datum/ Transect	**n**	**Number of Plants (per M²)**	**% Leaves Infected**	**Infection Score**	**Epiphyte Score**	**Max Plant Length (Cm's)**
				Site 2		
1	8	150 (80-224)	51 (0-100)	0.9 (0-4)	2.6 (0-5)	68 (15-142)
2	8	108 (32-192)	51 (0-100)	0.7 (0-3)	1.6 (0-5)	75 (17-140)
Transect	11 (*2)	109 (16-336)	41 (0-100)	0.7 (0-3)	2.7 (0-5)	46 (9-156)
Mean	**-**	**122 (16-336)**	**48 (0-100)**	**0.8 (0-4)**	**2.3 (0-5)**	**63 (9-156)**

* Number of quadrats in which no *Zostera marina* was recorded

The mean attribute values are largely comparable between Sites 1 and 2 (which may be expected given their close proximity), though Site 2 does have a lower mean epiphyte score. The upper and lower range of plants per square metre on the Transect is greater, as is the range for the maximum leaf length which results in a lower mean maximum leaf length on the Transect.

Two flowering plants were observed within the same quadrat on the Transect, but none were recorded elsewhere in Cellars Cove. Cuttlefish eggs were recorded as an additional target note by Natural England divers.

4.5 Red Coves (North and South)

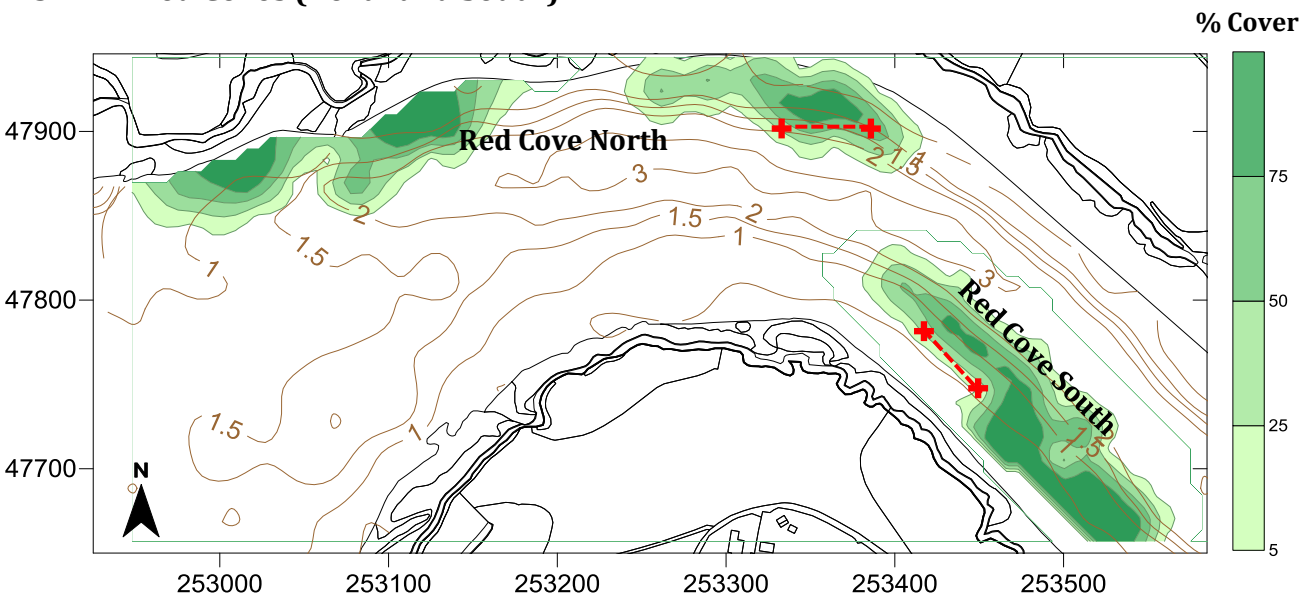


Figure 9. Contour plots of % cover of seagrass, bathymetry (brown contours represent depth in metres below chart datum (C.D)) and locations of dive transects at Red Cove (North and South Coves).

4.5.1 Attributes Measured Using DDTV

The mean percentage seagrass cover within the extent of the bed at Red Cove North is 77%.

The two areas of seagrass at Red Cove North are considered here as one extended bed. The patch of seagrass to the west was not included within the coverage of the 2007 aerial photography and therefore has not been previously mapped fully (although the eastern extent of this patch does appear to have been represented to some degree by the map produced for Red Cove North in 2007[3] . The total area of seagrass which qualifies as a bed at Red Cove North is 26,188 m². The total area of seagrass in each category of percentage cover is presented in Table 11 below:

Table 11. Area of seagrass in each Percentage Cover Category at Red Cove North

% Cover	Area (m²)
5-25 (Very Sparse)	6,050
26-50 (Sparse)	5,470
51-75 (Moderate)	5,874
76-100 (Dense)	8,794
5-100	26,188

The mean percentage seagrass cover within the extent of the bed at Red Cove South is 80%.

The total area of seagrass which qualifies as a bed at Red Cove South is 11,447 m². The total area of seagrass in each category of percentage cover is presented in Table 12.

Table 12. Area of seagrass in each Percentage Cover Category at Red Cove South

% Cover	Area (m^2)
5-25 (Very Sparse)	2,920
26-50 (Sparse)	2,823
51-75 (Moderate)	2,650
76-100 (Dense)	3,054
5-100	11,447

At both beds extreme patchiness caused percentage cover in the camera field of view to change very rapidly from 100% to 0% in some areas. The substrate in the area was very different from that observed elsewhere within the SAC. The seabed consisted of coarse sand, gravel, cobbles and stones between very dense patches of seagrass. The percentage cover contours plotted for Red Cove North were produced from relatively few target stations where cover of 60-100% was recorded (See raw data plots in Appendix 1). There is therefore a lower confidence in the area of seagrass mapped as 'very sparse' or 'sparse' (5-50% seagrass cover) as these contours are an inference by SURFER 10 between two or more sampling points where 0% cover and moderate or dense % cover has been recorded. 56% of the total area of bed at Red Cove North can however be confidently assessed as having moderate or dense % cover.

As at Red Cove North, the percentage cover contours plotted for Red Cove South were produced from relatively few target stations where cover of 20-100% was recorded (See raw data plots in Appendix 1). The bed was seen to extend approximately another 10m inshore of where it was too shallow to manoeuvre the boat safely without damaging the seagrass. Additional target stations were therefore added to the data post-survey to account for these observations. There is greater confidence in the 'very sparse' and 'sparse' contours at Red Cove South given that these contours have been created at least in part by real data. A slightly smaller proportion of the seagrass bed in Red Cove South is categorised as 'moderate' and 'dense' with these categories accounting for 50% of the total bed.

Small isolated patches of dense drift algae were observed in both beds, but only the occasional presence of other algae species was recorded in the north cove.

One boat was anchored in Red Cove North during the survey, and one boat was moored in Red Cove South, though no definitive evidence of damage to the seagrass beds from these activities was evident. This failure to identify impacts resulting from anchoring activity is likely to be compounded by the longer leaf length found in the Red Cove beds, which when laying across the seabed in the strong currents inevitably covers a larger area and may conceal scars to some extent. Some minor transient litter was also observed being carried by the tide in Red Cove North.

4.5.2 Bathymetry

Both beds extend from chart datum down to depths of 2.5m below C.D. The 3m depth contour represents the main channel of the Yealm, where very strong currents and scouring are likely to preclude the establishment of seagrass.

4.5.3 Attributes Measured Using Diving Methods

The attribute data which was collected using diving techniques is summarised in Table 13, data is presented using mean values and ranges for each dive site.

Table 13. Mean and range values for each attribute measured using diving methods

		Mean and Range Values				
Central Datum/ Transect	**n**	**Number of Plants (per M^2)**	**% Leaves Infected**	**Infection Score**	**Epiphyte Score**	**Max Plant Length (Cm's)**
Red Cove North	11 (*4)	57 (0-144)	55 (0-80)	0.8 (0-3)	1.9 (0-5)	58 (15-101)
Red Cove South	10 (*1)	134 (0-240)	56 (0-100)	1.0 (0-5)	1.7 (0-5)	50 (9-78)
Mean	**-**	**96 (0-240)**	**56 (0-100)**	**0.9 (0-5)**	**1.8 (0-5)**	**54 (9-101)**

* Number of quadrats in which no *Zostera marina* was recorded

The mean attribute values are largely comparable between Red Cove North and Red Cove South with the exception of plants per m^2 which is significantly lower at Red Cove North.

Two flowering stems and 5 plants with attached eggs were observed Red Cove South. No flowering plants or attached eggs were observed in the north cove.

Natural England took additional samples from Red Cove North however and recorded two Hydroids; *Obelia geniculata* and *Kirchenpauria pinnata*. Two species of stalked jellyfish, both of which are Biodiversity Action Plan priority species were also recorded; *Haliclystus auricula* and *Lucernariopsis campanulata*.

4.6 Tomb Rock

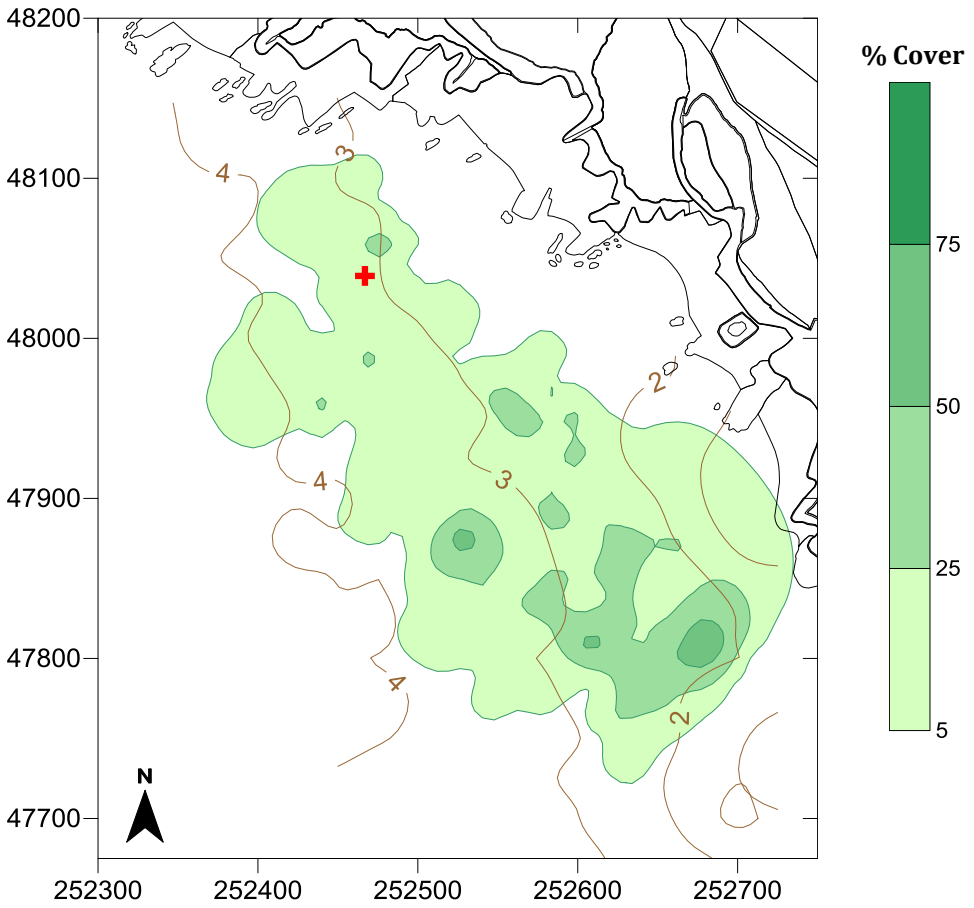


Figure 10. Contour plots of % cover of seagrass and bathymetry (brown contours represent depth in metres below chart datum (C.D)), in relation to location of dive site at Tomb Rock.

4.6.1 Attributes Measured Using DDTV

The mean percentage seagrass cover within the extent of the bed at Tomb Rock is 19%.

The total area of seagrass which qualifies as a bed at Tomb Rock is 66321 m². The total area of seagrass in each category of percentage cover is presented in Table 14 below:

Table 14. Area of seagrass in each Percentage Cover Category

% Cover	Area (m²)
5-25 (Very Sparse)	55,423
26-50 (Sparse)	10,083
51-75 (Moderate)	815
76-100 (Dense)	0
5-100	66,321

Almost 85% of the total area of bed is considered to be 'very sparse' (5-25% seagrass cover), and the majority of the remaining area is 'sparse'. Despite the sparse nature of the bed at Tomb

Rock, its extent was significantly greater than expected given the initial reports that the bed was approximately 50m in length and narrow. The bed stretches up to 400m along the coast and spans 165m at the widest part.

Generally, the bed was very patchy and the percentage cover in the field of view altered significantly in a short space of time in some places. Where present, the seagrass found closest inshore was dense. The main core of the bed where a maximum percentage cover of 65% was observed is to the southeast (See the raw data plot in Appendix 1).

The seagrass at Tomb Rock generally had a very 'clean' appearance with very little drift algae or other algae species.

One small piece of litter was seen during the survey which was not affecting the seagrass. Two yachts were anchored within the extent of the bed and had to be manoeuvred around during the survey. No definitive evidence of damage to the seagrass beds from these activities was evident, though as was found at Cawsand Bay, the extensive and patchy nature of the bed at Tomb Rock made it difficult to determine whether all patches were due to natural variation in density, or whether some patches were as a result of past anchor scars. Attempts to determine whether localised impacts from anchoring activity are occurring was made more difficult by the fact that anchored vessels have to be avoided during the survey to prevent risk of entanglement of camera equipment.

4.6.1 Bathymetry

The seagrass extends from extreme low water to just beyond the 4m depth contour. The patch of highest percentage cover lies 2-3m below C.D. The south-easterly extent of the bed clearly abuts the sand bar at the mouth of the Yealm.

4.6.2 Attributes Measured Using Diving Methods

Given that the dive at Tomb Rock was largely intended to be exploratory, only one quadrat fell within the extent of the seagrass bed and that quadrat was very much on the periphery of the bed. The mean of each attribute measured within the quadrat is presented in Table 15 below (for interest), but caution should be applied when considering this data given the limits of its source raw data:

Table 15. Mean (and range) values for each attribute measured using diving methods

		Mean (and Range)				
Central Datum/ Transect	**n**	**Number of Plants (per M²)**	**% Leaves Infected**	**Infection Score**	**Epiphyte Score**	**Max Plant Length (Cm's)**
Tomb Rock	1	240*	29 (0-67)	0.4 (0-2)	1.1 (0-3)	34 (13-48)

* This figure is the actual number of plants within the single quadrat surveyed

One flowering stem was counted within the quadrat.

4.7 Jennycliff North

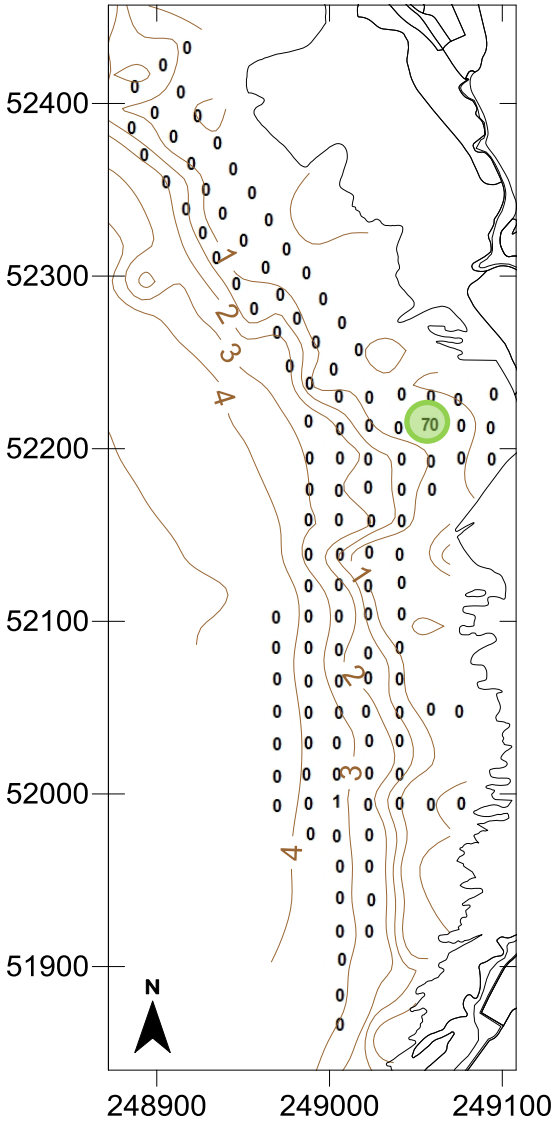


Figure 11. % cover of seagrass raw data plotted alongside bathymetry contours that represent depth in metres below chart datum (C.D) at Jennycliff North. 70% cover was recorded at single target station (highlighted green).

4.7.1 Attributes Measured Using DDTV

The mean percentage seagrass cover within the extent of the bed at Jennycliff North is 70%. However, the total area of seagrass which qualifies as a bed at Jennycliff North is extremely small, and was observed only at a single station where 70% cover was recorded close inshore just off Jennycliff beach (See raw data plot in Appendix 1).

Many of the stations were found to be occupied by kelp. *Ulvae spp* were also frequently observed alongside red algal species. A single plant of the invasive species *Sargassum muticum* was observed amongst fucoids at the station closest to Jennycliff beach in extremely shallow water.

Although Jennycliff is known to be a popular yacht anchorage in the summer months no anchored yachts were seen in the bay during the survey and no other anthropogenic effects were observed.

No diving survey was carried out at Jennycliff North.

4.7.2 Bathymetry

The patch of seagrass is present between extreme low water (0m C.D) and 1m below C.D.

4.8 Jennycliff South

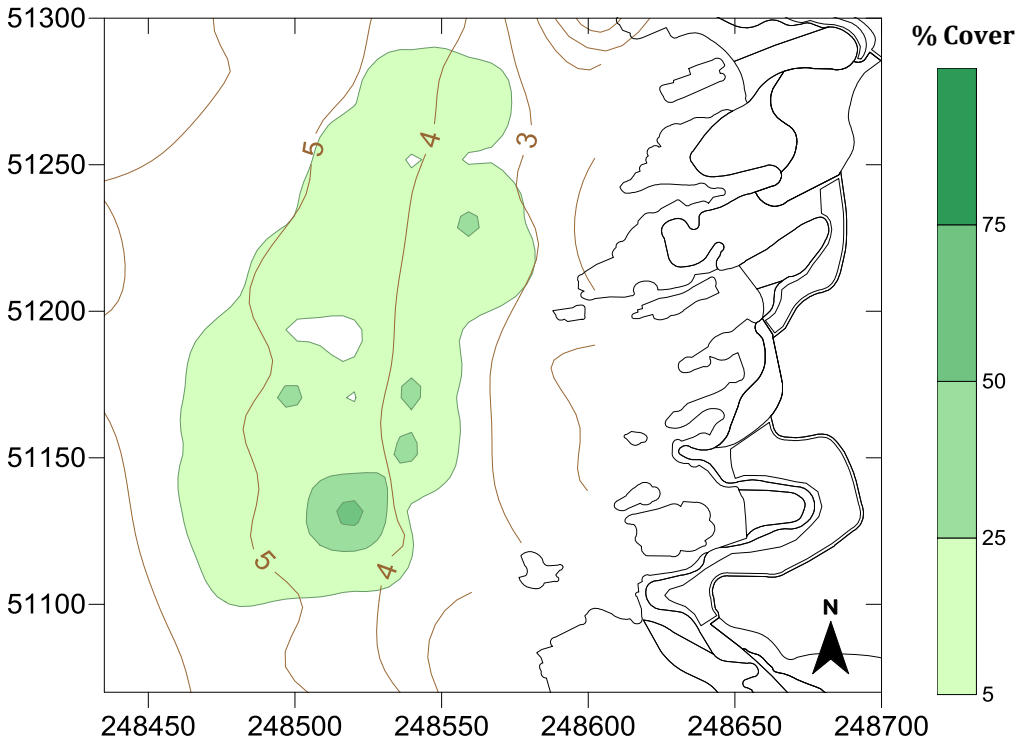


Figure 12. Contour plots of % cover of seagrass and bathymetry (brown contours represent depth in metres below chart datum (C.D)) at Jennycliff South.

4.8.1 Attributes Measured Using DDTV

The mean percentage seagrass cover within the extent of the bed at Jennycliff South is 21%.

The total area of seagrass which qualifies as a bed at Jennycliff South is 14378 m^2. The total area of seagrass in each category of percentage cover is presented in Table 16 below:

Table 16. Area of seagrass in each Percentage Cover Category

% Cover	Area (m^2)
5-25 (Very Sparse)	13,554
26-50 (Sparse)	768
51-75 (Moderate)	56
76-100 (Dense)	0
5-100	14,378

The bed at Jennycliff Bay South was very patchy with % cover of generally no more than 30%, though 65% was observed at a single station (See raw data plot in Appendix 1). 94% of the bed is considered 'very sparse'. Barren sand (which appeared to be an ideal substrate for seagrass) was observed at a number of stations in the survey area (this observation was also made by Bugg, A. 2004 [5]). Other algae species and drift algae were sparse. Kelp species were found to occupy the shallower waters that fringed the rocky shore to the east where no seagrass was present.

No evidence of anthropogenic effects was observed in the bed.

No diving survey was carried out at Jennycliff South.

4.8.2 Bathymetry

The bed is present in depths from 3m below C.D to just over 5m below C.D.

4.9 Firestone Bay

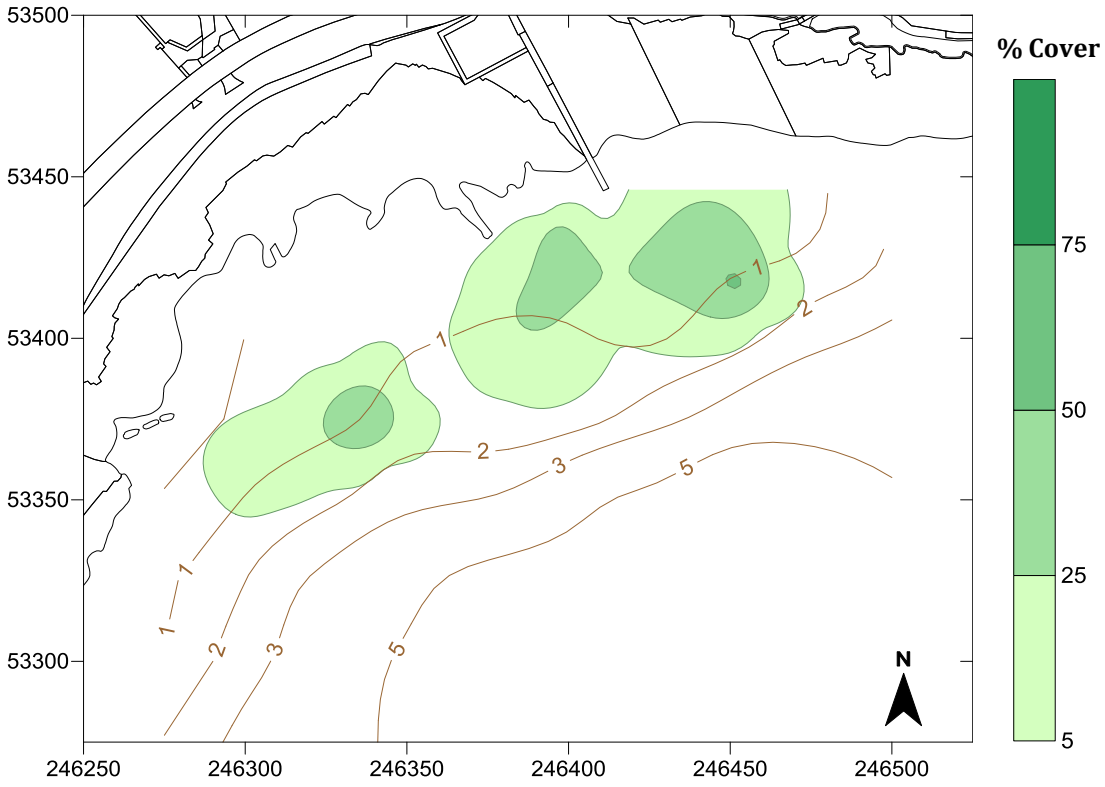


Figure 13. Contour plot of % cover of seagrass at Firestone Bay

4.9.1 Attributes Measured Using DDTV

The mean percentage seagrass cover within the extent of the bed at Firestone Bay is 21%.

The total area of seagrass which qualifies as a bed at Firestone Bay is 7607 m^2. The total area of seagrass in each category of percentage cover is presented in Table 17.

Table 17. Area of seagrass in each Percentage Cover Category

% Cover	Area (m^2)
5-25 (Very Sparse)	5,691
26-50 (Sparse)	1,901
51-75 (Moderate)	15
76-100 (Dense)	0
5-100	7607

The bed at Firestone Bay is patchy and formed by two main areas of seagrass which lay either side of the main approach to the shore. 75% of the bed is considered 'very sparse' and the remainder mostly 'sparse'. Percentage cover of up to 50% and 55% were recorded on the western and eastern side of the bay respectively (See raw data plot in Appendix 1), but these patches are very limited in size.

Other algae species, mainly foliose red algae, were commonly reported at those stations where seagrass was present.

No evidence of anthropogenic effects was observed in the bed.

No diving survey was carried out at Firestone Bay.

4.9.2 Bathymetry

The bed extends from extreme low water (0m C.D) down to the 2m C.D contour.

5 DISCUSSION

5.1 Comparison Between Seagrass Beds in Plymouth Sound SAC

Tomb rock has been omitted from the comparisons of attributes measured using diving methods because only one quadrat containing seagrass was surveyed. Although some inferences have been drawn from comparing the diving measured attributes between beds, these should be treated tentatively given the relatively limited sampling effort from which the data has been derived. Furthermore, given that the sampling effort was also variable between beds (i.e. mean values have been drawn from different numbers of quadrats) the accuracy of the data from each bed will also be variable.

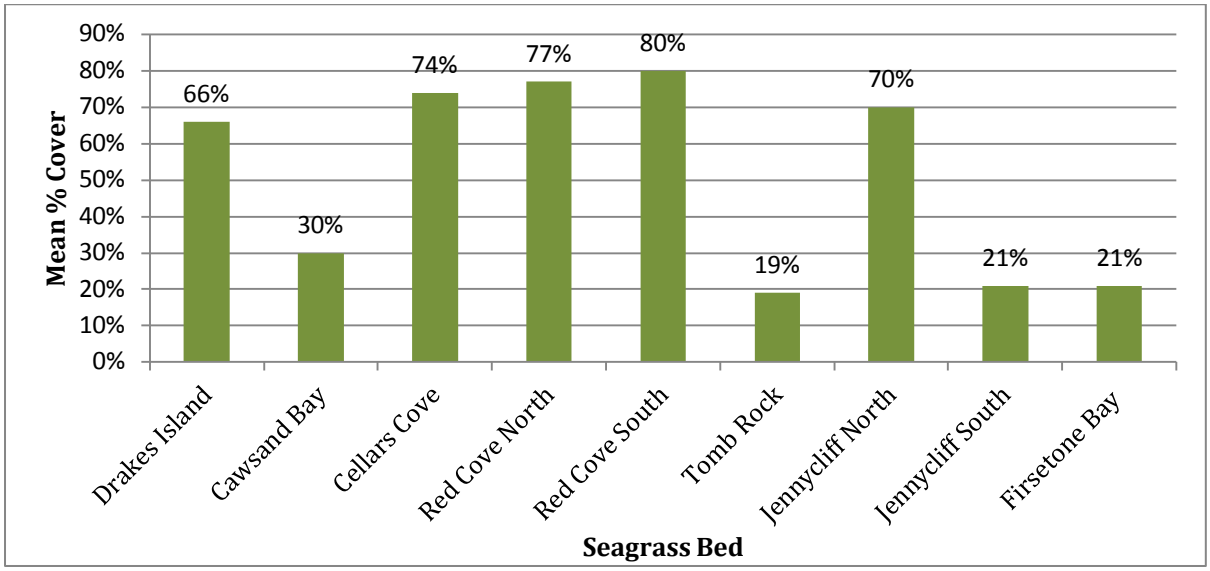


Figure 14. Mean percentage cover at all seagrass beds in Plymouth Sound and Estuaries SAC

The mean percentage cover is greatest at Red Cove South (80%), but closely followed by Red Cove North and Cellars Cove. The percentage cover at Tomb Rock, Jennycliff South and Firestone Bay are all comparably low at around 20%.

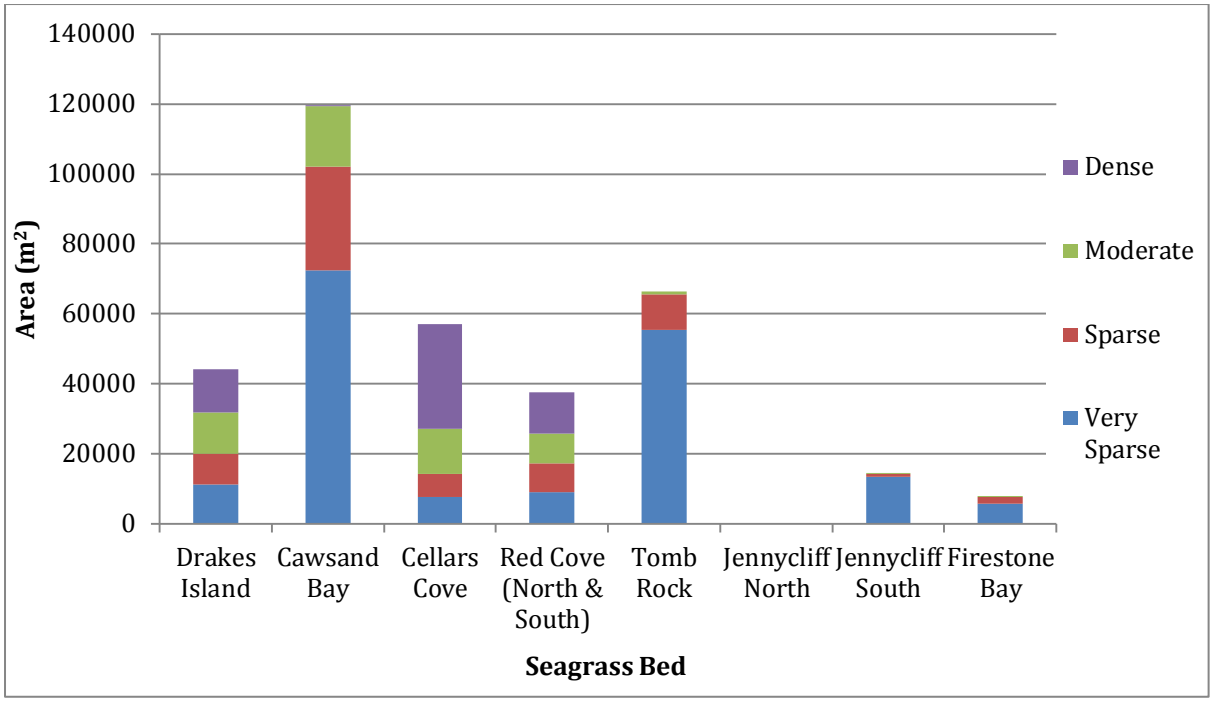


Figure 15. Total area and area of each category of percentage cover at all seagrass beds in Plymouth Sound and Estuaries SAC

The largest beds are Cawsand Bay and Tomb Rock, but a large proportion of these beds are made up of sparse seagrass. Cellars Cove has the largest area of 'dense' seagrass, and therefore arguably may be considered the most substantial bed within Plymouth Sound and Estuaries SAC.

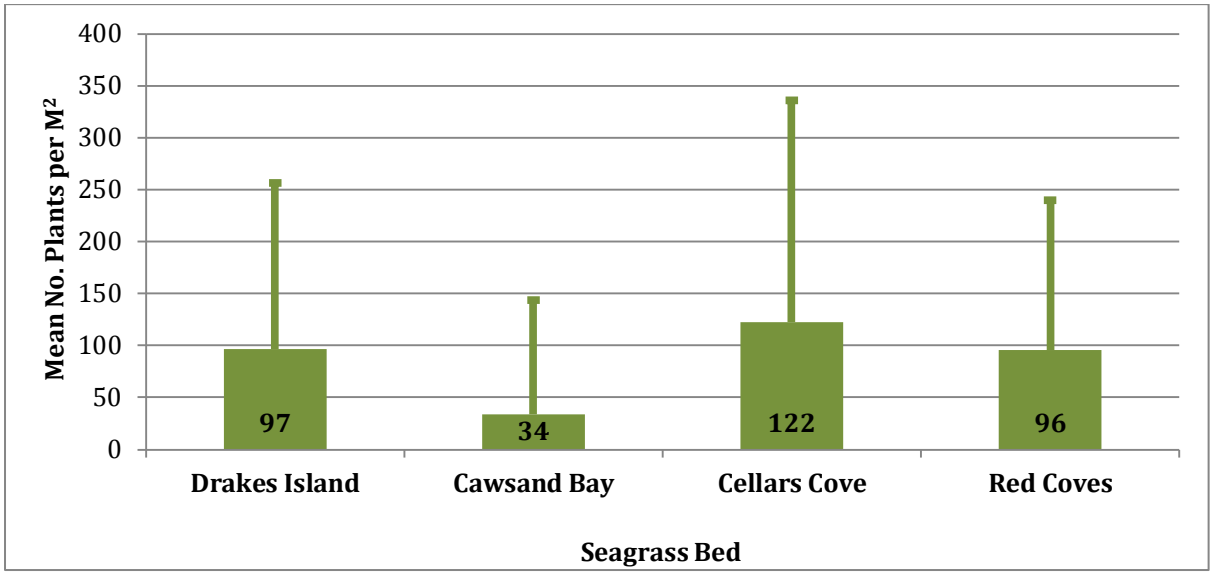


Figure 16. Mean (and maximum represented by range bars) number of plants per m^2 at main seagrass beds in Plymouth Sound SAC (the minimum number of plants was zero at all beds).

The greatest number of plants within an individual quadrat was found in Cellars Cove, but the greatest mean number of plants per m^2 was recorded at Red Cove South.

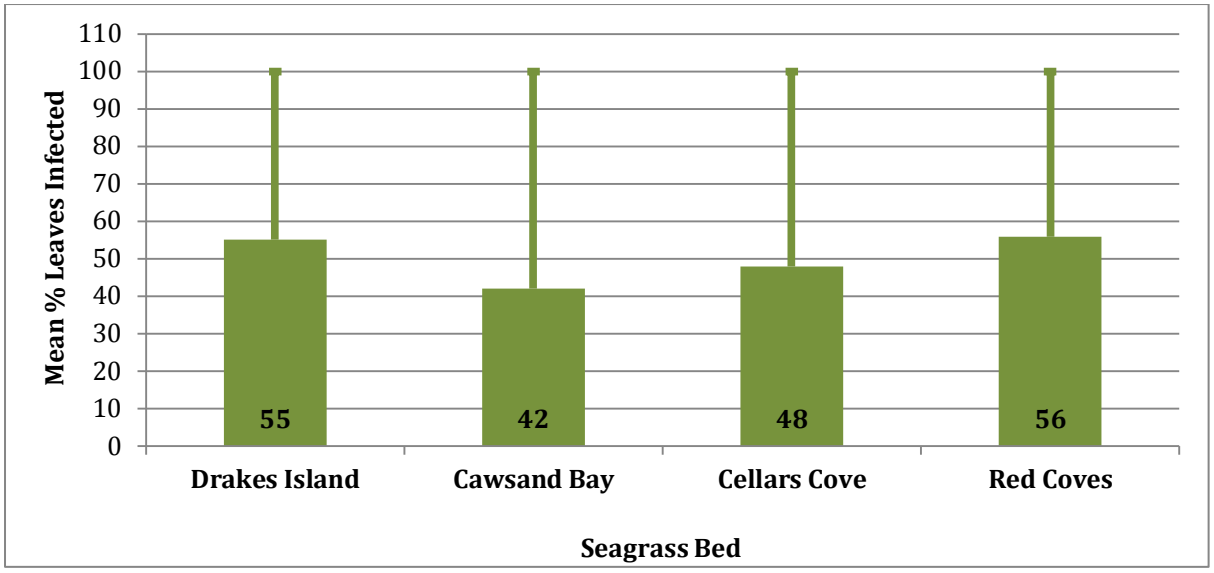


Figure 17. Mean (and maximum represented by range bars) % leaves infected at main seagrass beds in Plymouth Sound SAC (minimum number of plants was zero at all beds)

The percentage of leaves infected was broadly similar between all sites assessed.

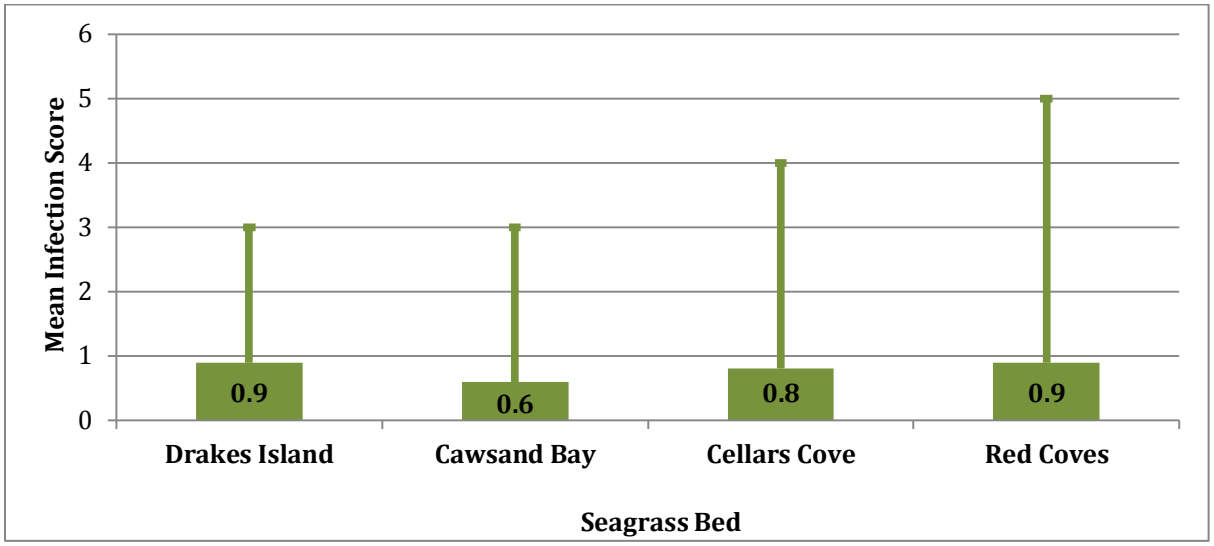


Figure 18. Mean maximum (and maximum represented by range bars) infection score at main seagrass beds in Plymouth Sound SAC (minimum score was zero at all beds)

The infection score was greatest at Red Cove South which also had the greatest mean percentage cover and mean number of plants per m^2 values. Cawsand Bay has the lowest infection score; the bed at Cawsand Bay also has the lowest number of plants per m^2 and a large proportion of very sparse percentage cover.

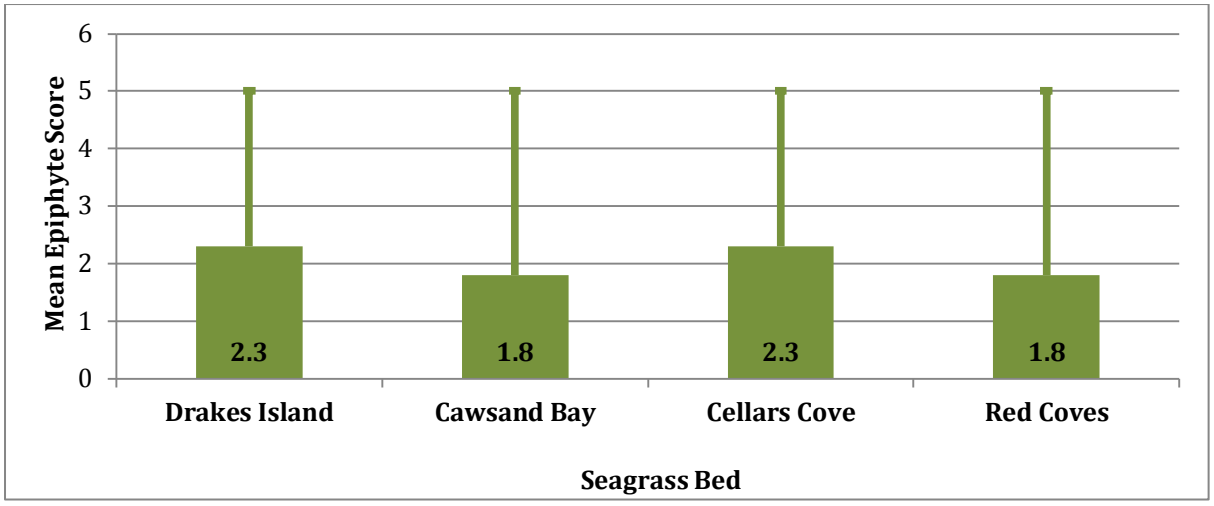


Figure 19. Mean (and maximum represented by range bars) epiphyte score at main seagrass beds in Plymouth Sound SAC (minimum score was zero at all beds)

The largest epiphyte scores were recorded at Cellars Cove and Drakes Island, two beds which also had the greatest area of 'dense' seagrass cover.

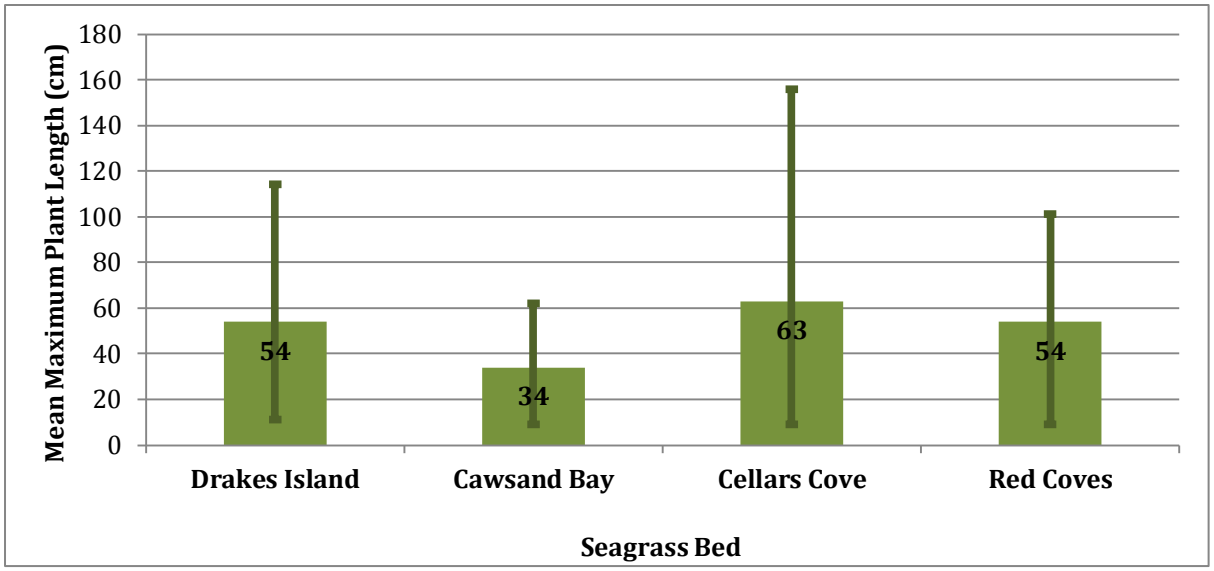


Figure 20. Mean maximum plant length (and range represented by range bars) at main seagrass beds in Plymouth Sound SAC

The longest plant lengths were recorded at Cellars Cove, the shortest at Cawsand Bay, the remaining beds had similar mean plant lengths.

The mean percentage leaf infection and mean epiphyte scores are relatively constant between all beds assessed. The remaining attributes that were measured using diving methods do appear to vary between beds to some degree, the most significant variation is in the number of plants per m^2.

5.2 Temporal Comparisons/Condition Assessment

The *Zostera marina* beds in Plymouth Sound SAC have been the subject of a number of studies, each of which have employed a number of methods and looked at a variety of different

attributes/parameters. Those studies which are most relevant to the Condition Assessment are listed in Table 18.

Table 18. Historical studies key in the condition assessment of the seagrass in Plymouth Sound SAC

Author(s)	Year	Seagrass Beds Studied	Attributes/Parameters measured	Methods employed
Irving, R.A. *et al*	2010 [2]	Drakes Island Cawsand Bay Cellars Cove Red Coves	Number of plants, mean length of 3 longest leaves, % cover of macroalgae (drift and attached), epiphyte score, 'browning' score, nutrient status (green algal matt).	Diving
Irving, R.A. *et al*.	2007[3]	Drakes Island Cawsand Bay Cellars Cove Red Coves	Extent, distribution and spatial configuration*	Desk based analysis of aerial photographs taken in 2006 with some ground-truthing using drop down camera
Bugg, A. (Seasearch)	2004[5]	Jennycliff South	Extent, density, average length of shoot, % epiphyte cover, presence of algal matt, presence of hydroids	Diving

The different methods employed in previous studies (and where relevant the associated limitations) make the direct comparison of results here difficult. This issue is compounded by the fact that different monitoring locations were applied within the beds, many of which display a patchy spatial configuration. Consequently it is only possible to make broad comparisons with previous studies data.

5.2.1 Limitations of Data

A number of limitations were encountered when directly comparing data for all attributes measured, these are described:

- **Seagrass Percentage Cover and Extent**

The confidence applied to the results produced by Irving *et al*, 2007 was very variable between beds. The variation in accuracy was as a result of poor image quality at some beds, problems with GPS positioning accuracy during ground-truthing surveys and the inability to define extents in deeper water from the images. As such, the definitive extent of beds was difficult to define at all beds except Cellars Cove. The extent of Drakes Island was mapped with confidence

in shallower water but was less well mapped in deeper water where the image quality deteriorated and where there were few ground-truthing points.

A drawback to consider when comparing the 2007 seagrass cover and extent data with the 2012 data is that the coverage categories reported in 2007 (very sparse, sparse, moderately dense and dense) were not defined against percentage cover, but against photographs which were used as guides in the categorisation process. Furthermore only the areas of 'moderately dense' and 'dense' beds were calculated. Because percentage cover was not assigned to the categories these areas of 'moderately' dense and 'dense' seagrass can only be broadly compared with the areas of seagrass categorised as 'moderate' and 'dense' in this study.

Similar issues are encountered when comparing the current data with the study by Bugg, A. at Jennycliff South in 2004[5]. The 2004 study measured extent to some degree and density, however, no indication of how density was defined in this study was provided, and it is not known if the 5% cover threshold was applied in defining the extent of the bed.

A final point to consider when comparing data is that the aerial photographs used to determine extent in 2006 were taken in the month of June; the DDTV survey in 2012 was carried out between August and September, much later in the growing season. Therefore any differences observed in extent may be at least in part due to the different stage of the growing season during which monitoring was carried out.

- **All Diving Measured Attributes**

The main limitation in making comparisons for all diving-measured attributes is that the dive sites and/or transects were different within each bed studied, and as such, particularly in patchy beds, differences have been observed which cannot definitively indicate changes in bed attributes (see section 5.2.2.2 and 5.2.2.3). An additional factor to consider is that in 2012 a much smaller sample size was used (0.0625 m^2) compared to the standard sample size (0.25 m^2) which was adopted in 2009. Furthermore, fewer quadrats were sampled in 2012 (with the exception of surveys at Red Cove) and therefore the overall sample size in 2012 is comparatively small. For example in 2009 the total area of bed sampled at Drakes Island equated to 9 m^2, in 2012 the area was just 1.2m^2. Although the post-dive analysis will have provided more precise data for 2012, the accuracy of the data (.i.e. how well the data represents the total population of *Zostera marina* at a given bed) at all surveyed seagrass beds is likely to be comparatively low.

A further but less pertinent point to consider is that different methods were adopted; data was collected in situ in 2009 (with the exception of 'browning score' and epiphyte cover data), whilst plants were removed for post dive analysis in 2012. In addition, the 2012 survey was carried out in the month of August, a month later in the seagrass growing season than the 2009 survey. Therefore any differences in attributes measured may be due at least in part to the different stages within the seagrass growing season during which monitoring was carried out.

Number of Plants per m^2 and Mean Maximum Plant Length

Data relating to plant density and mean maximum plant length are comparable to some degree between the study by Irving *et al*, carried out in 2009 and the survey by Natural England in 2012. The main limitations in making comparisons are those which to relate to all the diving

measured attributes as described above. However, there are some differences in how the mean longest leaf length was measured. Irving *et al*, 2010 measured the longest leaf of three random shoots/plants within each quadrat (in the field) and took the mean to provide a value for mean longest leaf length; within this study Natural England divers measured the longest leaf from each plant post-dive.

Percentage of Leaves Infected, Infection Scores and Epiphyte Scores

The percentage of leaves infected and infection scores was reported by Irving *et al*, 2010 as 'browning' (the 'browning' was considered likely to be caused by cell breakdown but which may have also indicated the presence of *Labyrinthula macrocystis*).

Different methods to those used in 2012 were applied when measuring all three of these attributes; specifically, in 2009 only the terminal 10 cm of leaves were assessed in situ (the full leaf length was assessed post-dive in 2012). In addition, the scoring system was different to that applied by Natural England divers for both infection and epiphyte scores.

Given the variables in methods and limitations in data produced by the 2010 and 2012 studies, it is not possible to make useful comparisons between the infection cover/score data. It had been suggested by Natural England surveyors that the percentage of leaves infected in 2009 may be an over-estimate because infection and epiphyte growth is expected to be found more frequently on older, longer leaves. However, this does not appear to be reflected in the data and no significant correlation between mean longest leaf length and percentage of leaves infected was found during this study.

Bugg, 2004 assessed the presence of epiphytes at Jennycliff South in terms of total percentage cover within each quadrat, therefore a comparison with 2012 epiphyte score data here would not be useful either.

Temporal comparisons of extent, number of plants per m^2 and mean maximum plant lengths are described in sections 5.2.2.1, 5.2.2.2 and 5.2.2.3 respectively. A summary of comparisons of mean data for all attributes (both workable and unworkable) are presented in Table 19, together with a recommendation for the attribute condition status (and confidence level) where possible.

5.2.2 Comparisons

5.2.2.1 Extent and Percentage Cover

Seagrass extent maps from the Irving *et al*, 2007 report have been extracted, geo-referenced and plotted alongside 2012 percentage cover contours in this section (with the exception of Tomb Rock that was not studied in 2007 and Firestone Bay where no bed was detected in the aerial image). (Note that the red box in each of the Figures indicates the 100m x 100m subset that was applied to the landscape configuration assessment by Irving *et al*, 2007 which is not relevant here).

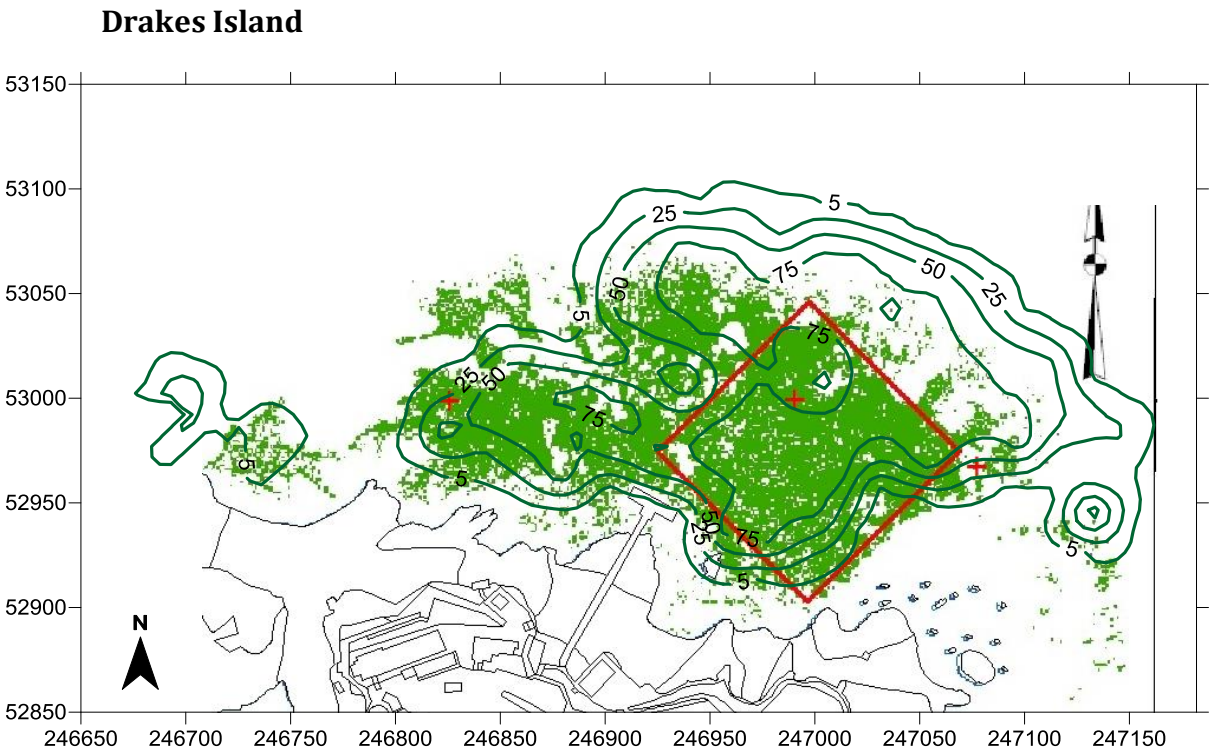


Figure 21. Seagrass extent at Drakes Island mapped by Irving *et al*, 2007 plotted alongside 2012 % cover contours

The bed at Drakes Island was not found to extend in a northwest direction as far as expected given the results presented by Irving *et al*, 2007. The bed falls short of the westerly to north-westerly distribution previously reported by 60 to 80 metres. It is not known whether this represents a real loss in extent or whether it represents an inaccuracy in the 2007 data, which overall was assessed as being 69% accurate at Drakes Island.

The bed does appear to have extended approximately 50m further to the northeast. It is probable that an extension in an area of 'dense' cover of seagrass has in fact occurred at Drakes Island; however, it is also possible that the greater depth at the outer extent may have been a contributory factor in the failure of more sparse seagrass being picked up by the aerial image in 2006, resulting in the northeast extent being underestimated by Irving *et al*, 2007.

Cawsand Bay

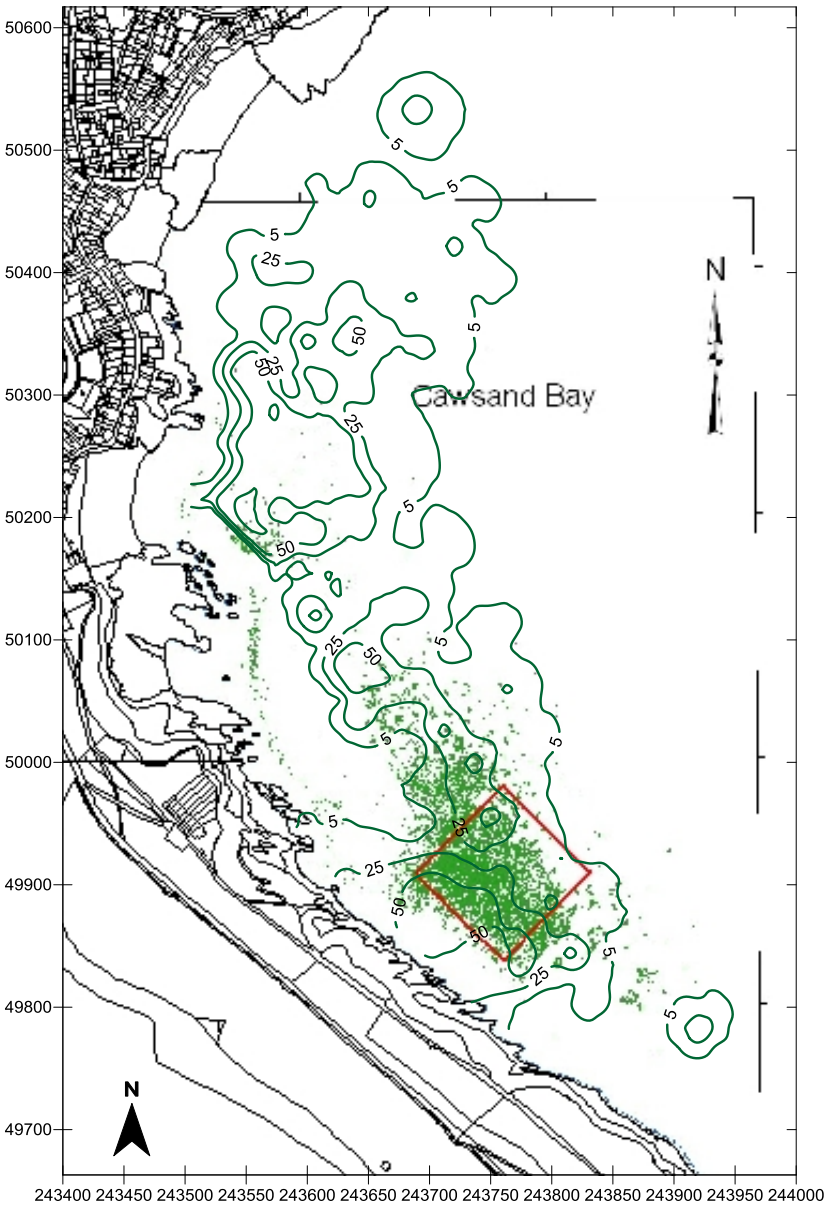


Figure 22. Seagrass extent at Cawsand Bay mapped by Irving *et al*, 2007 plotted alongside 2012 % cover contours

The image used in the 2007 study suffered from reflection issues making subsequent processing difficult; furthermore little ground-truthed data was collected resulting in a low confidence in the boundaries of the bed. As such it is not possible to conclusively determine whether the extent of the bed at Cawsand Bay has changed over time.

The extent of the bed at Cawsand was found to be significantly greater than previously reported, extending northeast by over 350m further than expected. This difference is caused by the fact that the aerial photograph used in the 2007 study did not encompass the area north of Cawsand beach. The bed also extends further east (offshore) than previously thought, although again this is likely to be at least in part due to the failure of the aerial image to detect the seagrass in deeper waters.

Cellars Cove

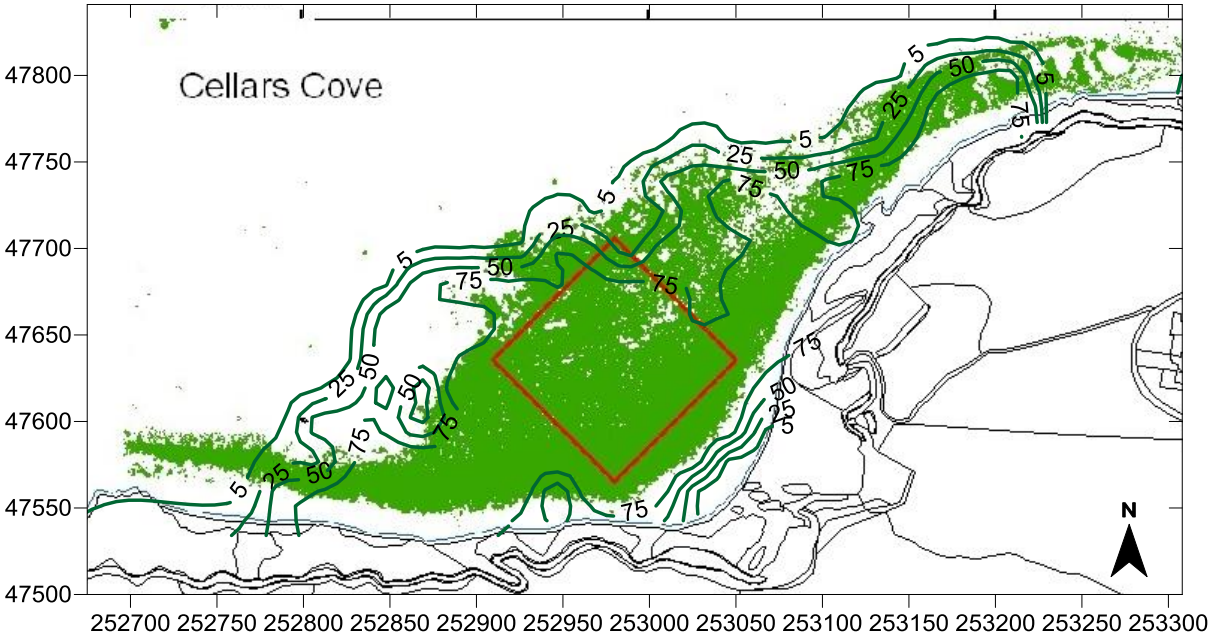


Figure 23. Seagrass extent at Cellars Cove mapped by Irving *et al*, 2007 plotted alongside 2012 % cover contours

The extent of the bed at Cellars Cove was generally in-line with that reported in 2007 by Irving *et al*. However, on the western side of the bed the near-shore distribution recorded during this survey was approximately 80m less than that reported in 2007, though the north-western distribution of the bed was approximately 60m greater (the lower cover of seagrass appears to have not been detected in 2007) resulting in a greater area of extent overall in 2012 .

The aerial image used in the 2007 study was very good (overall accuracy 95%). As such it can be broadly concluded that the extent of the bed at Cellars Cove has not changed significantly from 2006 (the year the aerial images were taken for the 2007 study).

Red Cove North and South

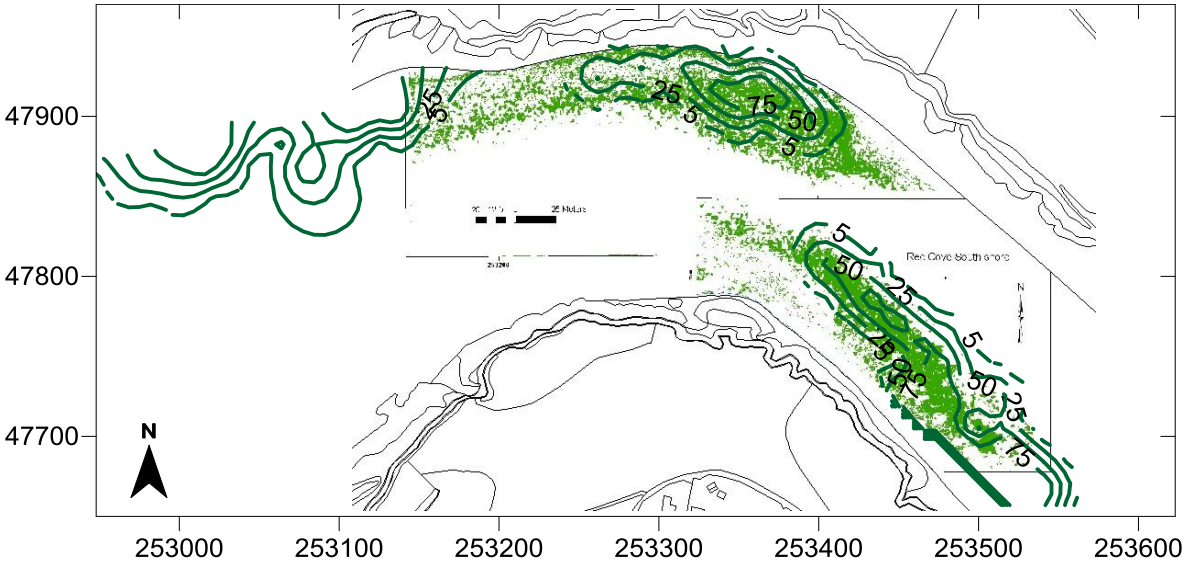


Figure 24. Seagrass extent in Red Cove mapped by Irving *et al*, 2007 plotted alongside 2012 % cover contours

The overall accuracy of the processed aerial images in Red Cove reported in 2007 were 78%. There was a large amount of macroalgae mixed with the 'dense' seagrass making it difficult to distinguish between the two. Consequently detailed comparisons with the 2012 would be ambiguous. The beds do however appear to be broadly similar in extent, though the westerly extent of seagrass in Red Cove North is represented as being much greater in 2012, though this is due to the fact that the 2006 aerial image did not encompass the western area.

A broad comparison of the two studies can conclude that the seagrass beds in Red Cove North and South have not changed significantly since 2006.

Jennycliff North

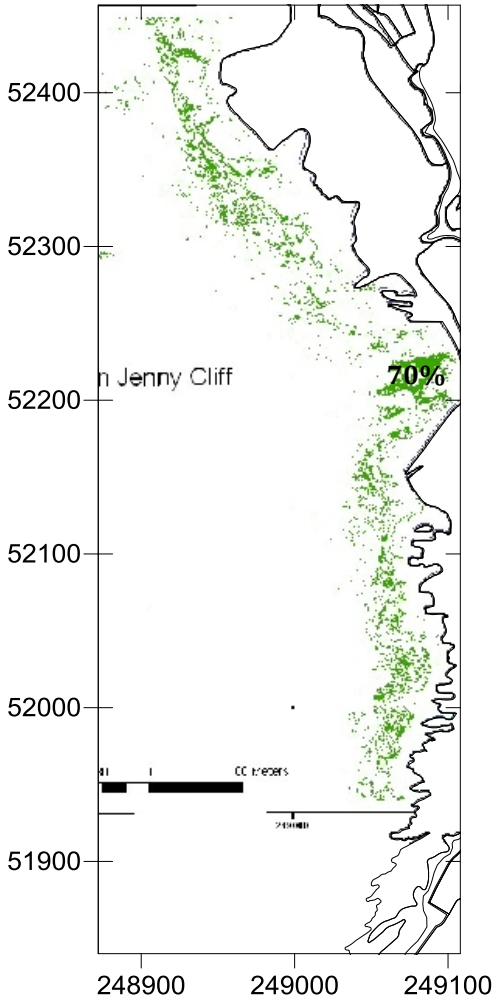


Figure 25. Seagrass extent at Jennycliff North mapped by Irving *et al*, 2007 plotted alongside a single target station in 2012 where 70% seagrass cover was recorded.

No seagrass was found during the 2007 ground-truthing survey, so there was no confidence that anything classified as seagrass in the image was actually seagrass. However, having studied the aerial photography and applying familiarity with other images where seagrass was confirmed, some confidence was applied by Irving *et al*, 2007 to the 'dense' patch of seagrass mapped just off Jennycliff beach (but the boat used when ground truthing was not able to access the shallow water to confirm this).

If this patch had been confirmed it would have been consistent with that observed in 2012. Given that the unconfirmed area of 'dense' seagrass mapped off Jennycliff beach using 2006 aerial photography is in exactly the same location as that which has been confirmed in 2012, it can be concluded with some confidence that the extent of the bed at Jennycliff North is limited to a small area and that it has not altered greatly since 2006.

Jennycliff South

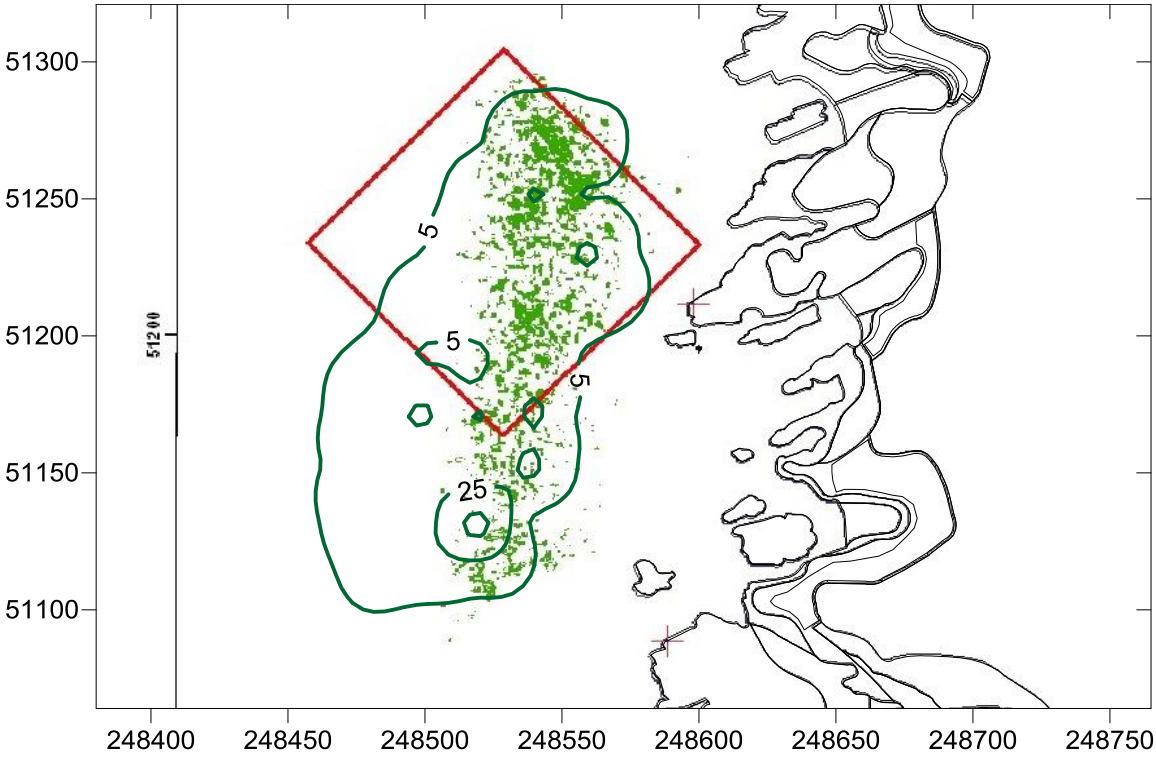


Figure 26. Seagrass extent at Jennycliff South mapped by Irving *et al*, 2007 plotted alongside 2012 % cover contours

Poor quality aerial images, lack of survey time and few ground truthing points in the 2007 study resulted in little confidence in the resulting data at Jennycliff South. The comparison however does show very similar seagrass extent, except for on the western side of the bed where again, deeper water is likely to have prevented the seagrass from being detected in the 2006 aerial image (the 2012 westerly extent is approximately 50m greater than that reported in 2007).

It can be concluded with some confidence that the extent of the bed at Jennycliff South has not changed significantly since 2006.

5.2.2.2 Number of Plants per m²

The mean number of plants per m² at each seagrass bed has been calculated by taking the mean of the values measured from each quadrat within each dive site, and then taking a mean of the mean values for each dive site to represent each entire bed. The standard error has been calculated using the mean values for each dive site

The method of calculating the mean and standard error values has been used because as explained in section 4.1.3, data from quadrats *between* dive sites are not considered to be replicates of the same *Zostera marina* population due to the patchy nature of attributes being measured.

The mean and standard error of number of plants per m^2 has been graphed for all beds where data is available, see Figure 27.

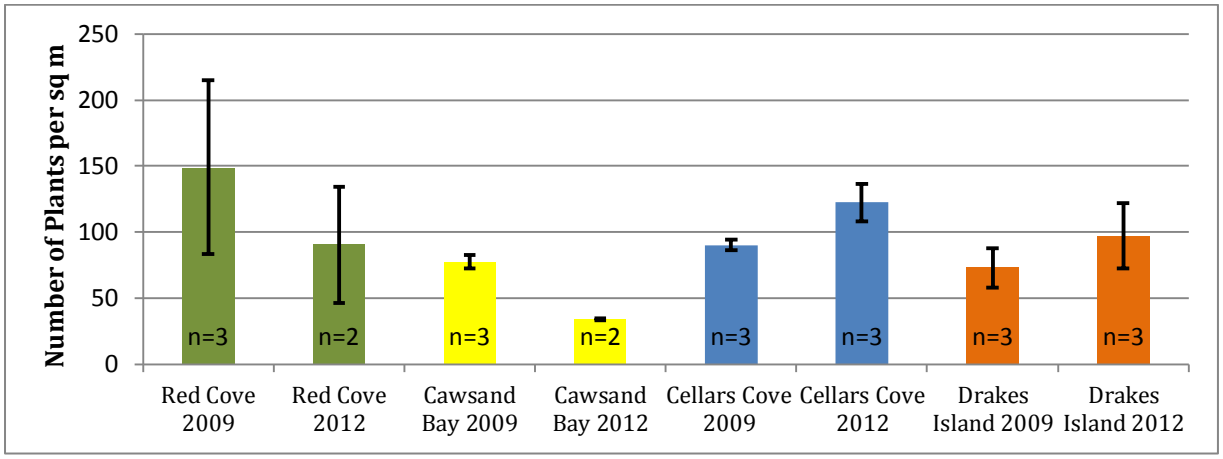


Figure 27. Mean and standard error of number of plants per m^2 at seagrass beds in Plymouth Sound SAC in 2009 and 2012

Figure 27 suggests that change may have occurred at Cawsand Bay and Cellars Cove over time, where the number of plants per m^2 appear to have decreased and increased respectively. However, a drawback in attempting to determine temporal variation from the available data is that the number of dive sites within a bed (n) is very low (n= 2 or n=3). The value in making these comparisons is therefore extremely limited.

5.2.2.3 Mean Maximum Plant Length

The mean maximum plant length at each seagrass bed has been calculated by taking using the same method as described in section 5.2.2.2 for mean number of plants per m^2 and for the same reasons. The mean and standard error of mean maximum plant length has been graphed for all beds where data is available, see Figure 28.

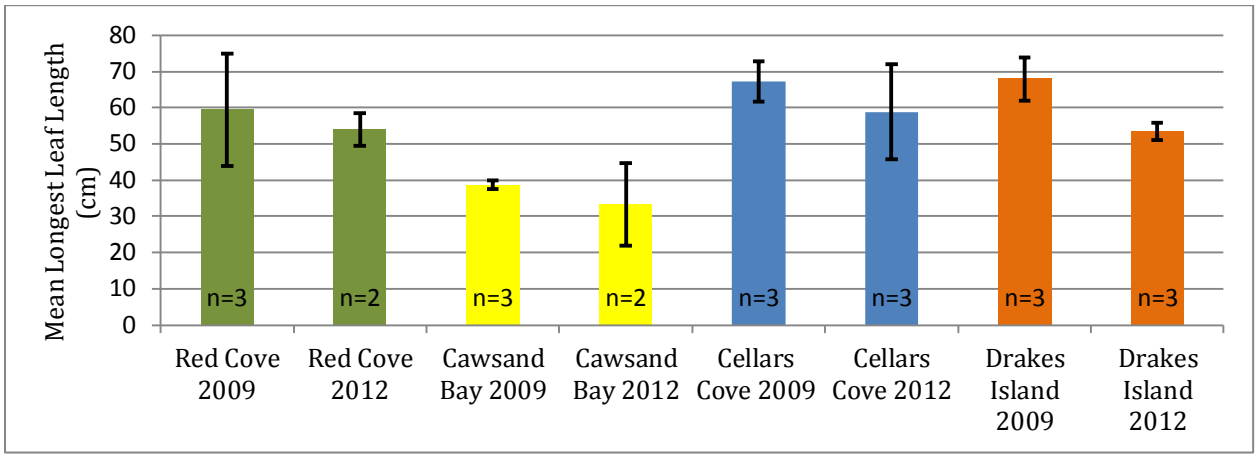


Figure 28. Mean and standard error of mean maximum plant length at seagrass beds in Plymouth Sound SAC in 2009 and 2012

Figure 28 suggests that change may have occurred at Drakes Island since 2009, where the where the mean maximum plant length appears to have decreased. However, again given the low n value and the limitations in the data as discussed in section 5.2 above the value in making these comparisons is limited and should be treated with caution.

5.2.3 Summary of all Attributes and Condition Assessment

Table 19. Summary of attributes and an assessment of the condition of the *Zostera marina* beds within Plymouth Sound and Estuaries SAC

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
Seagrass (*Zostera marina*): Percentage Cover	See section 5.2.2.1.	**Mean percentage cover of seagrass:** Drakes Island: 66% - Moderate Cawsand Bay: 30% - Sparse Cellars Cove: 74% - Moderate-Dense Red Cove North: 77% - Dense Red Cove South: 80% - Dense Jennycliff North: 70% (single data point) – Dense Jennycliff South: 21% - Very Sparse Firestone Bay: 21% - Very Sparse Tomb Rock: 19% - Very Sparse	Despite the limitations in comparing data with previous studies, overall the extent of the seagrass beds in Plymouth Sound SAC do not appear to have declined. The apparent extension of many of the beds is thought to be largely due to seagrass not being detected in the 2006 aerial images, particularly in deeper waters. However, an extension in 'dense' seagrass cover at Drakes Island is probable.	**Favorable Condition -** High confidence

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
Extent	**Irving *et al*, 2007 Combined area of 'dense' and 'moderately dense' seagrass <u>excluding</u> 'sparse' and 'very sparse':**	**Total area of seagrass bed including percentage cover from 5-100%:**	The percentage cover is broadly consistent with that expected given the results of previous surveys.	**Favorable Condition** - High confidence
	Drakes Island: 2162m^2	Drakes Island: 44207m^2		
	Cawsand Bay: 2314 m^2	Cawsand Bay: 119739m^2		
	Cellars Cove: 2315m^2	Cellars Cove: 64171m^2		
	Red Cove North: 762m^2	Red Cove North: 16889m^2		
	Red Cove South: 458m^2	Red Cove South: 11447m^2		
	Jennycliff North: 455m^2	Jennycliff North: 1176m^2		
	Jennycliff South: 2193m^2	Jennycliff South: 14378m^2		
	Firestone Bay: No data available	Firestone Bay: 7607m^2		
	Tomb Rock: No data available	Tomb Rock: 66321m^2		

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
Number of Plants per m² (to inform the measure of the characteristic species density of *Zostera marina*).	**Irving *et al*, 2010 mean shoot density and range:** Drakes Island: 73 (12-156) per m² Cawsand Bay: 78 (no range) per m² Cellars Cove: 90 (24-152) per m² Red Coves: 142 (4-496) per m² Tomb Rock: No data Jennycliff North: No data Jennycliff South: No data Firestone Bay: No data	**Mean number of plants per m²:** Drakes Island: 97 (0-256) per m² Cawsand Bay: 34 (0-144) per m² Cellars Cove: 122 (32-336) per m² Red Coves: 96 (0-240) per m² Tomb Rock: Not assessed Jennycliff North No data Jennycliff South: No data Firestone Bay: No data	Between 2009 and 2012 a change in the number of plants per m² may have occurred at Cawsand Bay and Cellars Cove, where numbers of plants appear to have decreased and increased respectively. However, given the limitations of the data and the subsequent limited ability to make direct comparisons it is not possible to definitively conclude changes in number of plants per m². The condition status has therefore been recommended based on the absence of evidence of anthropogenic impacts.	**Favorable Condition -** Low confidence

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
% Leaves Infected and Infection Scores (and presence of *Labyrinthula sp.*)	**Irving *et al*, 2010 'browning' score expressed as % cover (as per methods described – <u>not</u> comparable with 2012 results):** Drakes Island: 10% (0-80%)	**Mean % leaves infected and infection scores together with ranges (as per methods described in this report):** Drakes Island: 55 (30-77) % 0.9 (0.5-1.8)	Given the variables in methods and data produced by the 2009 and 2012 studies, it is not possible to make meaningful comparisons between the data. No signs of *Labyrinthula sp* were confirmed in 2012 as was the case in 2009.	**Not known**
	Cawsand Bay: 0% (0-80%)	Cawsand Bay: 42 (0-75) % 0.6 (0-1.2)		
	Cellars Cove: 3% (0-80%)	Cellars Cove: 50 (25-78) % 0.8 (0.6-1.0)		
	Red Coves: 0% (0-80%)	Red Cove North: 55 (35-67) % 0.8 (0.6-1.0)		
		Red Cove South: 56 (33-80) % 1.0 (0.5-2.0)		
		Tomb Rock: 29 (0-67) % 0.4 (0-0.8)		
		Jennycliff North: No data		
		Jennycliff South: No data		
		Firestone Bay: No data		

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
Characteristic species epiphytic community - Epiphyte Scores	**Irving *et al*, 2010 epiphyte cover (as per methods described – <u>not</u> comparable with 2012 results):** Drakes Island: 23% (0-80%) Cawsand Bay: 15% (0-80%) Cellars Cove: 27% (0-80%) Red Coves: 80% (0-80%)	**Mean epiphyte scores and ranges (as per methods described in this report):** Drakes Island: 2.4 (1.8-3.3) Cawsand Bay: 1.8 (0.4-2.9) Cellars Cove: 2.3 (0.9-3.8) Red Cove North: 1.9 (0.9-3.2) Red Cove South: 1.7 (0.7-2.8) Tomb Rock: 1.1 (1.0-1.5) Jennycliff North: No data Jennycliff South: No data Firestone Bay: No data	Given the variables in methods and data produced by the 2010 and 2012 studies, it is not possible to make useful comparisons between the data. Given that no anthropogenic impacts were observed the condition status of this attribute has been recommended but the confidence in the recommendation is low.	**Favorable Condition** – Low Confidence

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
Maximum Plant Length	**Irving *et al*, 2010 mean length of 3 longest leaves and range:** Drakes Island: 68 (21-110) cm	**Maximum plant lengths and ranges (as per methods described in this report) where n = number of shoots measured:** Drakes Island (n=146): 53 (25-75) cm	Some change may have occurred at Drakes Island since 2009, where the where the mean maximum plant length appears to have decreased. However, given the limitations in data the value in making these comparisons is limited and should be treated with caution. The variation observed is likely to be as a result of natural variation between the different sampling locations between years.	**Favourable Condition** – Moderate Confidence
	Cawsand Bay: 40 (33-90) cm	Cawsand Bay (n=35): 33 (14-57) cm		
	Cellars Cove: 68 (33-122) cm	Cellars Cove (n=204): 63 (19-91) cm		
	Red Coves: 49 (22-77) cm	Red Cove North (n=32) : 58 (39-81) cm Red Cove South (n=84): 50 (39-75) cm Red Coves Combined (n=116): 53 (39-81) cm		
	Tomb Rock: No data	Tomb Rock: 34 (13-48) cm		
	Jennycliff North: No data	Jennycliff North: No data		
	Jennycliff South: No data	Jennycliff South: No data		
	Firestone Bay: No data	Firestone Bay: No data		

Attribute	Previous study and results	2012 study results	Assessment of attribute	Recommended Condition Status and Confidence in assessment
Presence of macroalgae including drift macroalgae within seagrass beds.	Irving 2010 reported a species list of macroalgae for each bed together with a range of the percentage cover of the collective attached macroalgae species recorded during dives. In summary Irving 2010 did note the 'rare' or 'occasional' presence of *Enteromoprha* (*Ulva*) *lactuca*. The invasive species *Sargassum muticum* was also noted as being present in small amounts.	The presence of other algae species and drift macroalgae was has been briefly described within this report in the summary description sections, as the collection of macroalgae data was subsidiary to the main DDTV survey. The raw data of stations where drift or attached macroalgae were observed are provided in the GIS files associated with this report.	Although Irving 2010 reported a comprehensive species list of macroalgae for each bed together with a range of the percentage cover of the collective attached macroalgae species recorded, given the very brief subsidiary nature of the type of macroalgae data collected in 2012 it has not been possible to directly compare the two types of data. However, no significant presence of macroalgae and/or drift macroalgae was observed in any of the seagrass beds. A single plant of *Sargassum muticum* was observed inshore of the bed at Jennycliff North but was outside the extent of the seagrass.	**Favorable Condition** – High confidence

5.3 Review of Methods

An objective of this study was to critically review the two methods of measuring seagrass density i.e. plants per square metre (using diving methods) and percentage cover (using DDTV) in order to elucidate the feasibility and appropriateness of using only one method in future.

Percentage cover was not assessed by Natural England's divers which made comparing the two parameters difficult to do with any degree of confidence. The percentage cover determined using DDTV has instead been compared to the plant density in each diver quadrat (see Table 21 below). DDTV stations and quadrats did not exactly overlap (compounded by the fact that dGPS is accurate only to 5m), therefore the statistically manipulated data from the contour plots had to be used (data inferred by the contouring software package SURFER 10 between 20m spaced target stations). Some of the seagrass densities were shown to be variable within very short distances during the diving surveys therefore it would have been far more valid to estimate percentage cover during the diving survey (assuming that percentage cover assessed by divers and DDTV is comparable). Consequently, although some positive correlation exists between plant density and percentage cover, the range of plant densities within each percentage cover category is so large that one parameter could not be used to determine the other:

Table 21. Percentage cover and plants per m^2

Percentage Cover Category	Mean (and Range) of Number of Plants per M^2
Very Sparse	3 (0-9)
Sparse	4 (0-13)
Moderate	5 (0-15)
Dense	9 (1-16)

The relationship between percentage cover and plant density would also be expected to change between beds, as longer leaf lengths would be expected to cover a greater area where the same number of shoots exist. For example, the longer leaf length at Cellars Cove is likely to result in a higher percentage cover for a given shoot density when compared to a bed with a shorter leaf length such as that at Tomb Rock. However, this may not be of great importance when looking at the overall condition for each bed.

There are a number of advantages and disadvantages to each method of assessing seagrass density. Although diving methods are probably far more applicable to small scale impact measurements, for example, from dredging or development projects, DDTV is more applicable to large areas where it provides good large-scale coverage, detects patchiness and provides an accurate measure of extent at a relatively low cost. The limitation of using DDTV methods alone however is that not all attributes can be measured and no information on epiphytes, infection or leaf cover is provided. DDTV also provides less detailed information regarding macroalgae populations.

Given the results presented here it is concluded that both methods are valuable in measuring different attributes when assessing the condition of seagrass beds. There is scope for using DDTV methods only to determine seagrass density which would provide a much broader scale assessment. However, such an assessment would provide a lower resolution of density measure. Consequently, changes in density (particularly in beds which have particularly long

plant lengths) would need to be sufficiently large to be detected using DDTV video methods alone.

There is no doubt in the value of DDTV methods for assessing extent of beds; the efficiency and accuracy of the survey process and the quality of the resulting data for measuring bed extent is by far the most effective method employed in Plymouth Sound SAC to date.

6 CONCLUSIONS

- The apparent extension of beds is expected to be largely due to seagrass not being detected in the 2006 aerial images. The percentage cover is broadly consistent with that expected given the results of previous surveys.
- Between 2009 and 2012 a change in the number of plants per m^2 may have occurred at Cawsand Bay and Cellars Cove, where numbers of plants appear to have decreased and increased respectively. However, given the limitations of the data and the subsequent limited ability to make direct comparisons it has not been possible to definitively conclude changes. Observed differences may be due to different recording methods or different sampling locations (the dive sites in 2012 at Cawsand Bay in particular correspond with the low percentage cover patches) or due to real natural fluctuations.
- Given the variation in methods between the 2009 and 2012 surveys to determine plant infection, it has not possible to make useful temporal comparisons between the infection score and percentage cover data. No confirmed presence of *Labyrinthula sp* was recorded.
- Given the variables in methods between the 2009 and 2012 surveys to determine epiphyte scores, it has not been possible to make useful temporal comparisons between the mean epiphyte score data.
- The mean maximum plant length data are largely consistent 2009 and 2012. The variation observed at Drakes Island is likely to be as a result of the different sampling locations between years.
- No significant presence of macroalgae and/or drift macroalgae was observed in any of the seagrass beds. A single plant of *Sargassum muticum* was observed inshore of the bed at Jennycliff North but was outside the extent of the seagrass.
- The definitive identification of anchor scarring during the course of DDTV surveys for seagrass percentage cover and extent is difficult. Problems encountered during the 2012 survey included 'task overload', particularly at large beds where hundreds of target stations require visiting and the concentration required by surveyors to record percentage cover over a number of hours results in a 'tunnel vision' of the main attributes that require recording (i.e. % cover, presence of drift and attached macroalgae). In patchy beds it was not possible to determine whether all patches void of seagrass were a result of natural variation or past anchor scarring. An additional challenge encountered was that in areas where currents are strong and leaf lengths are longer (i.e. Red Coves) the seagrass laid horizontally across the seabed, covering a proportionally larger area of seabed and possible evidence of disturbance that may be present below. Mooring scarring is more likely to be observed than anchor scarring as more targeted searches can be carried out aided by the surface buoys. Observations of both anchoring and mooring scaring are more likely during good visibility conditions where the distance between the seabed and the camera can be increased and a larger field of view is possible. The use of DDTV to effectively detect both anchor and mooring scarring is possible. However, additional targeted transects should be applied to surveys for the single purpose of detecting such anthropogenic impacts so that a greater confidence in observations can be gained. Although no definitive evidence of

negative effects from anchoring or mooring activity was apparent in Plymouth Sound and estuaries SAC, this may not necessarily be the case, and further targeted studies would be required in order to make a definitive conclusion.

- Both DDTV and diving methods are valuable in measuring different attributes when assessing the condition of seagrass beds. There is scope for using DDTV methods only to indicate seagrass density which would provide a much broader scale assessment. However, such an assessment would provide a lower resolution measure. Consequently, changes in density (particularly in beds which have particularly long plant lengths) would need to be sufficiently large to be detected using DDTV methods alone.
- There is no doubt in the value of DDTV methods for assessing extent of beds; the efficiency and accuracy of the survey process and the quality of the resulting data for measuring bed extent in 2012 is by far the most effective method employed in Plymouth Sound SAC to date.

It is recommended that the seagrass beds within Plymouth Sound SAC are assessed as being in *Favourable Condition* for all attributes with the exception of infection scores/percentage cover, where the condition of the attribute is unknown. The confidence in the recommendations of condition for the remaining attributes attribute has been indicated and ranges from low to high.

7 RECOMMENDATIONS

A number of recommendations are suggested for future condition assessment of the seagrass beds in Plymouth Sound and Estuaries SAC, these are listed as follows:

- The use of DDTV to effectively detect anchor and mooring scarring is possible. However, additional targeted transects should be applied to surveys for the single purpose of detecting such anthropogenic impacts so that a greater confidence in observations can be gained.
- As suggested by CEFAS statisticians, a triangular lattice design should be applied within the target station transect structure when carrying out DDTV surveys in future (rather than the 20m square grid design that was used here). By applying a triangular design to the sample station arrangement the distance between stations would be reduced for the same sampling effort. This would enable 'patchiness' within beds to be better detected and more accurately mapped.
- Diving surveys should be carried out following the DDTV extent surveys so that the extent of the bed can be accurately located and targeted. This is less important in beds which have reliable baseline data, but is crucial when collecting quality temporally comparable data for baseline studies.
- In order to ensure that more meaningful and rigorous temporal statistical analysis can be carried out on any future data collected, the diving survey design should be improved. Specifically, the survey design should be altered to include more replicates within each bed (perhaps with fewer quadrats per replicate to minimise costs down).
- Where comparable baseline data does exist, the same diving monitoring locations (central datum markers and transects) should be used in future surveys, particularly in patchy beds where attributes can vary significantly within the same bed.
- In order to enable data to be compared directly with historical studies, all methods and analysis should be replicated as far as possible, where doing so does not preclude the ability to collect more useful data for future analysis.

- To increase the sample size and subsequent accuracy of data relating to the number of plants per m^2, surveyors should return to using a larger quadrat size (50 cm x 50 cm) and count plant shoots in situ. This is recommended because the added precision of carrying out counts post dive is not considered to be sufficiently beneficial to offset the disadvantages of the smaller sample size which results from using a smaller quadrat.

REFERENCES

[1] English Nature. (2000). Plymouth Sound and Estuaries European marine site, English Nature's advice given under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994

[2] Irving, R. A. (2010). "Plymouth Sound and Estuaries SAC seagrass diving survey, 15-17 July 2009". Unpublished Report to Natural England by Sea-scope Marine Environmental Consultants, Devon.

[3] Irving, R.A., Jackson, E.L. & Cole, H. (2007). "Mapping eelgrass Zostera marina beds within Plymouth Sound and Estuaries SAC". Unpublished report to Natural England by Sea-Scope, Marine Environmental Consultants, Devon.

[4] OSPAR Commission, "Zostera beds, Seagrass Beds - OSPAR Background Document Version 3," 2008. [Online]. Available: www.ospar.org. [Accessed 15 July 2012)

[5] Bugg, A. (2004) Survey of *Zostera marina* bed at Jennycliff Bay, Plymouth. MCS Plymouth Local Group. Unpublished report for Seasearch and Natural England

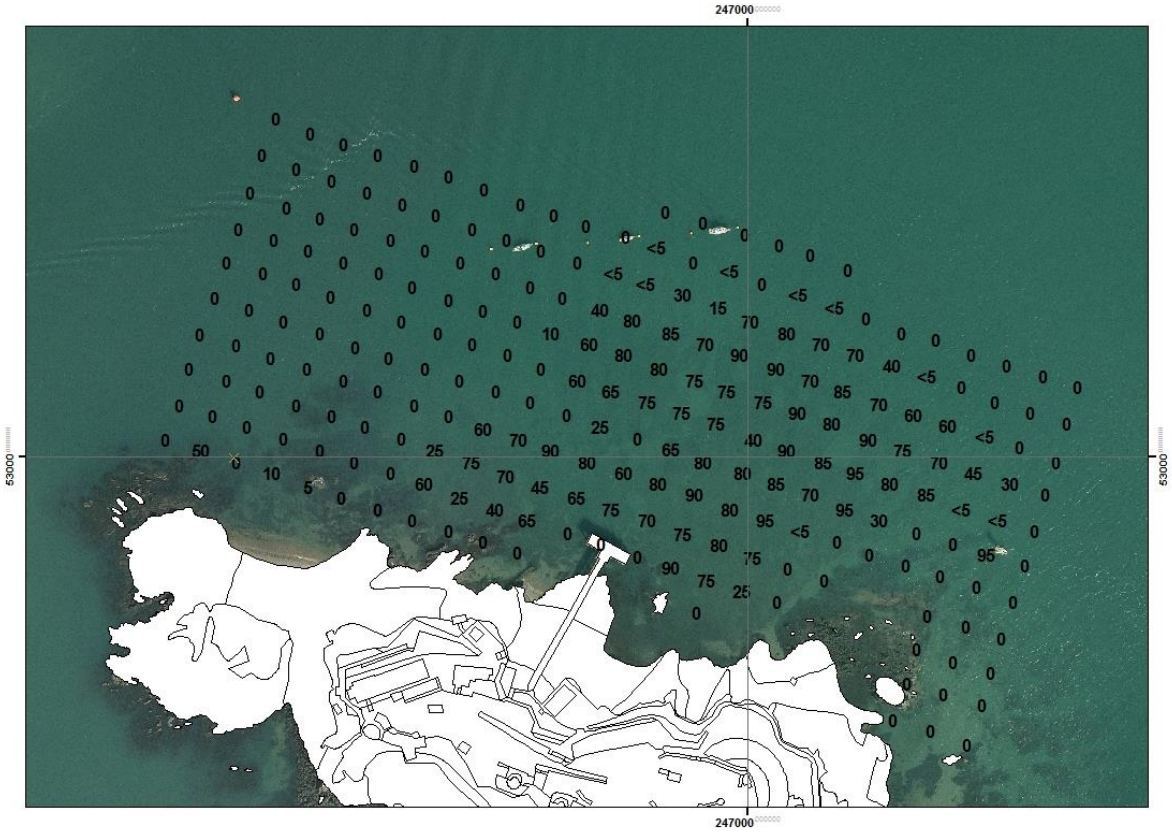
[6] McGarigal, K., Cushman, S.A., Neel, M.C. & Ene, E. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. University of Massachusetts, Amherst.

[7] Clarke, K., and Warwick, R.M., (1994). Change in marine communities: an approach to statistical analysis and interpretation. 2nd edition, NERC, UK.

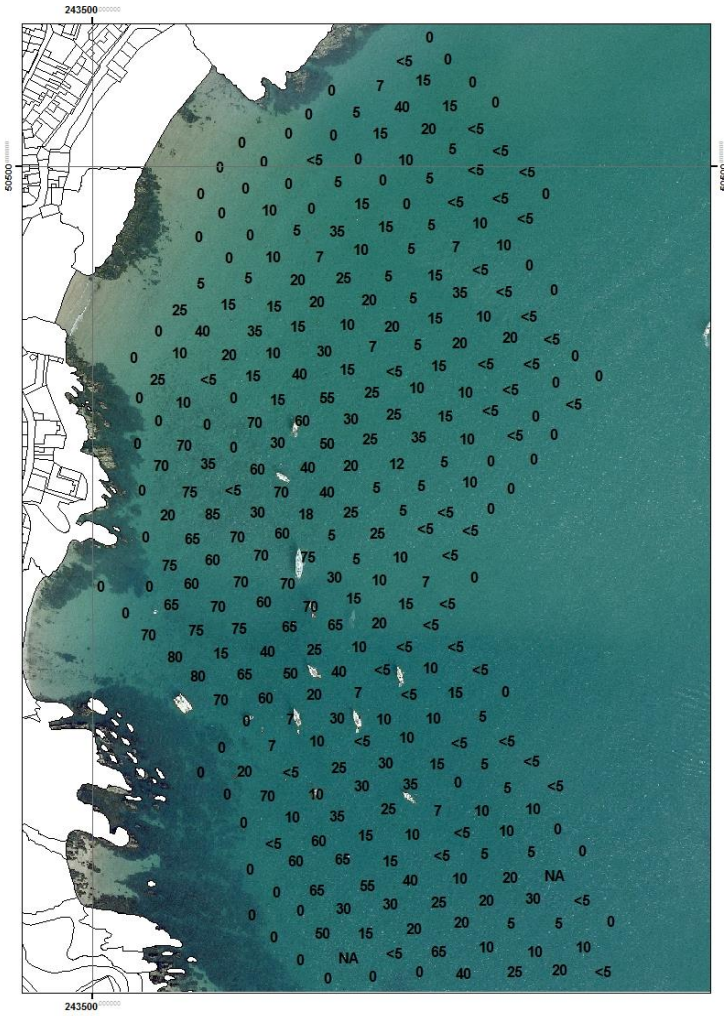
APPENDIX

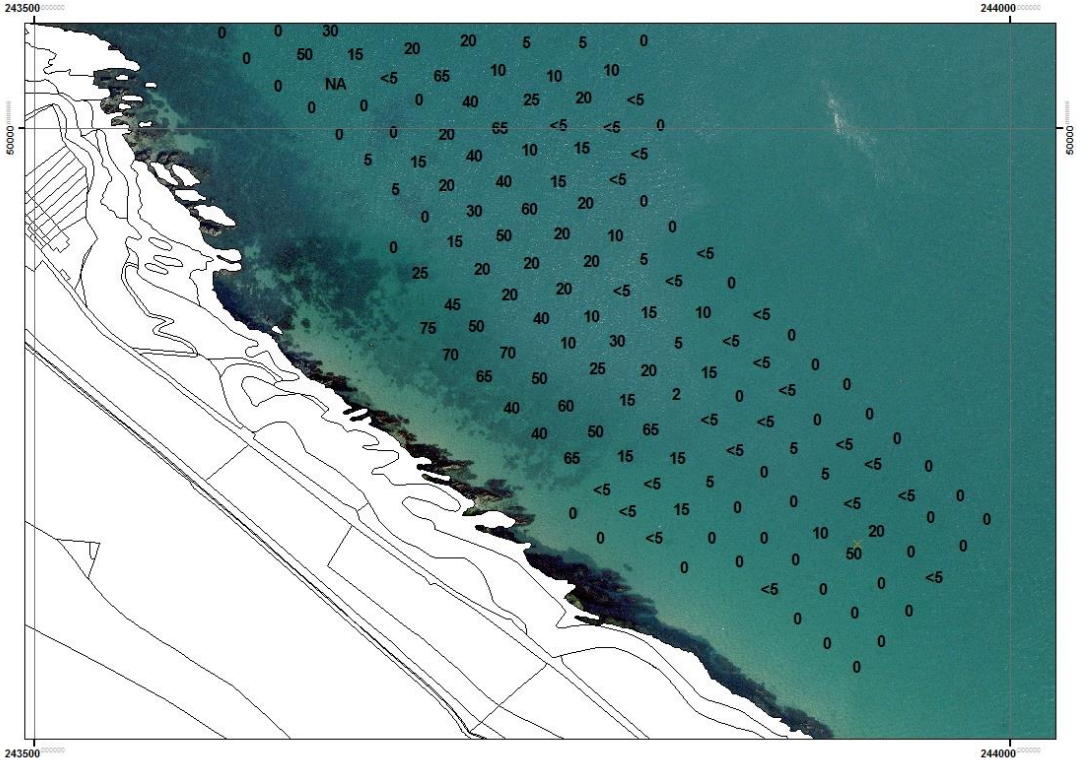
Appendix 1: Percentage Cover Raw Data Plots

Drakes Island

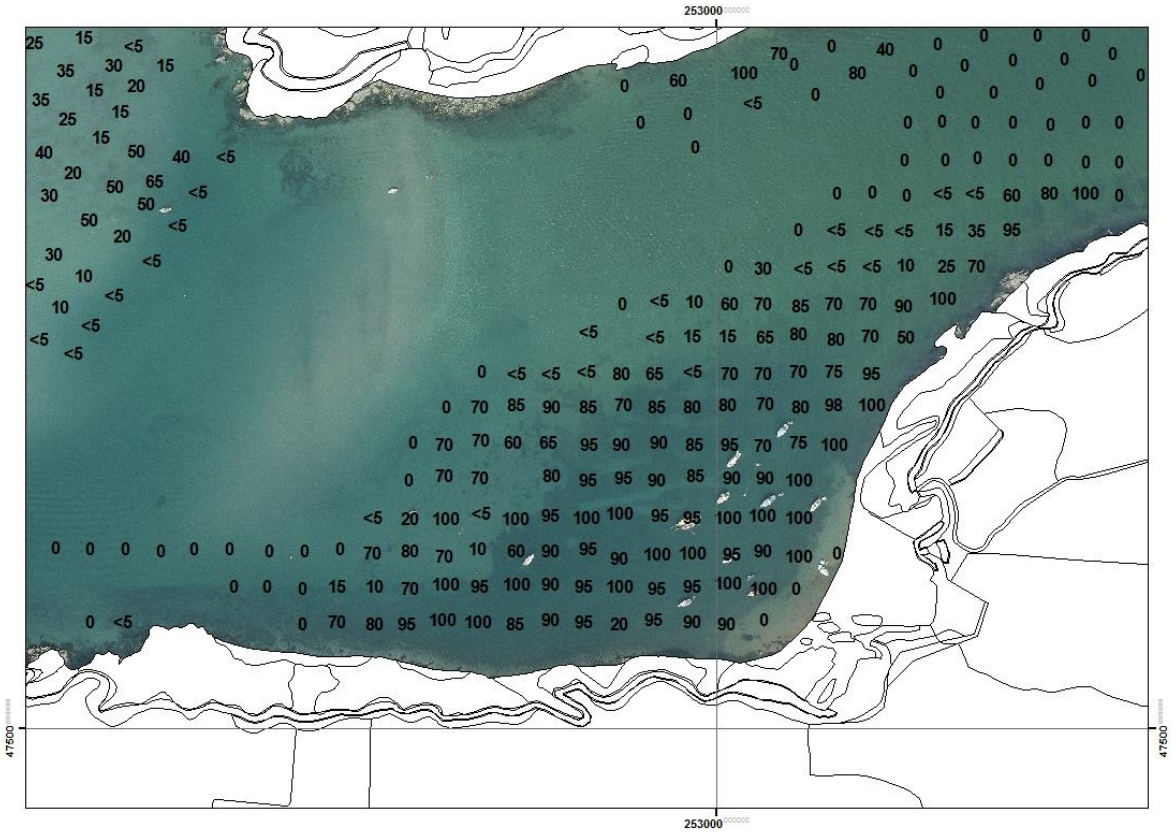


Cawsand Bay

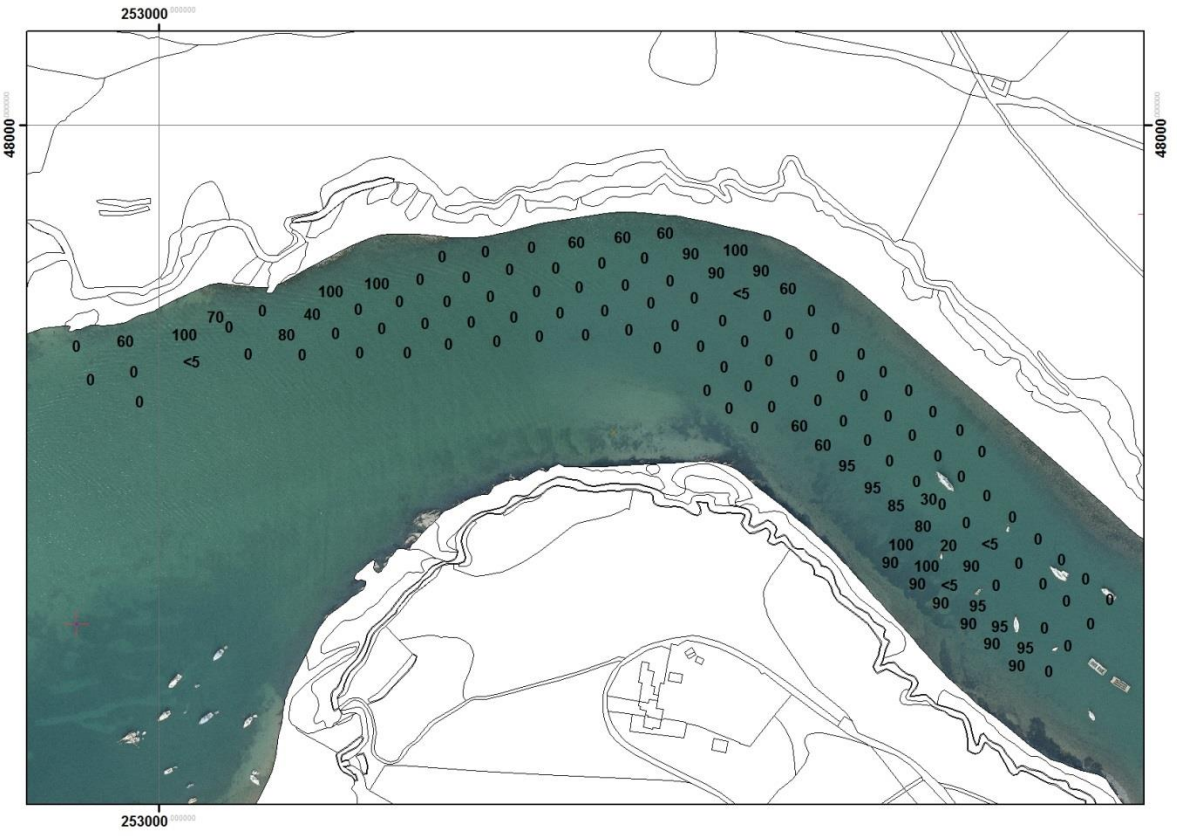

243500
50500
243500


243500
244000
50000
50000
243500
244000

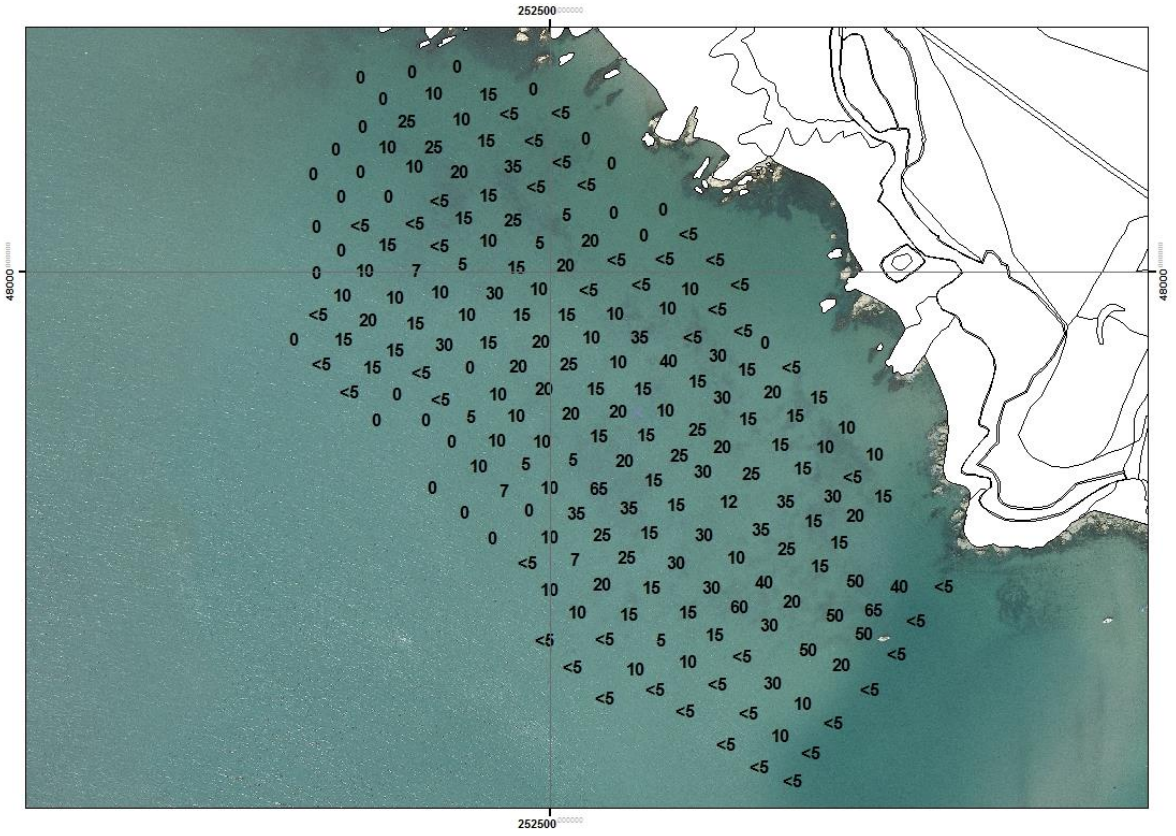
Cellars Cove



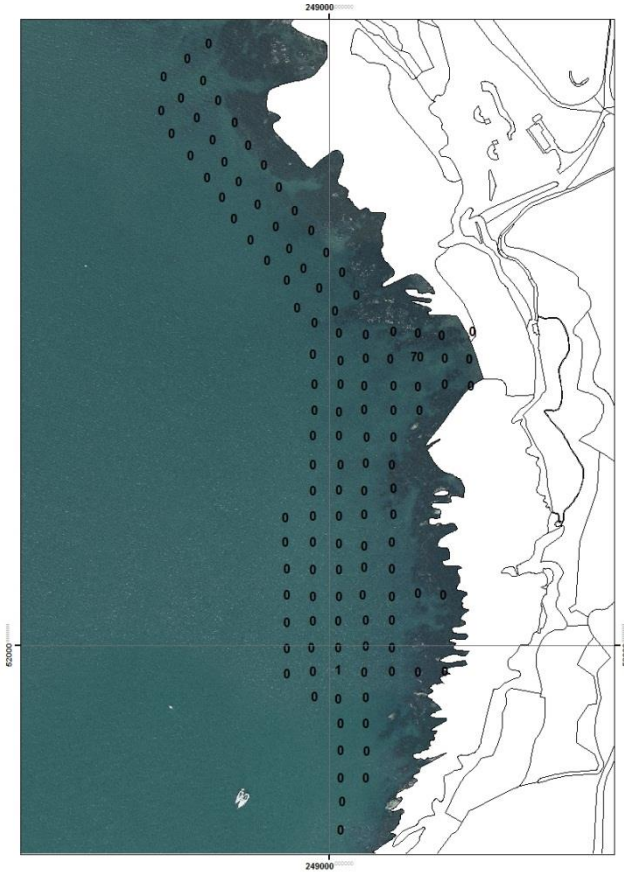
Red Cove North and South



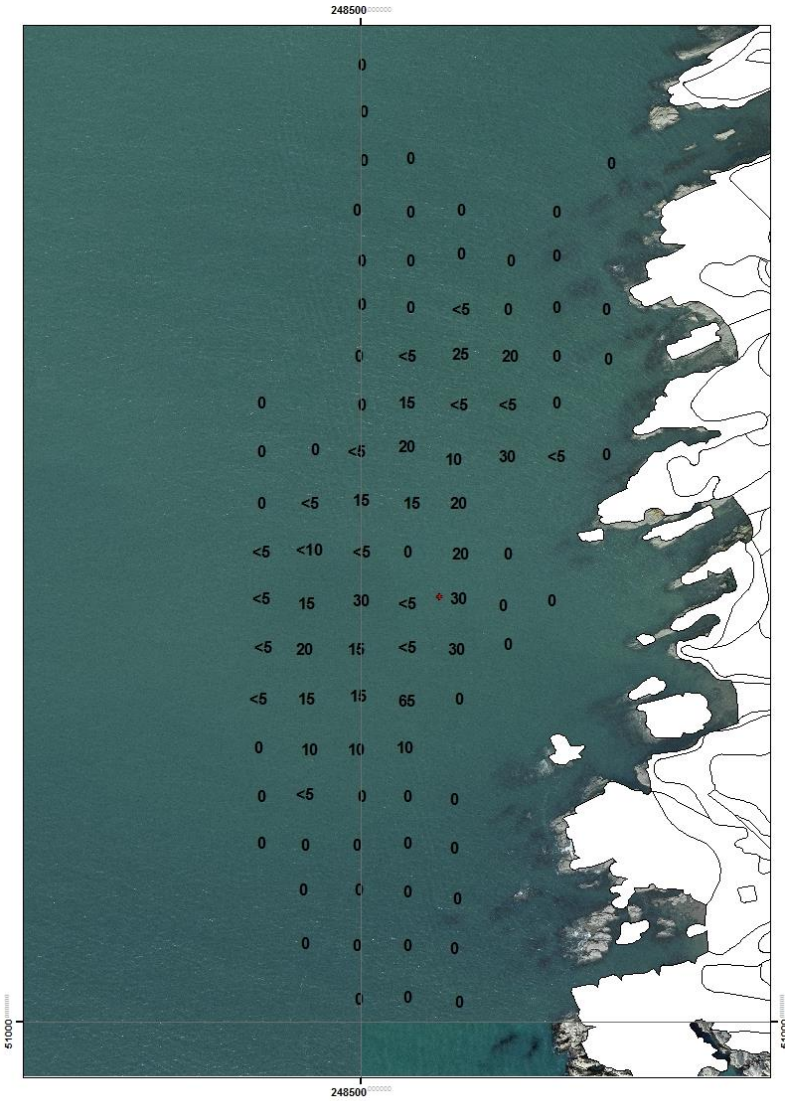
Tomb Rock



Jennycliff North



Jennycliff South



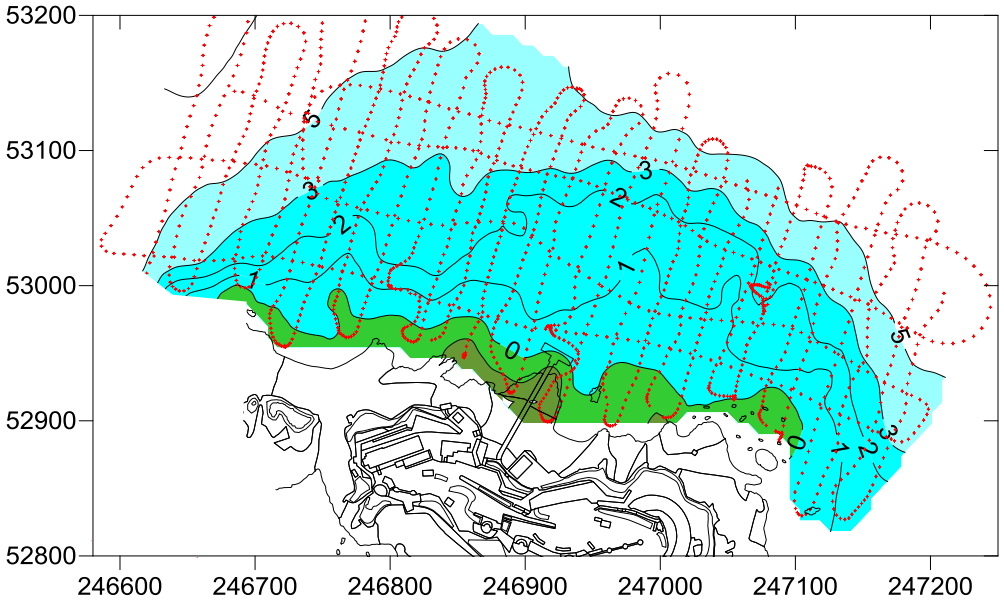
Appendix 2: Bray-Curtis Similarity Index Results

Station	% Seagrass Cover			
	Real Time Data	Secondary Verification of Video Footage	Categorised Real Time Data	Categorised Secondary Verification Data
428	15	15	Very Sparse	Very Sparse
327	15	5	Very Sparse	Very Sparse
386	25	40	Very Sparse	Sparse
447	7	15	Very Sparse	Very Sparse
314	25	30	Very Sparse	Sparse
450	5	10	Very Sparse	Very Sparse
406	10	5	Very Sparse	Very Sparse
457	10	15	Very Sparse	Very Sparse
446	5	10	Very Sparse	Very Sparse
416	5	7	Very Sparse	Very Sparse
313	30	60	Sparse	Moderate
258	40	40	Sparse	Sparse
437	15	10	Very Sparse	Very Sparse
399	20	7	Very Sparse	Very Sparse
260	10	15	Very Sparse	Very Sparse
449	5	5	Very Sparse	Very Sparse
311	35	35	Sparse	Sparse
426	5	7	Very Sparse	Very Sparse
411	5	5	Very Sparse	Very Sparse
391	15	17	Very Sparse	Very Sparse
Bray-Curtis Similarity	**82.1% Similar**		**95.8% Similar**	

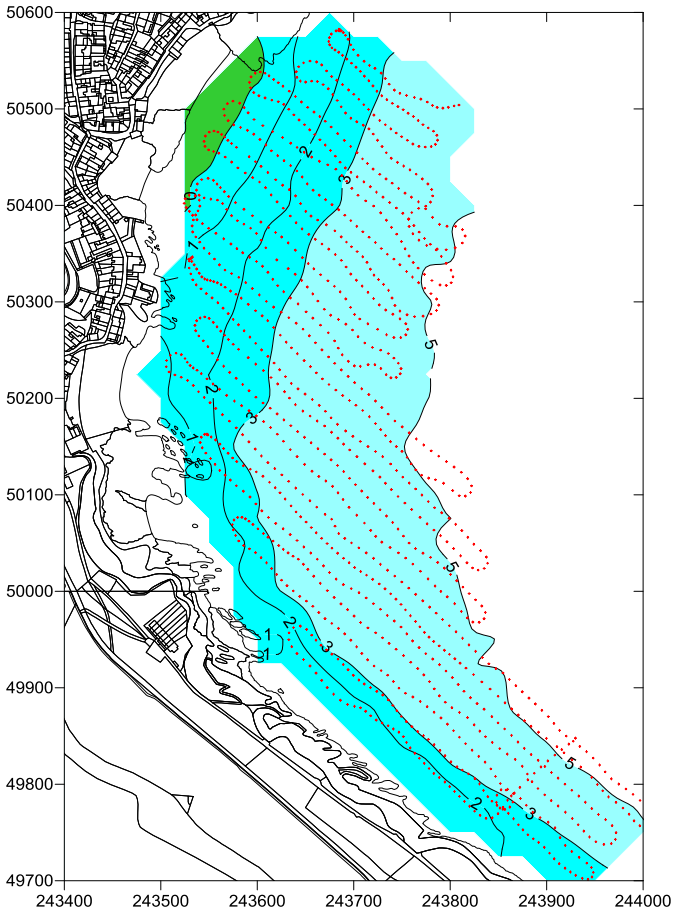
Appendix 3: Bathymetric Survey Boat Tracks

All positions were logged in WGS 84 and converted to OSGB 1936 (British Uniform Grid).

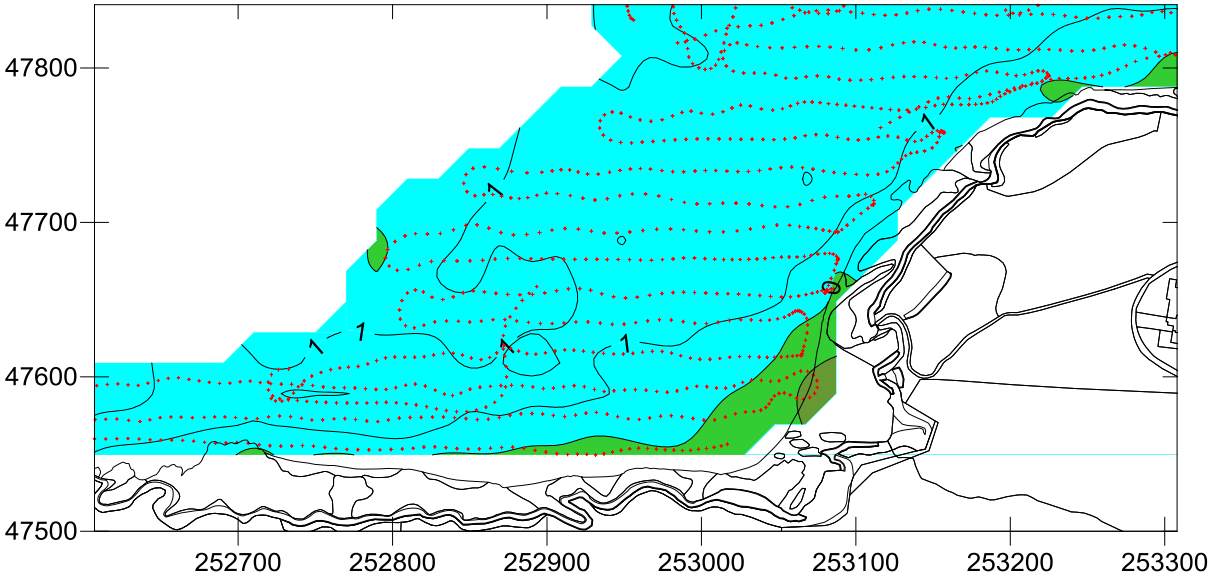
Drakes Island



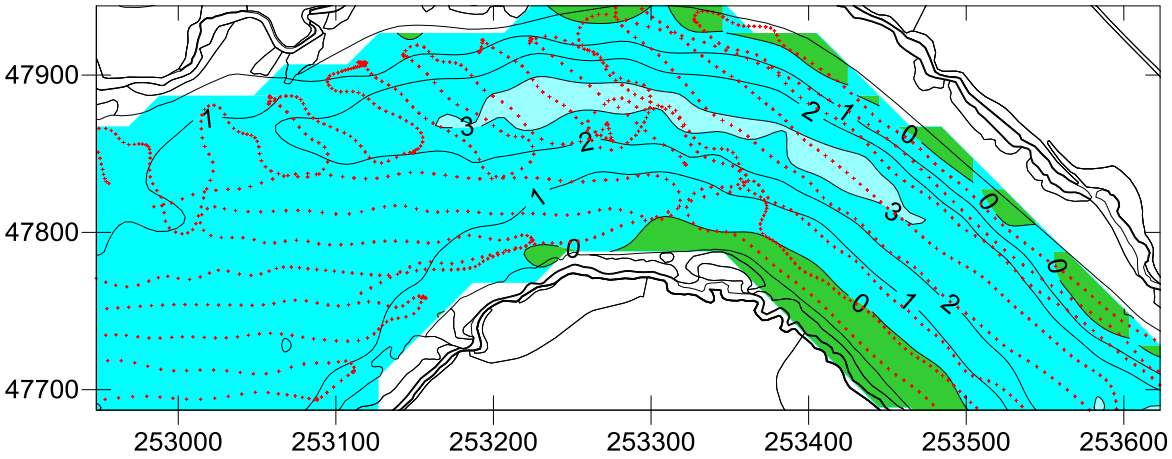
Cawsand Bay



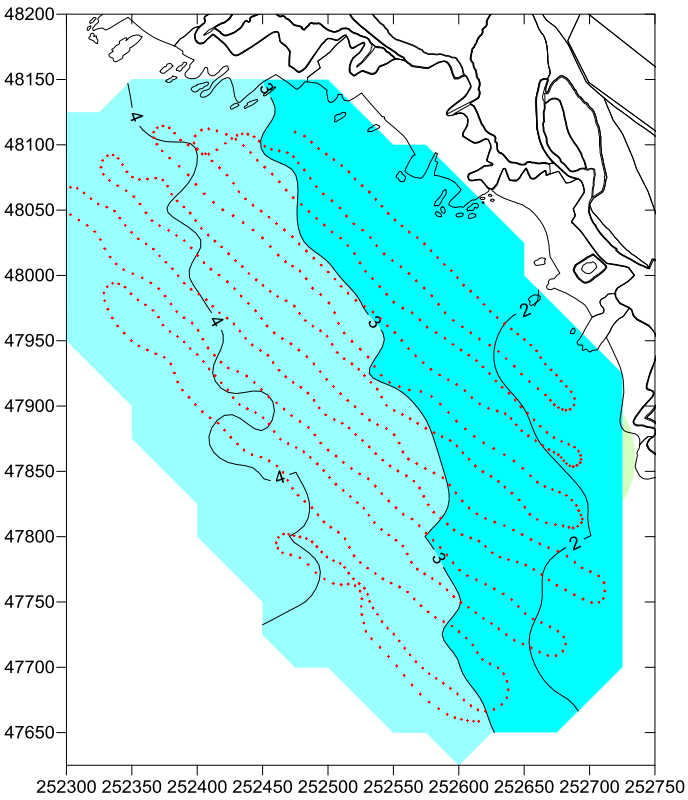
Cellars Cove



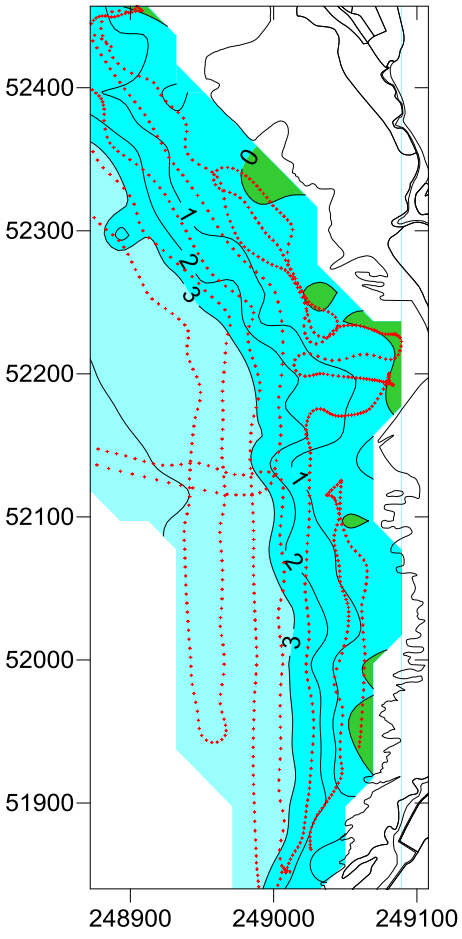
Red Cove North and South



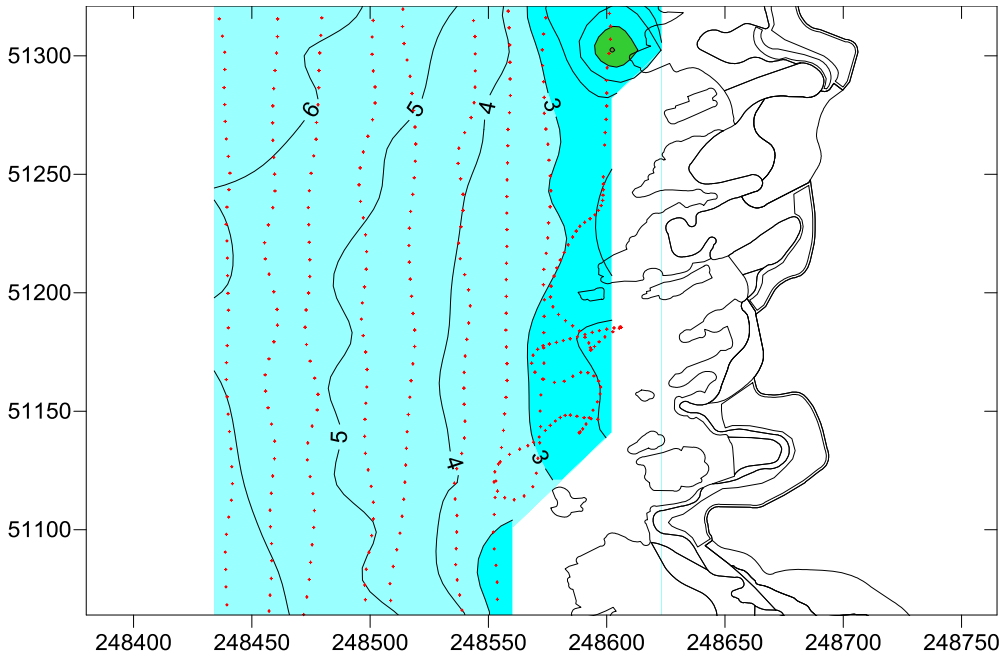
Tomb Rock



Jennycliff North



Jennycliff South


51300
51250
51200
51150
51100
248400
248450
248500
248550
248600
248650
248700
248750
6
5
4
3
5
4
3

Appendix 4: Dive Data Summary

Drakes Island Site 1 Summary

Central Datum Point at: 50 21.414 4 09.144

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m^2	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	317	18.4	nil					Sand	6.0
2	175	12.7	7	77.4%	1.3	2.3	73.3	Sand	6.1
3	112	25.9	16	62.6%	1.1	1.9	61.5	Sand	5.9
4	253	29.8	9	56.7%	0.9	2.2	43.3	Sand	6.0
5	76	29.4	11	43.9%	0.7	1.8	60.0	Sand	5.7
6	52	7.9	3	74.4%	1.4	2.8	50.0	Sand	5.6
7	109	19.4	11	55.9%	0.8	1.9	41.2	Sand	5.8
8	62	18.3	10	40.2%	0.6	2.0	62.4	Sand	5.4

Drakes Island Site 2 Summary

Central Datum Point at: 50 21.398 4 09.070

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m^2	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	273	18.9	nil					Sand	5.5
2	117	20.8	8	40.6%	0.5	2.9	51.0	Sand	6.3
3	156	20.6	12	56.3%	0.8	2.6	50.6	Sand	6.3
4	341	29.7	7	57.1%	0.8	2.3	63.3	Sand	5.4
5	76	28.6	13	66.5%	1.3	2.5	49.5	Sand	5.5
6	6	13.9	1	66.7%	0.7	3.0	25.0	Sand	5.7
7	304	27.2	4	47.9%	0.7	2.7	57.3	Sand	5.4
8	206	8.9	9	49.8%	0.7	2.6	44.4	Sand	5.6

Drakes Island Site 3 Summary

Central Datum Point at: 50 21.411 4 09.283

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m^2	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	103	18.9	nil					Sand	5.8
2	341	10.2	nil					Sand	6.3
3	10	21.3	5	56.7%	1.1	2.5	69.2	Sand	6.3
4	113	24.9	5	30.0%	0.8	2.2	42.2	Sand / Gravel	5.4
5	241	19.8	1	75.0%	1.8	3.3	30.0	Sand	5.5
6	48	19.9	3	38.9%	0.5	2.2	71.7	Sand	5.7
7	265	15.7	5	45.0%	0.7	1.9	47.6	Sand	5.4
8	191	6.4	6	61.1%	1.1	2.1	74.7	Sand	5.6

Cawsand Bay Site 1 Summary

Central Datum Point at: 50 19.685 4 11.785

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m^2	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	259	25.4	nil					Sand	6.2
2	276	17.5	nil					Sand	6.0
3	218	6.4	4	59.2%	1.0	1.7	57.3	Sand	5.9
4	43	15.7	7	71.4%	1.1	2.1	43.1	Sand	5.3
5	163	22.5	2	50.0%	0.9	1.7	38.5	Sand	6.0
6	303	20.5	3	66.7%	0.8	1.8	35.3	Sand	5.7
7	94	4.1	2	73.3%	1.2	2.2	36.0	Sand	5.4
8	356	26.2	1	50.0%	0.5	2.0	44.0	Sand	5.4
9	126	12.7	1	75.0%	0.8	2.0	50.0	Sand	5.5
10	159	27.7	2	67.5%	1.1	1.6	54.0	Sand	5.7

Cawsand Bay Site 2 Summary

Central Datum Point at: 50 18.710 4 11.803

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.062 5 m²	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	356	28.6	nil					Sand	n/a
2	208	10.6	nil					Sand	n/a
3	249	20.8	nil					Sand	n/a
4	271	28.5	nil					Sand	n/a
5	339	24	nil					Sand	n/a
6	280	20	nil					Sand	n/a
7	340	29.3	nil					Sand	n/a
8	259	22.7	nil					Sand	n/a
9	321	14.9	3	8.3%	0.1	2.1	20.7	Sand	5.5
10	275	7.8	1	0.0%	0.0	0.4	21.0	Sand	5.7
11	310	15.3	2	10.0%	0.1	0.7	20.5	Sand	n/a
12	302	20.5	7	0.0%	0.0	1.6	18.0	Sand	n/a
13	24	17.4	1	33.3%	0.7	1.7	14.0	Sand	5.3
14	318	24.4	6	39.7%	0.6	1.8	23.8	Sand	5.3
15	230	28.8	4	20.0%	0.2	2.1	30.8	Sand	3.7
16	306	28.1	9	45.2%	0.5	2.9	27.1	Sand	5.4

Cellars Cove Site 1 Summary

Central Datum Point at: 50 18.596 4 04.012

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m²	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	122	28.6	12	41.0%	0.6	2.3	70.9	n/a	n/a
2	354	6.2	9	63.3%	1.1	2.5	68.3	n/a	n/a
3	175	19.8	8	77.9%	1.6	3.0	86.8	n/a	n/a
4	246	15.5	6	63.9%	1.3	2.5	80.7	n/a	n/a
5	313	25.9	14	40.6%	0.7	2.5	64.6	n/a	n/a
6	43	11.4	11	40.2%	0.7	2.5	52.4	n/a	n/a
7	82	23.8	10	35.3%	0.6	2.3	72.5	n/a	n/a
8	27	28.7	5	43.3%	0.8	2.8	49.6	n/a	n/a

Cellars Cove Site 2 Summary

Central Datum Point at: 50 18.616 4 03.971

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m^2	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	60	23.1	9	56.5%	0.6	1.3	91.1	Sand	5.4
2	311	25.3	6	63.9%	0.7	0.9	58.3	Sand	5.3
3	211	9.4	3	47.8%	0.6	1.6	64.3	Sand	5.6
4	236	24.8	6	50.0%	0.8	2.2	67.5	Sand	5.4
5	77	27.6	12	38.9%	0.6	1.9	88.7	Sand	5.4
6	161	22.9	9	54.6%	0.9	2.0	83.6	Sand	5.4
7	55	15.0	7	48.8%	0.6	1.6	78.0	Sand	5.4
8	258	26.7	2	50.0%	0.6	1.4	71.5	Sand	5.3

Cellars Cove Transect Summary

Transect Start at: 50 18.660 4 03.865
Transect End at: 50 18.700 4 03.804

Quadrat #	Distance (m)	No. of Plants per 0.0625 m^2	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	0	1	40.0%	0.6	2.4	59.0	Sand / Gravel / Pebbles	5.6
2	10	1	25.0%	0.5	2.8	19.0	Sand / Gravel / Pebbles	5.6
3	20	10	24.5%	0.3	2.3	28.7	Sand / Gravel / Pebbles	5.0
4	30	nil					Sand / Gravel / Pebbles	5.7
5	40	18	27.7%	0.4	2.6	78.1	Sand / Gravel / Pebbles	5.0
6	50	nil					Bedrock	5.0
7	60	21	29.0%	0.4	2.9	52.9	Sand / Gravel / Pebbles	5.0
8	70	7	54.5%	0.8	2.8	39.1	Sand / Gravel / Pebbles	5.0
9	80	12	71.3%	1.3	2.6	50.5	Sand / Gravel / Pebbles	5.0
10	90	2	56.7%	1.3	3.8	50.5	Sand / Gravel / Pebbles	5.4
11	100	3	36.1%	0.6	2.6	39.0	Sand / Gravel / Pebbles	5.4

Red Cove North Transect Summary

Transect Start at: 50 18.761 4 03.613
Transect End at: 50 18.762 4 03.661

Quadrat #	Distance (m)	No. of Plants per 0.0625 m²	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	0	nil					Sand / Gravel / Shells	5.6
2	5	nil					Sand / Gravel / Shells	5.5
3	10	5	62.0%	0.8	2.6	80.8	Sand / Gravel / Shells	5.5
4	15	2	35.0%	0.6	1.0	59.0	Sand / Gravel / Shells	5.6
5	20	nil					Sand / Gravel / Shells	5.6
6	25	4	53.8%	0.8	2.6	74.5	Sand / Gravel / Shells	5.6
7	30	3	61.1%	0.8	0.9	38.7	Sand / Gravel / Shells	5.4
8	35	nil					Sand / Gravel / Shells	5.3
9	40	1	66.7%	1.0	1.7	48.0	Sand / Gravel / Shells	5.3
10	45	8	60.0%	0.8	3.2	51.4	Sand / Gravel / Shells	5.2
11	50	9	44.1%	0.7	1.6	56.2	Sand / Gravel / Shells	4.9

Red Cove South Transect Summary

Transect Start at: 50 18.696 4 03.583
Transect End at: 50 18.677 4 03.553

Quadrat #	Distance (m)	No. of Plants per 0.0625 m²	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	0	1	80.0%	2.0	2.2	75.0	Gravel	5.0
2	5	5	59.0%	1.2	0.9	46.2	Gravel	5.1
3	10	8	77.7%	1.4	2.8	54.3	Gravel	4.9
4	15	2	33.3%	0.5	1.7	49.5	Gravel	5.0
5	20	nil					Gravel	5.1
6	25	12	36.9%	0.7	1.7	44.3	Gravel	5.1
7	30	15	57.7%	0.8	1.8	39.4	Gravel	5.2
8	35	15	35.3%	0.6	0.7	45.1	Gravel	5.3
9	40	12	55.3%	1.0	1.9	47.4	Gravel	5.2
10	45	14	67.1%	1.0	1.8	44.2	Gravel / Sand	5.3

Tomb Rock Summary

Central Datum Point at: 50 18.822 4 04.398

Quadrat #	Bearing (degrees)	Distance (m)	No. of Plants per 0.0625 m²	% Leaves Infected	Mean Infection Score	Mean Epiphyte Score	Mean Max Plant Length (cms)	Substrate	Depth (m)
1	0	50	nil					Fine Sand	6.2
2	90	50	nil					Fine Sand	6.1
3	180	50.0	15	29.6%	0.4	1.1	33.5	Fine Sand	7.2
4	270	50.0	nil					Fine Sand	7.2

Further information

Natural England evidence can be downloaded from our **Access to Evidence Catalogue**. For more information about Natural England and our work see **Gov.UK**. For any queries contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk** .

Report number RP0839
ISBN 978-1-78354-277-2

First Edition 17 December 2015