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Report on 2011 Isles of Scilly *Zostera marina* survey

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Foreword

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

Background

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

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

The objectives of this study were to continue annual survey effort on five main *Zostera marina* beds, for which data have been collected since 1992. The survey covered *Zostera* plant densities, mean maximum plant lengths, and levels of infection.

The results of this study will enable any changes to be monitored and so inform the site managers as to any adaptations that may need to be made to the future management of the SAC.

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Further information
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Isles of Scilly *Zostera marina* monitoring
2011 Expedition Report

Summary

5 people took part in the 2011 expedition to survey the Isles of Scilly *Zostera marina* beds during the week 1st to 5th August 2011. During this time, volunteer divers carried out full *Zostera marina* monitoring dives on the five main *Zostera* beds for which data has been collected since 1992.

Compared with levels recorded in 2010, *Zostera* plant densities were lower at all beds surveyed. At Old Grimsby Harbour the *Zostera* in the bay amongst the moorings was once again surveyed although it remains only in small, isolated patches. The bed at the south-east entrance to Old Grimsby Harbour appears to be in good health. Evidence of anthropogenic damage to the rhizome systems from the swinging mooring chains and trampling has been illustrated in previous reports. Whilst the author does not wish to suggest that the only cause of the loss of seagrass in Old Grimsby Harbour is anthropogenic impacts, it is worth highlighting the fact that at the south eastern edge of the bay, there are no moorings, the water is deeper and the *Zostera* is not so liable to trampling.

Mean maximum plant lengths were consistent with the patterns recorded in previous years. The bed with the longest mean plant length was that at Little Arthur in the Eastern Isles. All but beds had mean leaf lengths shorter than recorded in 2008.

Infection by the parasitic slime mould *Labrynthula* remains broadly at similar levels to those recorded in 2010 in most sites but all beds had lower percentage numbers of leaves infected. The bed with the lowest percentage amount of infection was again that at West Broad Ledge St. Martin's, while the bed with the greatest percentage amount of leaves infected was that at Higher Town Bay, St. Martin's.

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The author would also like to thank the following for the use of their photographs in this report:

- Tom Reid Cover Photograph
- Emma Kenyon Chain and Anchor photographs on page 12

Contents

List of tables

List of figures

1 Introduction

1.1 The Isles of Scilly are approximately 40km south west of Lands End and are the most westerly land mass of Great Britain. The archipelago is comprised of approximately 200 granite islands and rocks separated by a shallow sea. The seafloor between the islands is mainly comprised of a mixture of reefs, smaller pebbles and sands. Transport of sediments occurs throughout the archipelago. The pattern of sediment transport on Scilly tends to be from north to south (Futurecoast, 2002) in response to tidal currents. Wave energy drives transport from the west and east – this can tend to counteract the tidal current transport. There is however generally no dominant direction of net movement, due to the Islands exposure to waves and currents from all directions. Locally, sediment tends to be moved onshore in response to both wave and tide forcing. This tends to be in the form of larger coarser particles, while finer sediments tend to be moved offshore and lost to the system, due to the high-energy environment (Futurecoast, 2002).

1.2 The five main islands; St. Mary's, St. Martin's, Tresco, Bryher and St. Agnes are inhabited and support farming, fishing and are a popular tourist destination.

1.3 The islands are a variety of unique compositions of natural history as a result of the combination of their physical environment and climate. Rare indigenous plants, as well as exotics more characteristic of subtropical climates, thrive on the Islands. The low level of traffic on the roads and plentiful windbreaks made from hedges and pines provide ideal conditions for a variety of birds.

1.4 The marine environment is also shaped by the extreme physical conditions. The rocky shores of the western islands are so extreme that the scientific classification of shore-types had to be extended to include a special category for Scilly - the 'super-exposed'. Below the low-water mark, only those species that are able to withstand periodic inundations of the full force of the Atlantic are able to survive. On the more protected eastern seaboard by contrast, sheltered, deep-water habitats are home to colonies of various delicate species such as sea fans and branching sponges which often have southerly distributions.

1.5 At the opposite end of the scale of exposure to the battered western shores, the sea bed inside the archipelago is very sheltered. Sediments derived from the granite bedrock are carried by tides and waves into the sheltered inter-island basin and deposited there. These shallow and sheltered inter island waters provide an ideal marine environment for the growth of *Zostera marina*, which grows in large beds on the sandy sediments found there.

1.6 Seagrass beds were identified under Agenda 21 (United Nations, 1992) as being of vital importance and worthy of preservation. They are ecosystems of high productivity and are found in sheltered shallow marine conditions. They are also environmentally susceptible to natural and human related activities, such as climatic changes, sea level rise, dredging and fill activities, sedimentation, sewage discharge and shoreline development. *Zostera marina* is an important species both ecologically and economically because it provides critical habitat for a range of invertebrates and fish, it protects coastlines from erosion, leads to increased sedimentation and enhanced recycling of nutrients and improves water clarity (IGC, 1996).

1.7 *Zostera marina* is a marine angiosperm. The flowering plants appear markedly different from the non-flowering ones in that they have extended stems containing the flowers growing from the rhizomes with small leaves off the main stem. The leaves of the plants die back at the end of each summer / autumn and then regrow in the spring with the rhizomes, the root system, remain in place. However, although *Zostera* can reproduce both sexually and vegetatively Grassle and Grassle (1978) suggest that due to the vigorous rhizome growth of this and other seagrasses, and their wide distributions and ecological success, vegetative reproduction generally prevails. Flowering stems have been noted on several *Zostera* plants within the beds surveyed, however it is not known whether any of the resulting seeds are viable.

1.8 The distribution of *Zostera marina* along the south coast extends from the beds in the Isles of Scilly eastwards along the channel as far as Studland Bay in Dorset in full marine but sheltered conditions in sand or mud substrates. However, it can also found in some brackish lagoons such as the Fleet in Dorset.

1.9 Annual surveys of the *Zostera marina* beds around the Isles of Scilly began in 1984 by the Nature Conservancy Council and were continued until 1988. Following a gap of two year, 1988 and 1989, when no studies were carried out a further limited survey was done in 1991 (Fowler & Pilley, 1992). Volunteer groups have since carried out surveys every year from 1992 to 2004 (Raines *et al.*, 1993; Cleator *et al.*, 1996; Mackenzie & Rickards, 1996; Irving *et al.*, Irving and Mackenzie, 1997 and Irving *et al.*, 1998, Cook *et al.*, 2000, Cook *et al.*, 2001, Cook, 2002, 2003, 2004 2006 & 2007, Cook and Foden, 2005 and Cook and Paver, 2008). The initial surveys were only carried out on two sites, English Island, East Higher Town Bay, St. Martin's and at Old Grimsby Harbour on the east side of Tresco. Since then additional sites at East Broad Ledge, St Martin's and West Broad Ledge, Tresco were added and following the investigation of a RoxAnn identified site, a further Zostera bed was surveyed at Little Arthur in the Eastern Isles. To complete the set of beds surveyed, the beds at Rushy Bay, Bryher and Bar Point, St. Mary's were added in 2000 (Cook *et al.*, 2001) though due to time constraints these beds have not been surveyed annually.

1.10 In addition to the initial concerns relating to the population and concentration of the plants within the beds it was noted in the surveys of the beds between 1988 and 1991 that the plants were infected with the parasitic slime mould of the genus *Labrynthula sp*. more common known as wasting disease. The infection of the *Zostera* plants with *Labrynthula* caused widespread loss in many areas during the 1930s and 1940s including the Isles of Scilly and various other beds in the south-west (den Hartog, 1987). The surveys carried out by the Nature Conservancy Council during the years 1984 to 1988 reported no incidences of Labrynthula within the beds surveyed (Fowler & Pilly, 1992). Although no formal surveys of the beds were carried out in the years 1989 and 1990, Fowler (1992) reported that during the years 1988 to 1991, the health of the beds had shown a marked deterioration. The cause of this was attributed to *Labrynthula* and this was later confirmed by the Coral Cay Conservation Sub-Aqua Club expedition to the islands in 1992 (Raines *et al.*, 1993).

1.11 It is unclear what caused the reoccurrence of the infection in the beds in the Isles of Isles of Scilly although Cleator *et al.*, (1996) suggested a worsening in environmental conditions i.e. changed water temperature water flow and sedimentation or even changes in irradiance. Whatever the cause it was thought, however, thought that the increase in occurrence of *Labrynthula* was due to metabolic stress making the individual *Zostera marina* plants more susceptible to infection by reducing the amount of organic compounds involved in the resistance of disease and the growth of epiphytes on the leaves.

1.12 The disease first becomes apparent with the appearance of small black spots on the leaves. These then spread along the length of the leaf until the leaf can become so infected that photosynthesis is no longer possible and the leaf dies. If the infection is not severe the plant will remain viable and continue to grow. However, should the infection continue for a number of years the leaf loss may cause the rhizomes to also become infected and cause the plant to die (den Hartog, 1989). This die back has yet to be confirmed in the beds around the Isles of Scilly.

1.13 The natural environment of the Isles of Scilly is protected through a series of terrestrial SSSIs (Sites of Special Scientific Interest) and the whole archipelago is designated as both an SAC (Special Area of Conservation) and SPA (Special Protection Area).

1.14 Zostera marina beds are a sub-feature of both:

- 1110 Sandbanks which are slightly covered by sea water all the time; and
- 1140 Mudflats and sandflats not covered by seawater at low tide

They are included “because of the diversity of species they may support and their general scarcity in UK waters” (JNCC).

1.15 Maintaining Seagrass beds in “favourable condition” is one of the Conservation Objectives for the Isles of Scilly Marine SAC (Natural England, 2010). The attribute table in which by which “favourable condition” is defined are included as Annex 1.

1.16 Measured during the 2011 survey were plant density within each bed, number of leaves and maximum leaf length per plant, the amount of *Labrynthula* infection and epiphytic cover with each bed. The results of these are included in Chapter 4.

1.17 Further groundtruthing of the extent work undertaken by Emma Jackson (2011) was also carried out. These results are included in Chapter 7.

2 The 2011 survey

Survey organisation and finance

2.1 The 2011 survey took place between 1st and 5th August 2011 and was the eighteenth consecutive year in which volunteers visited the Isles of Scilly to survey the coastal waters around the islands.

2.2 The survey was planned and led by Kevan Cook. Other members of the expedition team carried out various tasks associated with the work of the expedition.

2.3 The following people took part in the 2009 Isles of Scilly Survey:

- Kevan Cook;
- Olle Akesson;
- Jim Bull; and
- Emma Kenyon.

2.4 The team used the RIB Eva as their dive platform and for the survey. In this we were greatly assisted by Cyril Nicholas from Natural England who acted as Cox'n and guide around the islands.

2.5 The survey was funded in part by volunteer contributions and by a grant from Natural England to whom the author would like to acknowledge the continuing part they have played in maintaining the surveys.

3 Survey methodology

3.1 At each one of the five survey sites, a central datum line was lowered to the sea floor from which all bearings and distances were measured. The position of this line was chosen by eye to be approximately central in the bed to be surveyed by means of a surface swim over the bed to determine its extent. Care was also taken to ensure that the datum marker was located in a sand patch within the bed to avoid disturbing any plants. Once the central line was positioned, pairs of divers were then sent to take samples from points at randomly selected distances, between 0 and 30m, and bearings, between 0° and 359°, from the central line. At each of the sites, a 0.25m^2 quadrat, constructed of a 0.5m by 0.5m square constructed from copper tubing was positioned so that the bottom left hand corner of the quadrat lay against the right hand edge of the tape at the indicated distance. The bearing and distances used during the 2011 survey are attached as Annex 2.

3.2 The positions of the central datum marker for the beds surveyed during the 2011 survey were obtained using differential GPS and are correct to WGS84.

Table 1 Location of central datum point for survey sites

Site	Latitude (N)	Longitude (W)	Date surveyed	Max depth (m)
Old Grimsby Harbour, Tresco	49 57.611	006 19.796	2nd August	3.9
Higher Town Bay, St. Martin's	49 57.431	006 16.443	2nd August	0.2
Broad Ledge, Tresco	49 56.394	006 19.774	3rd August	5.7
West Broad Ledge, St. Martin's	49 57.440	006 18.296	4th August	1.2
Little Arthur, Eastern Isles	49 56.947	006 15.917	3rd August	2.5

3.3 The bearing was measured using a standard diver's compass and the distance from the central line was measured using a marked tape. 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 later analysis. Care was taken to ensure that only the plants with their rhizomes directly under the quarter square were taken by ensuring that all leaves were traced to the base.

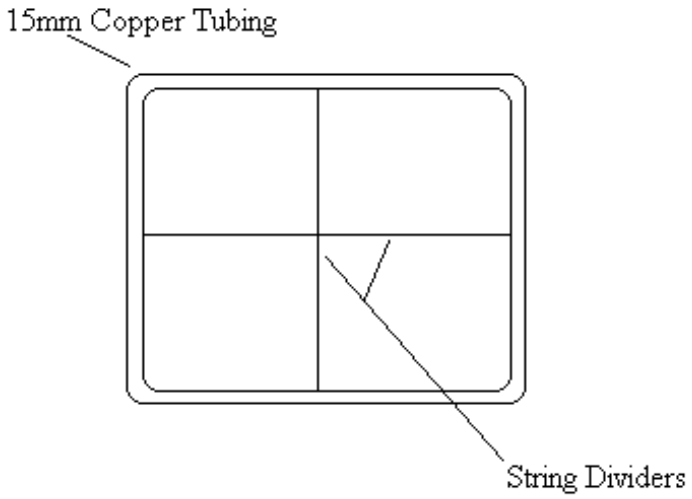

Figure 1 A quadrat

3.4 For each sample bag the following variables were recorded:

- Bearing and distance at which the sample was taken;
- Number of plants per bag;
- Maximum plant length;
- Amount of Labrynthula infection;
- Amount of epiphytic cover;
- Number of flowering plants; and
- Number of eggs on leaves.

Table 2 Scoring system for leaf infection and epiphyte cover

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

Figure 2 Zostera plant showing both clean leaves, infection and epiphyte cover

3.5 The data were initially recorded on a preformatted sheet and transferred onto an Excel spreadsheet for further analysis where the following were calculated:

- The density of plants per 0.0625m2.
- One-way Analysis of Variance (ANOV) on maximum leaf length and percentage of infected leaves between the different sites surveyed to examine if any significant difference (with a 95% confidence level) exists between the five sites.
- Correlation matrix of the variable listed above to investigate the existence of any relationship between these variables.
- Frequency analysis of longest leaf length to investigate the population structure at the five sites.

4 Data analysis

4.1 The five main sites were sampled between the 2nd and 4th August 2011 from the dive boat EVA.

Table 3 Summary of *Zostera* analysis, 2011 survey

	Old Grimsby Harbour, Tresco	Higher Town Bay, St. Martin's	Broad Ledge, Tresco	West Broad Ledge, St. Martins	Little Arthur, Eastern Isles
Total number of quadrats	25	25	24	22	24
Number of empty quadrats	14	2	10	2	1
Total number of plants	66	217	74	110	168
Total number of leaves	277	783	323	454	667
Percentage leaves infected	61.9	70.7	60.6	60.2	69.3
Mean infection score	1.04	1.16	0.98	1.01	1.03
Mean epiphyte score	2.02	1.66	0.95	2.46	1.48
Mean plant length (cm)	52.6	43.6	33.3	68.3	98.6
Standard deviation of plant length	17.0	20.8	15.6	26.7	27.6
Mean plant density / 0.0625m^2	2.64	8.68	3.08	5.00	7.00
Mean biomass index	138.9	378.4	102.7	341.5	690.2
Number of flowering plants	0	4	0	3	2
Percentage of flowering plants	0.0	1.8	0.0	2.7	1.2
Plant density ignoring empties	6.00	9.43	5.29	5.50	7.30
Mean number of leaves per plant	4.2	3.6	4.4	4.1	4.0

4.2 The number of null bags recorded at each of the sites surveyed is included to allow a fuller plant density comparison between sites.

Time series analysis – Percentage leaf infection

Table 4 Percentage number of leaves infected per site

	Old Grimsby Harbour, Tresco	Higher Town Bay, St. Martin's	Broad Ledge, Tresco	West Broad Ledge, St. Martin's	Little Arthur, Eastern Isles
August '11	62	71	61	60	69
August '10	n/a	74	76	78	75
August '09	65	62	75	80	52
July '08	70	75	75	80	68
August '07	58	57	56	65	47
August '06	57	64	60	60	63
August '05	43	70	70	73	57
August '04	47	79	76	56	68
July '03	52	69	65	70	73
August '02	68	53	71	74	63
August '01	51	65	76	66	86
August '00	47	56	65	60	58
August '99	60	67	71	69	52
August '98	57	67	76	61	65
August '97	43	37	44	49	n/a
July '96	69	63	61	n/a	n/a
June '95	63	42	n/a	n/a	n/a
August '94	56	79	n/a	n/a	n/a
July '93	59	65	n/a	n/a	n/a

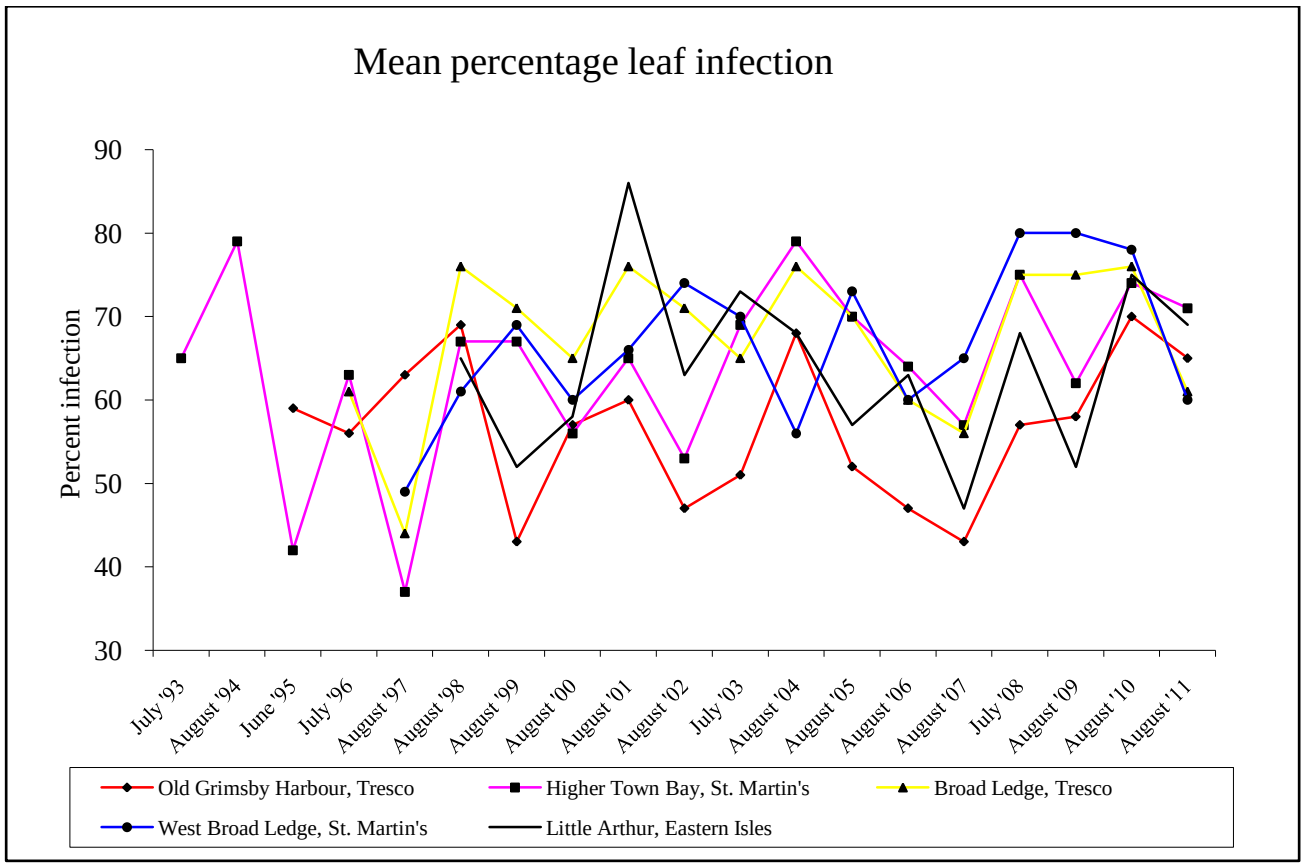

Figure 3 Percentage number of leaves infected per site

Time series analysis – Plant density

Table 5 Average plant density (plants per 0.0625m^2) per site

	Old Grimsby Harbour, Tresco	Higher Town Bay, St. Martin's	Broad Ledge, Tresco	West Broad Ledge, St. Martin's	Little Arthur, Eastern Isles
August '11	2.64	8.68	3.08	5.00	7.00
August '10	n/a	9.48	3.96	8.00	10.60
August '09	9.64	7.72	5.24	6.64	9.32
July '08	1.72	11.32	3.24	6.60	11.28
August '07	4.17	13.80	5.44	7.68	12.00
August '06	3.68	9.67	6.92	9.48	8.62
August '05	4.60	10.36	4.32	6.28	8.40
August '04	5.96	11.64	8.40	3.28	12.08
July '03	7.37	9.90	9.73	4.80	11.19
August '02	4.83	7.21	11.10	1.96	11.60
August '01	5.44	12.24	7.80	4.72	8.76
August '00	2.48	11.44	10.40	4.92	9.50
August '99	3.62	10.20	9.17	5.12	9.84
August '98	7.32	14.08	4.20	7.36	8.28
August '97	6.78	11.79	4.96	8.21	n/a
July '96	7.17	15.96	7.50	n/a	n/a
June '95	n/a	n/a	n/a	n/a	n/a
August '94	8.83	9.64	n/a	n/a	n/a
July '93	4.05	5.45	n/a	n/a	n/a

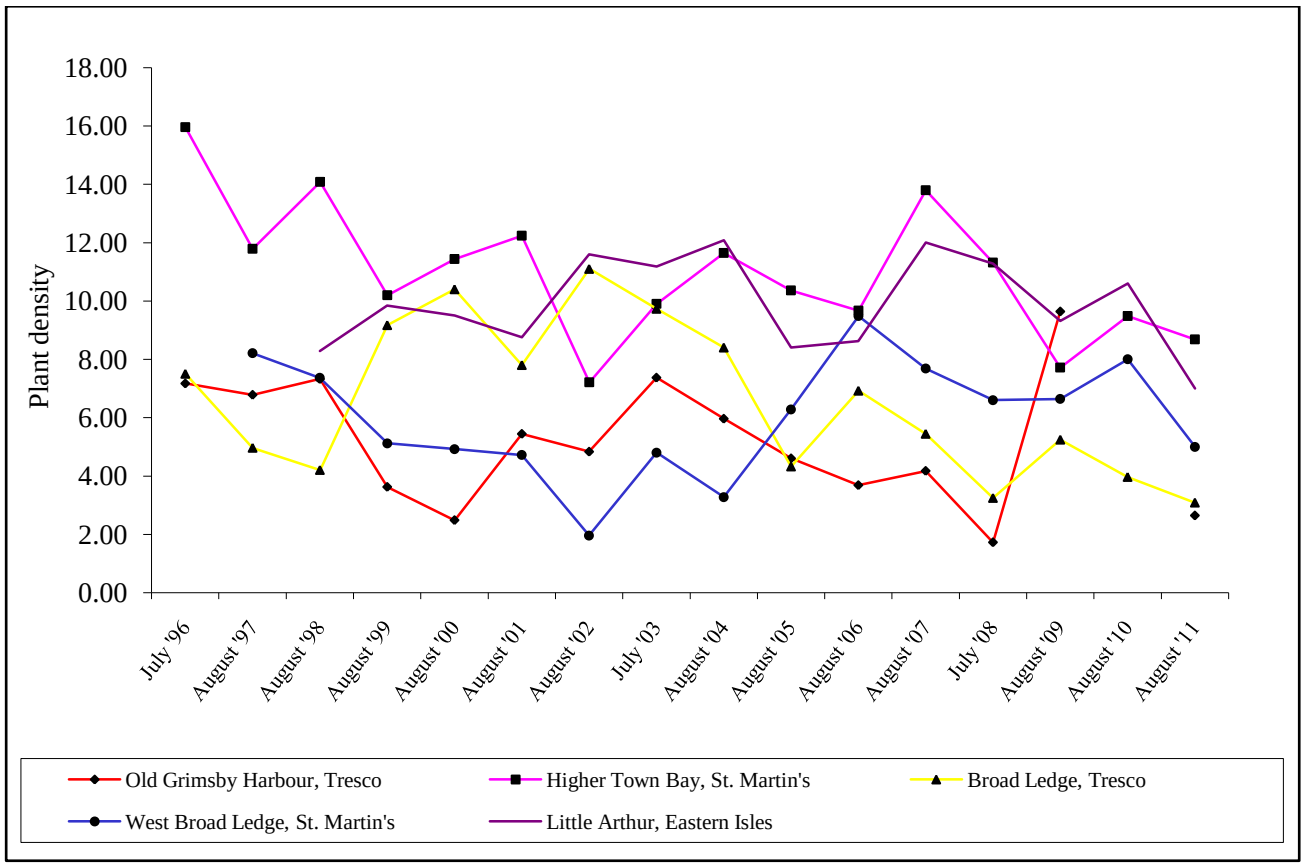

Figure 4 Average plant density (plants per 0.0625m^2) per site

Time series analysis – 5 year average plant density (plants per m^2)

Table 6 5 year average plant density (plants per m^2)

	Old Grimsby Harbour, Tresco	Higher Town Bay, St. Martin's	Broad Ledge, Tresco	West Broad Ledge, St. Martin's	Little Arthur, Eastern Isles
August '11	72.7	163.2	67.1	108.5	160.6
August '10	76.8	166.4	79.4	122.9	165.8
August '09	76.2	169.2	80.5	117.4	158.8
July '08	64.4	181.7	90.6	106.6	167.6
August '07	82.5	177.2	111.4	100.9	167.3
August '06	84.6	156.1	129.5	82.6	166.0
August '05	90.2	164.3	132.3	67.3	166.5
August '04	83.5	167.8	151.8	63.0	170.0
July '03	76.0	163.2	154.2	68.9	162.8
August '02	75.8	176.5	136.5	77.1	153.5

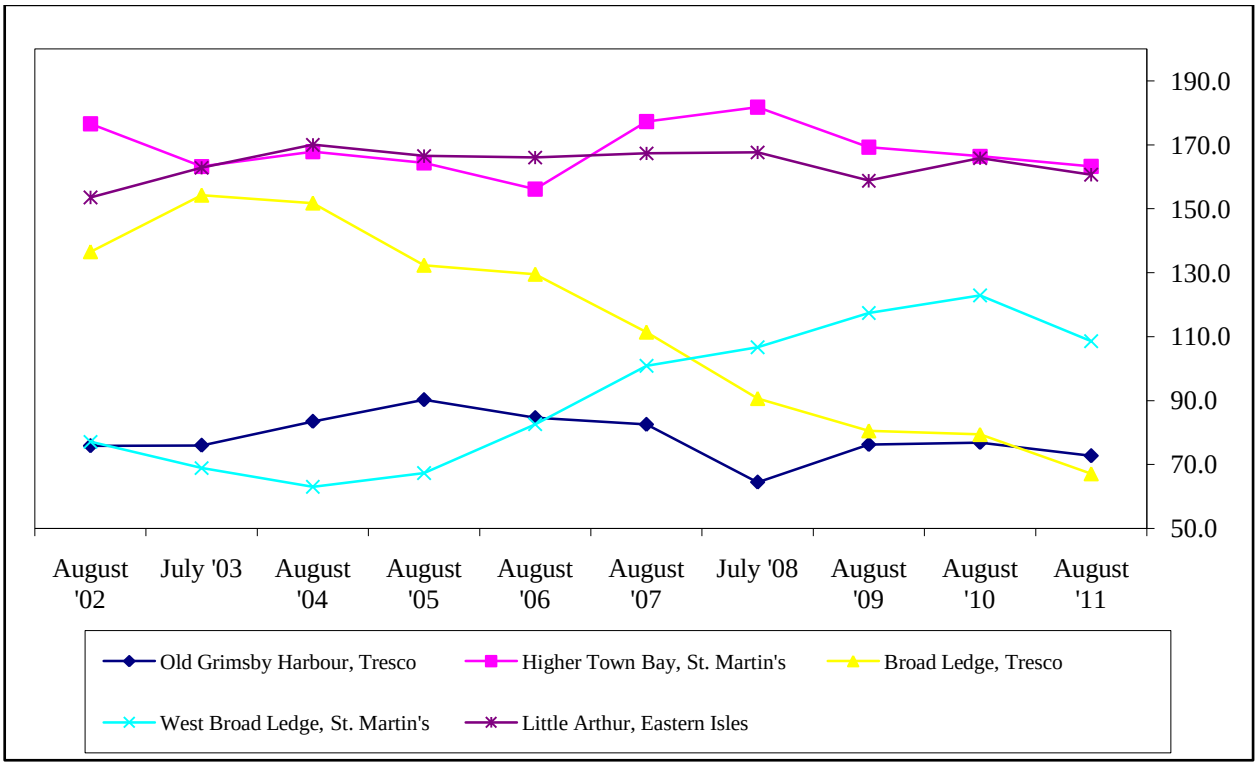

Figure 5 5 year average plant density (plants per m^2)

Time series analysis – Mean maximum plant length

Table 7 Mean maximum plant length (cms)

	Old Grimsby Harbour, Tresco	Higher Town Bay, St. Martin's	Broad Ledge, Tresco	West Broad Ledge, St. Martin's	Little Arthur, Eastern Isles
August '11	52.6	43.6	33.3	68.3	98.6
August '10	n/a	65.4	44.5	74.5	85.9
August '09	41.1	46.1	46.8	63.3	99.4
July '08	62.7	40.9	39.7	54.0	67.2
August '07	39.8	44.4	52.4	56.8	85.8
August '06	56.8	46.2	39.1	56.3	95.6
August '05	45.1	47.5	47.8	69.5	90.9
August '04	33.2	47.8	45.4	44.7	69.5
July '03	39.1	44.3	40.2	72.6	74.8
August '02	43.8	34.8	34.0	55.8	85.6
August '01	33.8	41.0	47.4	45.3	69.5
August '00	38.9	39.9	32.7	53.3	89.2
August '99	37.5	45.8	40.4	64.5	79.0
August '98	29.0	50.0	47.0	62.0	86.0
August '97	49.0	48.0	41.0	53.0	n/a
July '96	59.0	54.0	40.0	n/a	n/a
June '95	n/a	n/a	n/a	n/a	n/a
August '94	56.8	61.0	n/a	n/a	n/a
July '93	69.4	48.8	n/a	n/a	n/a

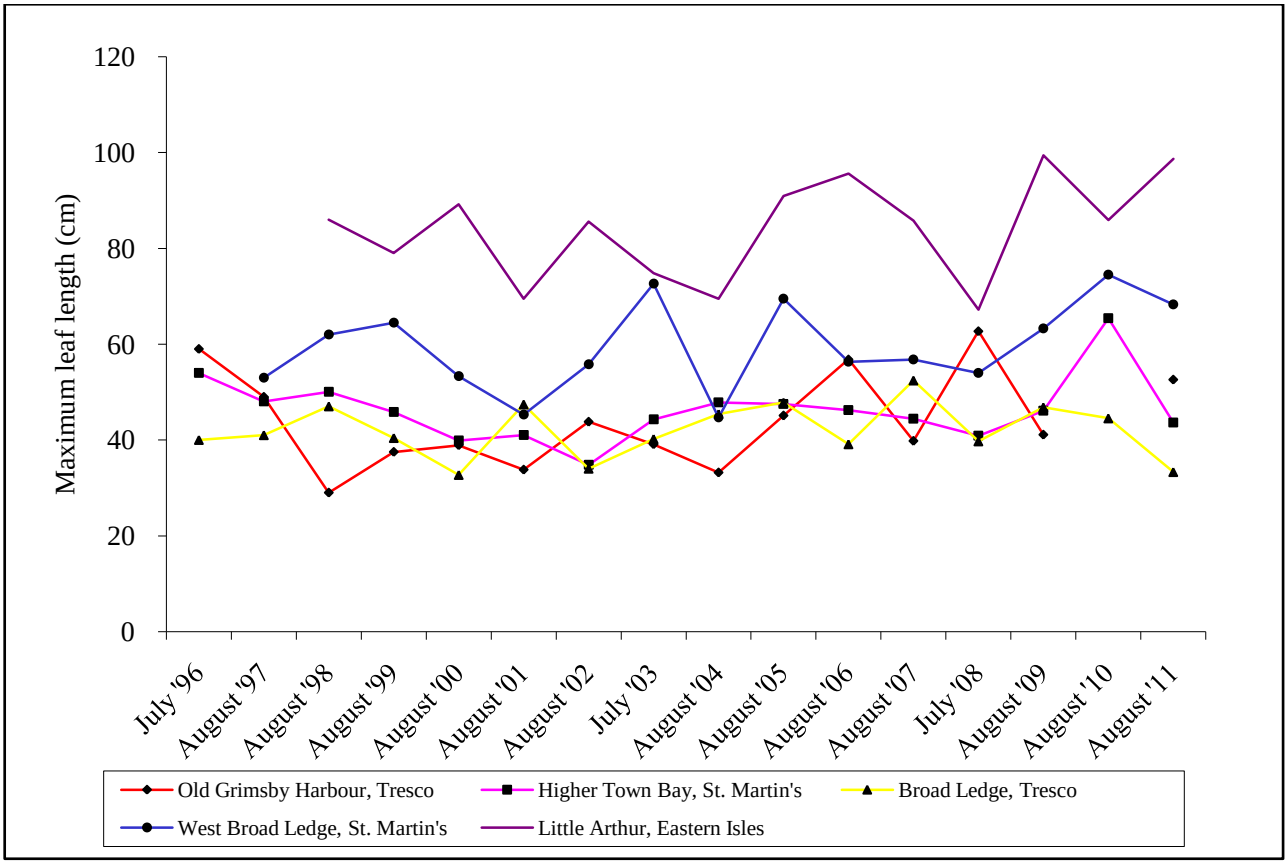

Figure 6 Mean maximum plant length (cms)

5 Individual bed analysis

Old Grimsby Harbour, Tresco

5.1 The bed lies along the southern edge of the natural harbour formed by the small bay on the eastern side of Tresco that forms one of the main access points to the island from the sea. Although this access is dependent on the state of the tide, a large number of boats use the stone quay situated in the centre of the western side of the bay. The bay is found on the eastern side of the island and it provides shelter for both the visiting boats that anchor on the edge of the bay and local boats that use the permanent mooring buoys in the bay, from the prevailing south westerly winds. As a result of the large tidal range experienced throughout the whole of the Isles of Scilly, large areas of the bay are exposed at low water. This includes the southern edge of the *Zostera* bed which lies close to one of the beaches used by visiting tourists.

5.2 Here, the water depth along the southern edge of the *Zostera* bed is shallow enough to allow trampling of the plants. Cook *et al*., (2001), Cook (2002), (2003) and 2004 described the highly patchy nature of the bed at this location. It was suggested that the movement of the mooring chains might be one factor. These moorings are anchored to base weight by means of a heavy sinker chain with a large buoy on the surface. The chains have to be long enough to allow for the rise and fall of the tide, which means that at low water there is a large amount of chain lying on the sea floor and over the *Zostera* plants. As the direction of the wind changes the moorings move round causing the chains to be dragged over the plants. This can cause plants to be dislodged and even for the rhizomes to be damaged. The presence of exposed and dislodged rhizomes within the arc of the chains movement confirms this theory.

Figure 7 Mooring chain in *Zostera*

Figure 8 Anchor in *Zostera*

5.3 Although Cook *et al*., (2001) did not find any direct correlation between the position of the buoys and the patches it was suggested that this was possibly due to the extreme patchiness of the bed and the overall low plant density during the 2000 survey. Surface swims during the 2001 (Cook, 2002) and 2002 (Cook, 2003) surveys during a period of higher plant densities, confirmed the continued patchy nature of the growth. This was further confirmed by the transect survey introduced by Cook during the 2003 survey (Cook, 2004). The correlation of the patches with the positions of the mooring chains described by Cook (2002) was again noted during the 2004 survey. There was clear evidence that the rhizomes forming the base of the *Zostera* bed had been removed within the swinging range of the mooring chains.

5.4 Since the warning issued in the report of the survey of this *Zostera* bed in 2000 (Cook *et al*., 2001) plant density has declined from 8.38 plants per 0.0625m^2 in 1994 to a low of 1.72 plants per 0.0625m^2 in 2008. In 2008 a separate smaller beds was identified to the south east of the usual survey area. The 2008 survey examined both of these beds for comparison and an attempt was made to do so again during the 2009 survey. However, so little seagrass was recorded at the original site in 2009 that only the new bed was fully surveyed. Therefore, although the data for Old Grimsby Harbour recorded above appear to show a recovery in the site, the majority of the seagrass from within the bay has gone.

5.5 The 2011 survey was again centred on the original site within the moorings. This is reflected in the mean plant density of 2.64 plants per 0.0625m^2 which should be compared with the mean plant density of 1.72 per 0.0625m^2 recorded in 2008. However, for the purposes of the five year rolling mean analysis, the two sites are treated as a single bed.

5.6 The health of the bed is in line with that recorded in other beds. The amount of infection in the leaves, as recorded by the mean percentage number of infected leaves (62%) was towards the lower end of values recorded during the 2011 survey, and slightly lower than the amount recorded in 2009. The mean infection score was 1.04 and mean epiphyte score was 2.02.

5.7 The seabed at Old Grimsby Harbour was described by Cook (2003) as being mainly medium sand overlaid with *Zostera* intermixed with some over lying loose macro algae. This was confirmed by the transect survey where all the survey points recorded sand. No *Sargassum* was noted on any of the survey swims though this is probably due the lack of any suitable holdfasts being present as *Sargassum* is found in several other locations around Tresco. It should also be noted that during the 2011 survey, large quantities of green and brown algal masses were recorded across the site of the old bed. Although hydrological modelling has been undertaken, there does appear to be a gyre that traps algae within the bay.

Table 8 Survey results from Old Grimsby Harbour

Bearing	Distance	No. of plants	% Leaves infected	Mean infection score	Mean epiphyte score	Mean max plant length
252	29.6	0	n/a	n/a	n/a	n/a
307	22.8	0	n/a	n/a	n/a	n/a
318	18.1	0	n/a	n/a	n/a	n/a
243	19.4	0	n/a	n/a	n/a	n/a
228	18.9	0	n/a	n/a	n/a	n/a
220	5.7	0	n/a	n/a	n/a	n/a
307	16.2	0	n/a	n/a	n/a	n/a
209	19.8	0	n/a	n/a	n/a	n/a
290	23.5	0	n/a	n/a	n/a	n/a
155	25.6	0	n/a	n/a	n/a	n/a
153	17.1	0	n/a	n/a	n/a	n/a
43	15.6	0	n/a	n/a	n/a	n/a
158	22.6	0	n/a	n/a	n/a	n/a
41	22.9	0	n/a	n/a	n/a	n/a
20	25.2	11	62%	1.00	2.09	59
119	27.4	8	58%	0.93	1.92	62
100	24.4	4	78%	1.01	1.70	59
100	17.2	8	72%	1.05	1.95	55
335	26.6	3	44%	0.72	1.39	54
127	7.5	4	35%	0.85	2.52	35
83	17.8	6	66%	1.23	2.46	29
347	21.9	9	59%	0.93	2.02	59
331	27.1	4	78%	1.50	2.11	66
193	12.0	4	60%	1.13	1.52	47
102	11.3	5	60%	1.12	2.20	40

Higher Town Bay, St. Martin's

5.8 The bay is situated on the southern edge of St. Martin's and is bounded by Cruther's Point to the west and English Point to the east. A small stone harbour, which acts as one of the main access points to the island from the sea, is situated at the western end of the bay. The bay is also used as an anchorage for a number of small vessels and the fringing beach and dune system are a popular destination for tourists.

5.9 The *Zostera* bed lies at the eastern end of the bay and runs from English Island along the edge of the bay. Strong tidal streams flow across the bay and the bed is also exposed to the prevailing south-westerly winds. The sea floor here is comprised of medium sands which, given the strong tidal streams, is liable to erosion. This sediment movement and erosion is prevented in some places however by the *Zostera* rhizomes that help bind the sand and also promote accretion to the extent that the *Zostera* forms prominent platforms that stand up to 20 to 30cm above the surrounding sea floor.

5.10 The strong tidal streams bring large fronds of loose macro algae from the rocky ground of the Eastern Isles and although there are very few other species growing here, there are large loose fronds of transported material that overlie the *Zostera*. The bed at Higher Town Bay is highly patchy in nature but where the *Zostera* rhizomes are well established, the plant density is high.

5.11 The mean plant density was 8.68 plants per 0.0625m^2. This is lower than the 9.48 plants per 0.0625m^2 recorded in 2010 but still well above the low of 7.21 plants per 0.0625m^2 recorded in 2002. The percentage number of infected leaves was 71%, with the mean infection score of 1.16 and mean epiphyte score of 1.66. The mean maximum plant length was 43.6cms, 21.8 cms shorter than recorded in 2008.

5.12 The seabed is a mix of sand and coarser material, mainly small gravel. Two *Sargassum* plant were noted. It is possible that the strength of the tide across the bed washes most of the *Sargassum* plants off the site given that any suitable holdfast is not enough to maintain a stationary position.

5.13 Examination of the edge of the *Zostera* platforms again showed exposed rhizomes and some obvious signs of erosion. The edges of the platforms are open to a variety of forces which might lead to their reduction and although the reasons for this erosion and hence reduction in the area of the bed are not clear there are several possible reasons.

- The strong tidal streams that flow across the bay may erode the base of the platform and cause the collapse of the overlying rhizome system.
- The bed is the shallowest of all those found in the Isles of Scilly, it is exposed at low water springs and as it is also exposed to the south-westerly winds, wave action will erode the edges of the bed.
- The proximity of the bed to the beach and the shallowness of the bed mean that it is liable to trampling; however this is not thought to be a major problem.

Table 9 Survey results from Higher Town Bay, St. Martin's

Bearing	Distance	No. of plants	% Leaves infected	Mean infection score	Mean epiphyte score	Mean max plant length
75	27.8	0	n/a	n/a	n/a	n/a
65	28.7	0	n/a	n/a	n/a	n/a
151	15.7	1	100%	2.00	1.00	15
156	21.7	6	67%	1.08	0.99	30
143	24.6	9	78%	1.84	1.29	24.0
137	24.7	12	77%	1.53	1.86	44.0
27	4.5	3	89%	1.78	1.11	21.0
111	22.2	4	64%	1.30	1.43	32.0
157	19.7	3	75%	1.17	1.11	19.0
65	16.4	16	51%	0.63	0.72	32.0
192	5.1	10	76%	1.22	1.53	33.0
304	17.0	13	65%	0.78	1.92	68.0
198	7.6	2	79%	1.08	2.54	32.0
310	27.9	10	81%	1.68	1.63	48.0
214	11.7	8	61%	0.98	1.52	50.0
247	28.9	19	70%	0.94	1.87	27.0
219	17.4	11	76%	1.23	1.52	41.0
242	23.2	14	58%	0.94	1.92	76.0
89	28.8	23	77%	1.17	1.75	69.0
358	22.5	9	79%	1.34	2.54	39.0
167	17.9	10	78%	1.38	2.03	25.0
201	19.4	1	50%	0.50	2.25	43.0
80	9.1	25	72%	1.10	1.15	43.0
316	20.5	4	88%	1.56	2.21	36.0
33	28.0	4	38%	0.52	2.08	30.0

Broad Ledge, Tresco

5.14 Broad Ledge lies on the southern edge of Tresco and together with Crab Ledge, Tobaccoman's Ledge and Green Island to the east, forms part of the large inter-tidal area that fringes the southern coast of Tresco. There is a small jetty that allows access to the island from the sea and is used by tourist boats when the tide allows. The bay is used on an occasional basis as and anchoring point for smaller yachts. The area is open to the prevailing south-westerly winds and weak tidal streams. The seabed here is comprised of coarse sand, mixed with small gravel, pebbles and some cobbles and some *Sargassum muticum* plants and small macro algae can be found attached to the small material. Despite the presence of the macro algae, the *Zostera* bed here is extensive and competes well with the other species.

5.15 The plant density, as recorded by the random sample point survey, was 3.08 plants per 0.0625m^2, the lowest density recorded at this site since surveys began.

5.16 This bed has shown signs of general decline in the past years and the density has more than halved from the high of 11.10 plants per 0.0625m^2. It is hard to identify a cause for this site. It continues to be one of the most exposed sites in the Isles of Scilly to the prevailing south westerly wind and waves. However, the author has no data on the frequency or severity of the weather patterns in Scilly.

5.17 The site does have yachts anchor there but this is infrequent to the more exposed nature of the location. The bed is close to the works that took place in 2008 to repair and extend the pier at Carn Near. However, no signs of disturbance nor plant smothering were recorded The seabed is comprised of sand with 'one or two small stones' to which a *Sargassum* plant could attach.

Table 10 Survey results from Broad Ledge, Tresco

Bearing	Distance	No. of plants	% Leaves infected	Mean infection score	Mean epiphyte score	Mean max plant length
78	19.4	0	n/a	n/a	n/a	n/a
30	19.8	0	n/a	n/a	n/a	n/a
22	10.9	0	n/a	n/a	n/a	n/a
292	3.9	0	n/a	n/a	n/a	n/a
258	9.0	0	n/a	n/a	n/a	n/a
314	4.8	0	n/a	n/a	n/a	n/a
157	8.7	0	n/a	n/a	n/a	n/a
212	12.9	0	n/a	n/a	n/a	n/a
92	15.1	0	n/a	n/a	n/a	n/a
229	5.9	0	n/a	n/a	n/a	n/a
139	12.5	4	77%	1.17	1.02	44.0
5	23.7	17	74%	1.18	0.90	47.0
78	23.6	13	64%	0.85	0.76	53.0
60	13.6	6	33%	0.50	0.28	22.0
50	19.5	2	71%	1.42	0.38	31.0
72	23.8	1	0%	0.00	0.50	10.0
111	29.4	8	55%	0.88	0.52	23.0
156	18.1	3	59%	0.70	0.72	34.0
348	29.9	2	50%	0.75	0.75	8.0
29	23.8	2	38%	0.75	0.96	19.0
282	28.5	6	54%	0.74	1.40	34.0
35	8.6	6	60%	0.97	1.44	39.0
81	26.3	13	62%	1.13	1.15	22.0
359	12.3	12	67%	1.26	1.38	26.0

West Broad Ledge, St. Martin's

5.18 West Broad Ledge lies on the south-western edge of St. Martin's and on the southern edge of the channel between St. Martin's and the island of Tean. This channel is used by pleasure boats navigating between the islands but not often as an anchoring point as boats generally choose to anchor further to the north of the access jetty. The seabed is comprised of medium and coarse sand with small gravel and pebbles on which some fronds of *Sargassum* and other species of small macro algae were noted. The *Zostera* bed covers a wide area but is highly patchy in nature. The bed is also swept by strong tidal currents, especially on spring tides.

5.19 During the 2002 survey, Cook (2003) reported that the mean plant density had fallen every year since recording began at this site in 1997, from 9.52 plants per 0.0625m^2 to 1.96 plants per 0.0625m^2 in 2002. At this stage, the bed was in danger of declining to the point where was in danger of disappearing altogether. Since that report, plant density has recovered well and the 2011 survey recorded a plant densitiy of 5.00 plants per 0.0625m^2. The bed, although swept by currents does not suffer from the anchor or mooring chain damage seen at Old Grimsby Harbour, Tresco. Cook (2003) stated that the reason for the fall in density was not clear and this is still the case.

5.20 The mean percentage number of infected plants was again static at 60%, the lowest amount recorded in 2011. The mean infection score was 1.01 and the mean epiphyte score was 2.46, the highest recorded at any bed in 2011.

Table 11 Survey results from West Broad Ledge, St. Martin's

Bearing	Distance	No. of plants	% Leaves infected	Mean infection score	Mean epiphyte score	Mean max plant length
101	24.3	0	n/a	n/a	n/a	n/a
123	11.9	0	n/a	n/a	n/a	n/a
347	20.1	5	60%	1.08	2.82	80
362	15.1	4	74%	1.41	3.16	93
351	17.0	2	46%	0.91	1.91	27
68	19.5	2	38%	0.68	1.25	28
242	22.2	2	67%	1.50	2.67	63
329	12.9	4	77%	1.31	2.54	66
98	17.2	3	77%	1.07	3.12	50
74	13.9	9	61%	1.11	2.09	100
112	28.7	5	62%	1.34	2.20	43
274	6.8	4	5%	1.25	3.00	102
164	10.9	2	30%	0.50	3.20	69
320	22.3	5	68%	1.25	3.12	71
58	25.3	4	42%	0.68	2.36	47
172	27.8	7	58%	1.08	2.50	65
250	18.7	6	73%	1.06	1.99	51
88	5.1	12	76%	1.28	2.06	55
220	14.1	7	69%	0.95	2.38	49
183	24.8	7	33%	0.40	2.11	50
158	16.5	8	61%	0.93	2.59	106
40	25.5	12	49%	0.59	2.69	76

Little Arthur, Eastern Isles

5.21 This bed lies in the Eastern Isles and to the east of Little Arthur where it is sheltered from the prevailing south-westerly winds and strong currents that flow round the islands. The Eastern Isles are also home to a colony of Grey Seals which attract boats of tourists who come to view them. Few of these boats, however, anchor here and impact the *Zostera* bed. The majority of the substrate within the islands is comprised of bedrock and large boulders which are covered by dense growths of macro algae. The *Zostera* patch, however, lies in a small patch of medium sand. Despite the large amount of surrounding macro algae, the *Zostera* bed is relatively free from any covering plants. This is one of the deepest beds surveyed in the islands and although small in area, exists as a complete single bed with few significant patches.

5.22 As noted above, this bed is unique within the Isles of Scilly in that it is well defined, being confined by the geology of the area and exists as a near complete bed with only a few small bare patches. The mean plant density recorded at this site during the 2011 survey was 7.00 plants per 0.0625m^2, down from 10.60 plants per 0.0625m^2 in 2010. The mean percentage number of

leaves infected was 69%, lower than recorded in 2010. The mean infection and epiphyte scores were 1.03 and 1.48 respectively. The mean maximum plant length was 98.6cms. It is also worth noting that only one of the the 24 sample bags were null or empty again evidence of the homogeneous nature of this bed.

Table 12 Survey results from Little Arthur, Eastern Isles

Bearing	Distance	No. of plants	% Leaves infected	Mean infection score	Mean epiphyte score	Mean max plant length
303	22.2	0	n/a	n/a	n/a	n/a
133	19.1	6	65%	1.15	1.79	99
216	17.8	4	69%	1.13	1.69	89
130	20.6	4	53%	0.99	1.41	116
239	23.9	6	68%	1.16	1.54	90
269	12.5	11	63%	1.05	1.57	97
79	25.2	8	69%	1.19	1.72	89
12	29.7	8	74%	1.25	2.02	102
58	10.8	6	74%	1.44	1.99	105
52	29.8	8	75%	1.07	1.79	90
218	28.3	10	72%	1.19	1.86	115
78	10.2	13	69%	0.86	1.43	138
130	23.6	4	69%	0.88	1.38	103
301	29.1	12	68%	1.00	1.52	98
5	13.6	7	67%	0.89	1.18	113
171	27.2	7	63%	0.76	1.60	55
181	12.6	3	78%	1.00	1.67	38
125	4.3	7	70%	0.89	1.21	88
353	16.5	10	63%	0.76	0.78	81
0	9.4	10	64%	1.06	1.16	87
169	21.2	10	72%	0.99	1.12	103
160	23.9	7	83%	1.02	1.12	100
127	26.9	6	81%	1.22	1.42	117
71	15.8	1	75%	0.75	1.48	99

6 *Zostera* survey conclusions

Favourable condition monitoring

6.1 The favourable condition table for the Isles of Scilly European marine site sets five targets in the assessment of the *Zostera marina* beds sub feature of Sub-tidal sandbanks. These are:

1) No decrease in extent from an established baseline, subject to natural change.
2) Average light attenuation should not decrease significantly from an established baseline, subject to natural change.
3) Average density should not deviate significantly from an established baseline, subject to natural change.
4) Presence and abundance of epiphytic species should not increase significantly from an established baseline, subject to natural change.
5) No increase in extent of green algal mats from an established baseline, subject to natural change.

6.2 The 2011 survey set out to examine attributes 3 and 4. Attributes 1, 2 and 5 were beyond the capability of the team to deliver.

Mean plant density

6.3 Table 5 gives a rolling five year average of mean plant density since 2002. The only individual bed that is showing a long term decline is that at Broad Ledge, Tresco.

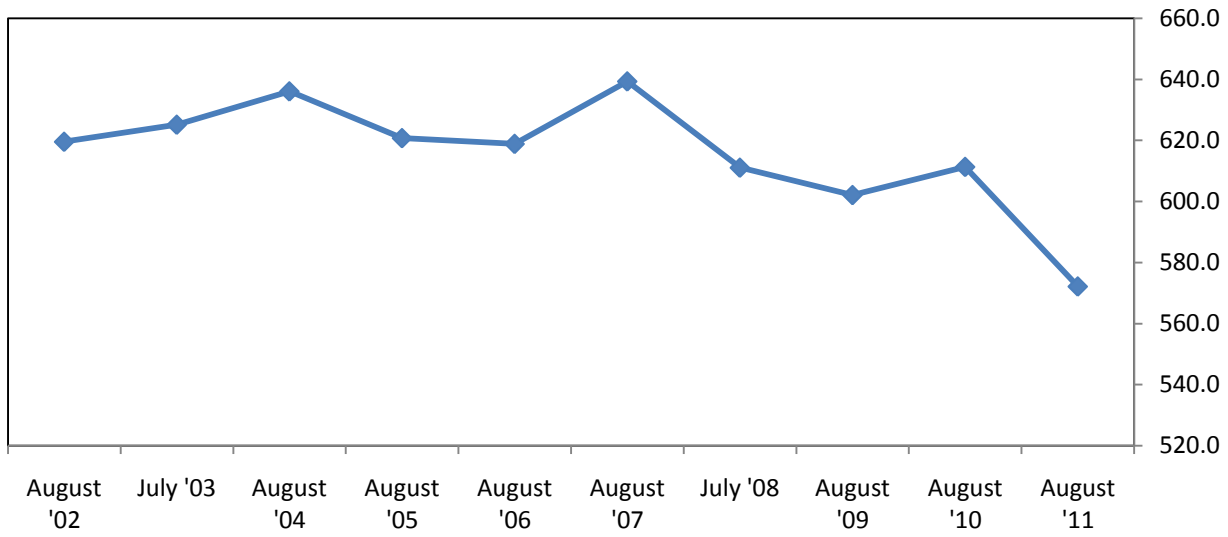

Figure 9 Rolling 5 year mean of plant density for the five main beds in Isles of Scilly

6.4 However, when totalled, the five year rolling mean across all five main beds shows a 6.4% reduction in overall plant density. Whilst this is a significant decline, it is only for one year and the author cautions against drawing any negative conclusion from this result.

Abundance of epiphytes

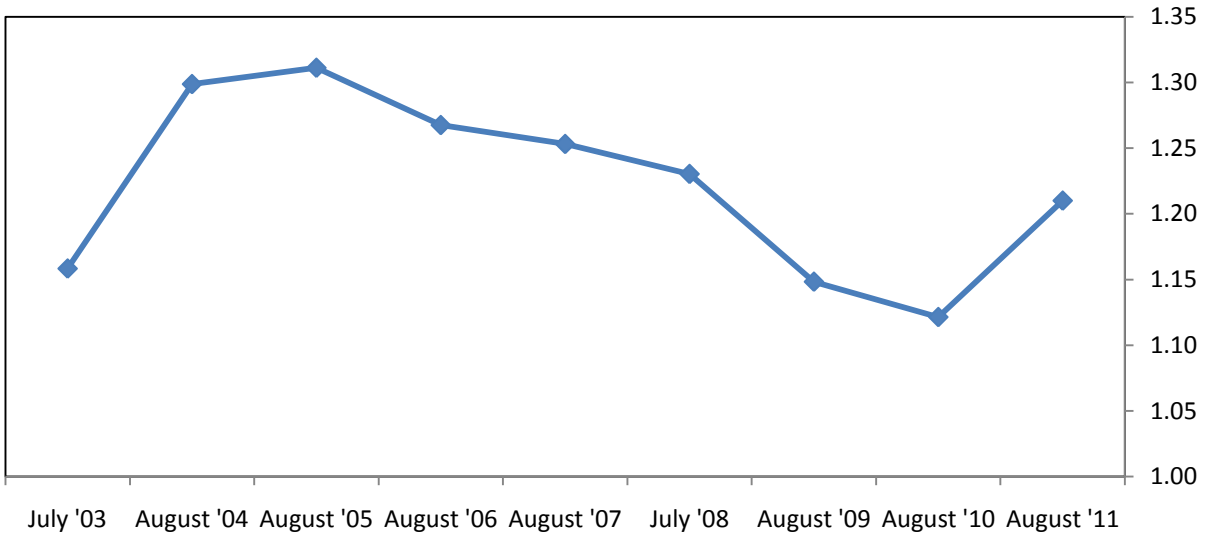

Figure 10 Rolling 5 year mean of epiphyte cover for the five main beds in Isles of Scilly

6.5 The rolling five year mean of epiphytes shows that after a nominal decline in cover the amount has increased. However, given that scores of 1.1 and 1.3 equate to an approximate % cover of between 2 and 3 percent, this is not a significant change.

Use of volunteer divers

6.6 2011 was the sixteenth consecutive volunteer survey of the five main *Zostera marina* beds in the Isles of Scilly has further illustrated the value of well managed surveys by dedicated and well trained volunteers. It is the author's recommendation that further use of such groups to deliver specific target focused outcomes is made.

7 Extent groundtruthing

Methodology

7.1 Jackson *et al*., (2011) estimated the extent of *Zostera marina* in Scilly by analysing orthorectified photographs from an aerial survey flown in 2008. These images were then modelled against extensive groundtruthing and analysis of previous surveys and *Zostera marina* in Scilly. The report suggested areas which would benefit from further groundtruthing. The presence or absence of *Zostera* was recorded at three of these areas:

- East of Higher Town Bay, St.Martin's;
- Broad Ledge, Tresco; and
- White Island.

7.2 Also recorded were areas where *Zostera* was present but mixed with algae species, the presence of algae alone or where the seabed was bare sand.

East of Higher Town Bay, St. Martin's

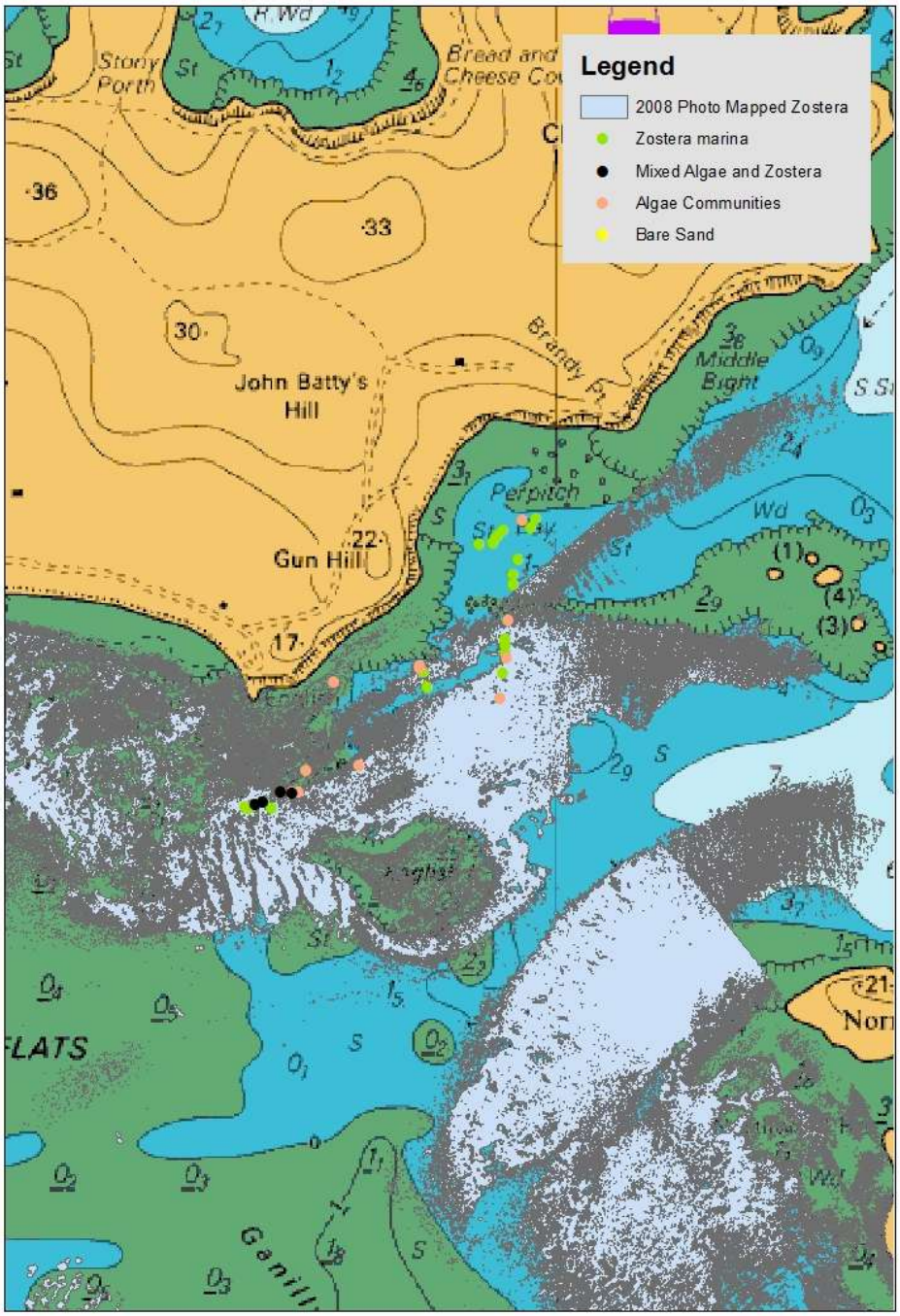

Figure 11 Groundtruthing results for Higher Town Bay, St. Martin's

7.3 This area is typified by a number of shallow reefs with sand patches infilling the areas between the reefs, though with the presence of the underlying rock substratum and cobble / boulders, there are several suitable holdfasts for a variety of algal species.

7.4 The *Zostera* is found within those patched where sand dominates and where algal species are absent.

7.5 The results of the *Zostera* groundtruthing at this location show poor correlation with the suggested distribution by Jackson *et al.,* (2011).

Broad Ledge, Tresco

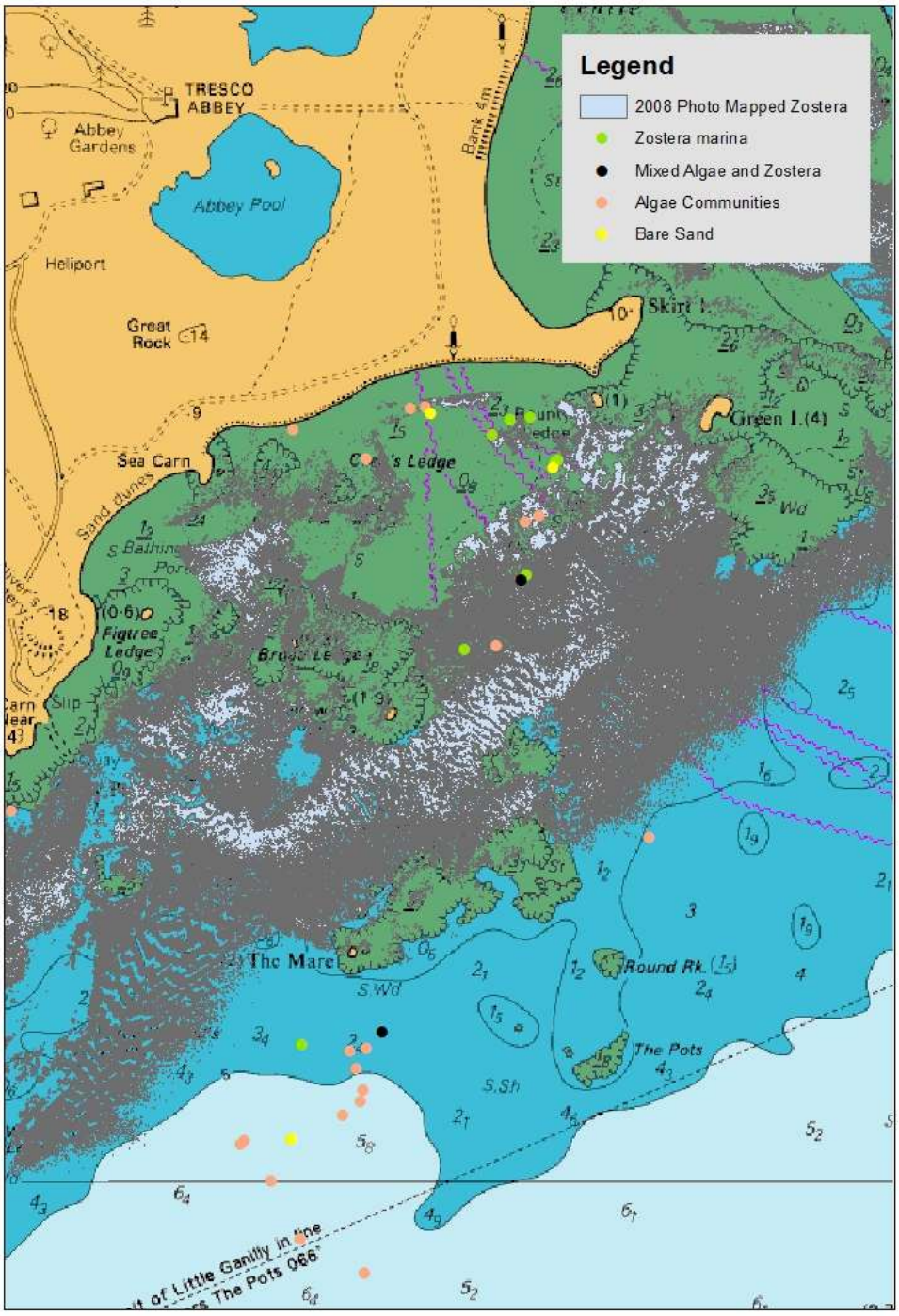

Figure 12 Groundtruthing results for Broad Ledge, Tresco

7.6 This site lies to the south of Tresco and is comprised of predominately coarse sand with cobbles of varying sizes.

7.7 The abundance of suitable holdfasts means that the whole area has a variety of algal species present.

7.8 This survey of this site shows better correlation with the findings of the Jackson *et al.*, (2011) report.

White Island

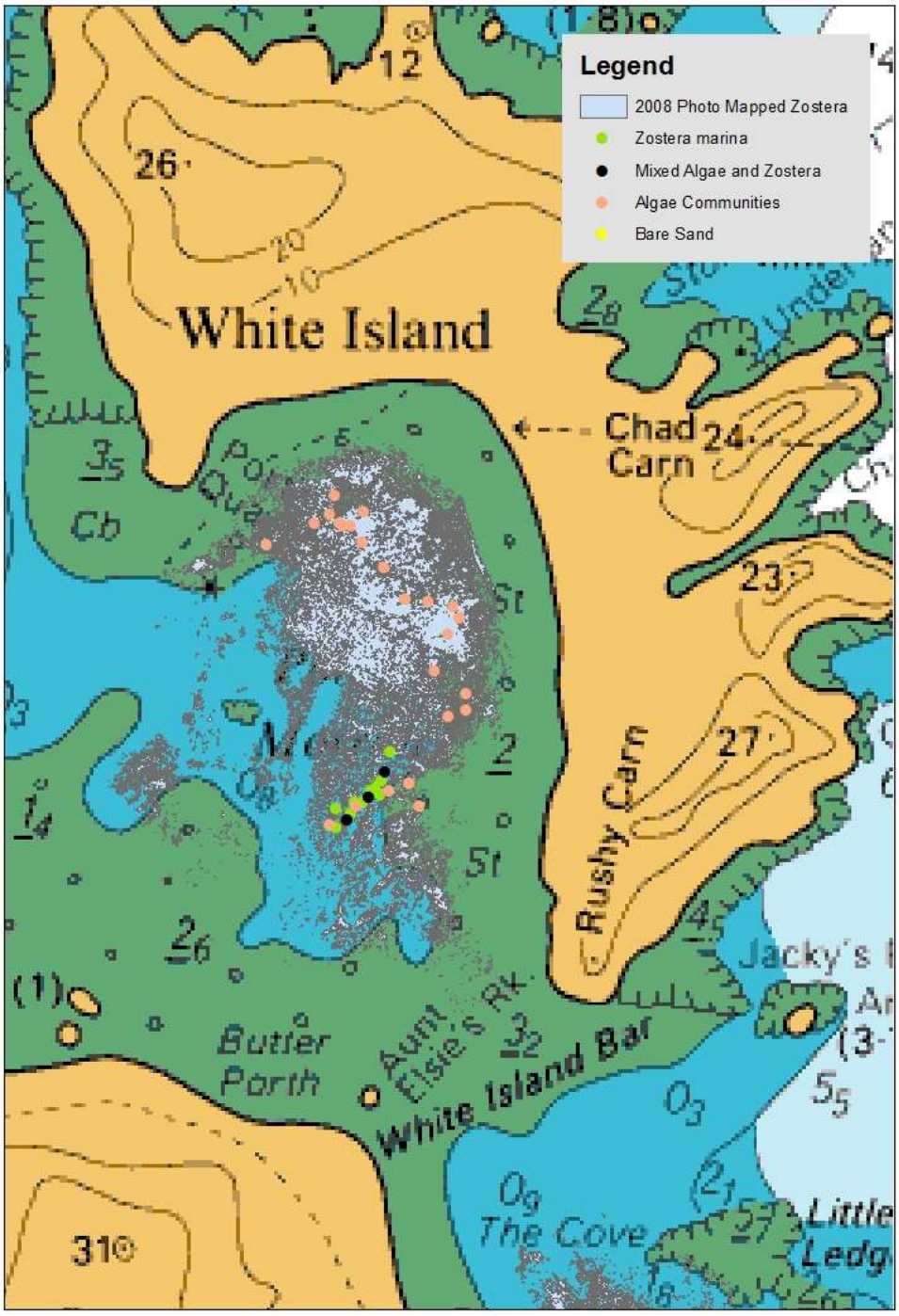

Figure 13 Groundtruthing results for Broad Ledge, Tresco

7.9 The *Zostera* at this site has not been surveyed previously at this site therefore the composition of the substrate is unknown. However, from the predominance of algal species it is thought to be mainly rocky.

7.10 *Zostera* was only found at the southern end of the bay towards White Island Bar.

7.11 The results of the *Zostera* groundtruthing at this location show poor correlation with the suggested distribution by Jackson *et al.,* (2011).

8 Temperature logging, Broad Ledge Tresco

8.1 Broad Ledge Tresco, has been monitored continually since 1996 and the extended dataset produced has helped build a model of the responsiveness of *Zostera marina* (Bull *et al*., 2011) beds to variations in seawater temperature. In order to better understand the relationship between such variables as:

- Plant density and spatial variation;
- Plant health; and
- Sea water temperature.

8.2 We deployed a 'Stowaway Tidbit Temperature Logger' close to the central datum for the bed at (49 56.394N, 006 19.774W) during the 2010 expedition. The logger was configured to record hourly ambient (in water) temperature and was successfully recovered on the 2011 expedition. The depth range at this site varies between approximately 1.3m at chart datum to a maximum depth on 6m at High Water Springs.

Table 13 Mean daily temperature (degrees C), Broad Ledge Tresco

Date	Aug 2010	Sept 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011	Apr 2011	May 2011	June 2011	July 2011	Aug 2011	Date
1		14.52	13.89	13.31	9.05	9.45	9.20	9.15	10.54	12.08	13.29	14.56	14.68	**1**
2		14.84	13.91	13.28	9.06	9.51	9.44	8.89	10.68	11.91	13.64	14.82	14.77	**2**
3		15.40	13.97	13.39	9.69	9.47	9.47	9.17	10.71	11.45	13.93	14.89		**3**
4		15.81	14.01	13.46	10.27	9.48	9.68	9.18	10.59	12.13	14.11	14.95		**4**
5	14.96	15.75	14.03	13.52	10.31	9.76	9.86	9.29	10.65	12.52	14.04	14.92		**5**
6	15.18	15.04	13.69	13.06	10.06	9.76	9.91	9.35	11.01	12.47	13.75	14.22		**6**
7	14.96	14.56	13.71	12.24	10.00	9.93	9.85	9.23	11.05	12.51	13.68	14.21		**7**
8	15.40	14.37	13.80	12.37	9.51	9.75	9.61	9.36	11.21	12.46	13.47	14.28		**8**
9	14.85	14.32	13.81	12.02	9.76	9.41	9.82	9.60	11.29	12.50	13.46	14.43		**9**
10	14.24	14.37	13.84	11.85	10.18	9.88	9.94	9.81	11.33	12.71	13.51	14.63		**10**
11	13.86	14.51	13.80	12.39	10.35	9.79	9.88	9.88	11.38	12.83	13.60	14.79		**11**
12	13.86	14.41	13.57	12.45	10.19	10.19	9.60	9.82	11.23	12.74	13.64	15.00		**12**
13	13.76	14.35	13.51	12.30	9.72	10.42	9.69	9.64	10.82	12.77	13.73	15.01		**13**
14	13.70	14.40	13.31	11.98	9.53	10.40	9.35	9.56	10.91	12.69	13.95	15.10		**14**
15	13.96	14.39	13.18	11.88	9.36	10.33	9.37	9.71	11.16	12.63	13.88	14.75		**15**
16	14.00	14.44	13.17	11.78	9.54	10.42	9.37	9.88	11.11	12.75	13.80	14.56		**16**
17	14.09	14.71	13.38	12.06	8.86	10.34	9.62	9.90	11.34	12.61	13.54	14.31		**17**
18	14.13	14.83	13.68	11.91	8.95	9.95	9.66	9.64	11.36	12.52	13.36	13.90		**18**

Table continued…

Date	Aug 2010	Sept 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011	Apr 2011	May 2011	June 2011	July 2011	Aug 2011	Date
19	14.22	14.68	13.54	11.93	9.19	9.64	9.92	9.68	11.42	12.53	13.31	13.93		**19**
20	14.61	14.71	13.05	11.96	9.17	9.60	9.86	9.91	11.67	12.80	13.41	14.29		**20**
21	14.83	14.67	12.97	11.67	9.27	9.46	9.73	9.99	11.74	12.76	13.84	14.57		**21**
22	14.65	14.33	13.08	11.44	9.14	9.45	9.79	10.12	11.73	12.67	14.05	14.92		**22**
23	14.31	14.05	12.98	11.47	8.86	9.55	9.98	10.24	11.77	12.66	14.06	14.82		**23**
24	14.03	13.84	12.82	11.38	8.80	9.53	10.07	10.28	11.79	12.63	13.85	14.79		**24**
25	14.02	13.38	12.69	10.64	8.97	9.54	10.00	10.40	12.11	13.08	14.13	14.71		**25**
26	13.88	13.38	13.08	10.35	9.15	9.66	9.96	10.36	12.27	12.69	15.12	14.85		**26**
27	13.70	13.62	13.32	10.07	9.59	8.78	9.60	10.28	12.63	12.78	14.79	15.07		**27**
28	13.64	13.91	13.30	10.08	9.90	8.19	9.32	10.29	12.62	12.89	14.35	15.02		**28**
29	13.85	14.02	13.29	9.89	10.06	7.85		10.53	12.42	13.14	14.28	14.87		**29**
30	13.99	13.88	13.01	9.57	9.99	8.09		10.54	12.31	13.15	14.33	15.00		**30**
31	14.15		13.39		9.71	8.59		10.59		13.04		14.83		**31**

Figure 14 Mean daily temperature (degrees C) Broad Ledge, Tresco

8.3 Bull *et al*., (2011) report an observed increase in the strength of the negative effects of disease on eelgrass population growth rate at higher temperatures. Therefore, it is possible that increase in mean sea water temperature will have an adverse impact on the amount of seagrass in the Isles of Scilly as a result of an increase in the amount of infection with Labrynthula.

8.4 During the period recorded (August 2010 to August 2011) the minimum mean daily temperature was 7.85 degrees C recorded on 29th January 2011 and the maximum was 15.81 degrees C recorded on 4th September 2010.

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