Seagrass (*Zostera marina*) monitoring and condition assessment in Whitsand and Looe Bay Marine Conservation Zone 2015 and 2017

A report to Natural England by MarineSeen

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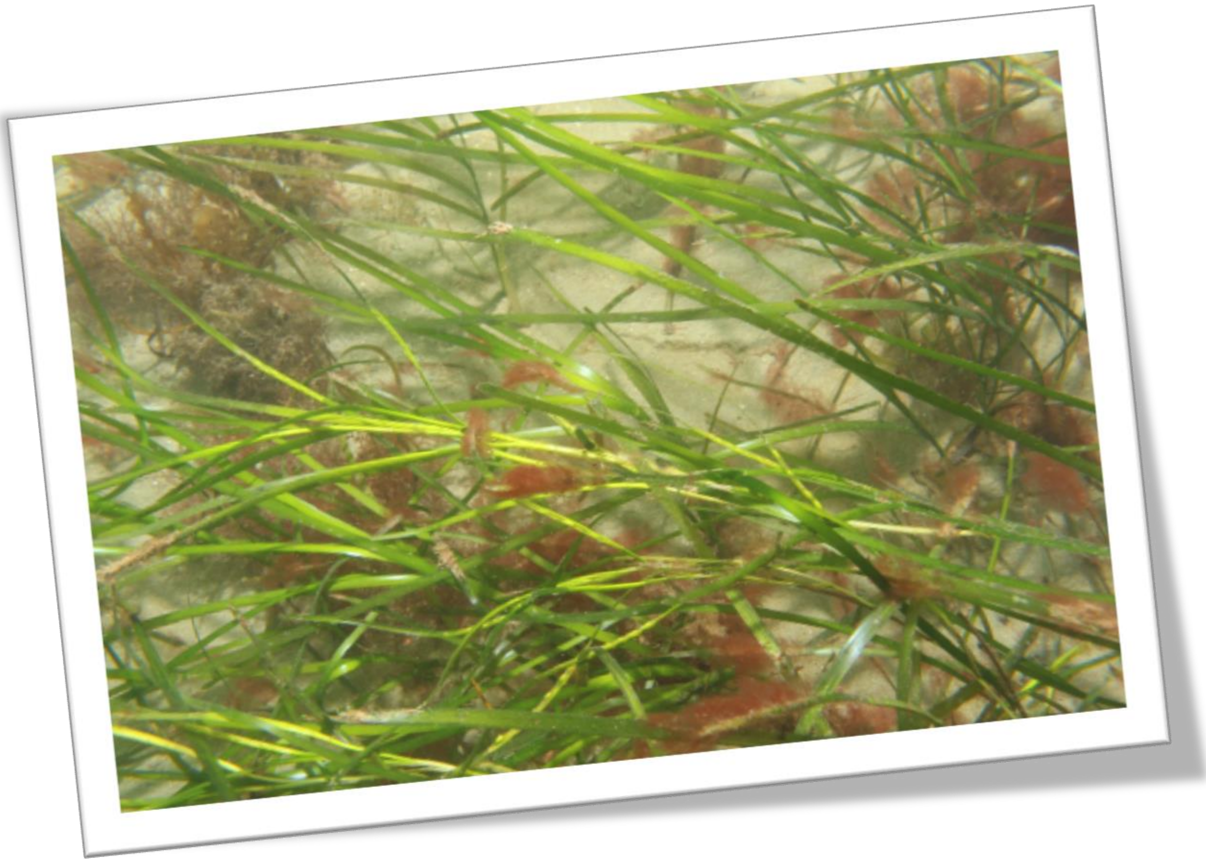

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Synopsis

A seagrass bed off Looe in Cornwall (which is part of the Whitsand Bay and Looe Marine Conservation Zone) was studied using a drop-down video (DDV) survey carried out by IFCA (Inshore Fisheries and Conservation Authorities) in 2015 followed by a diving survey by Natural England (NE) in 2017.

The 2015 and 2017 surveys followed preliminary studies by Cornwall Wildlife Trust in conjunction with Looe Voluntary Marine Conservation Area (VMCA), Plymouth University, Cornwall College Newquay and the Environmental Records Centre for Cornwall and the Isles of Scilly Looe (Clark, 2011, Cornwall Wildlife Trust, 2012).

The IFCA DDV survey measured the extent and abundance of the seagrass off Looe and determined the bed to be of a patchy and fragmented nature. Comparisons of extent and density could not be reliably compared with that of Clark (2011) due to differences in methodology and GIS output.

The NE diving survey determined plant densities, plant lengths, incidence of flowering and the presence and extent of infection by the 'wasting disease' fungus *Labyrinthula zosterae* and degree of epiphytisation of leaves.

As expected from the patchy and fragmented nature of the seagrass bed, plant densities were low but plant lengths were comparable to that found in Plymouth Sound in 2018 (Bunker and Green, 2019). Incidence of flowering was high compared to that recorded in Plymouth Sound and infection by *L. zosterae* and degree of epiphytisation was low.

The survey methodologies currently employed together with ideas for improving them are presented. In particular, adopting the DDV methodology used in Plymouth Sound (Bunker and Green, 2019) and changing from transect based surveys to one of stratified random sampling to provide more statistical power to the data is suggested.

1 Introduction

There are currently 91 Marine Conservation Zones (MCZs) around England. MCZs protect areas that are important for conserving the diversity of nationally rare, threatened and representative habitats and species. Designation of these zones takes social and economic factors into account, alongside the best available scientific evidence (DOE, MMO et al., 2015).

The Whitsand and Looe Bay MCZ was designated in 2013 it is an inshore site located off the south coast of Cornwall (Figure 1). The landward site boundary follows the coastline along the mean high-water mark, from Hore Stone near Talland Bay in the west, to a point between Queener Point and Long Cove on Rame Head in the east. The seaward boundary is formed by a straight line across the bay, with a small extension jutting out to the south around Looe Island. The site covers an area of 52 km^2 and is 25 metres deep at the deepest point. The targets and attributes for seagrass in the MCZ are given in Table 1.

Table 1 Attributes and targets for Seagrass in the Whitsand and Looe Bay MCZ (Natural_England, 2020)

Attribute	**Target**
Distribution: presence and spatial distribution of biological communities	Maintain the presence and spatial distribution of subtidal seagrass bed communities
Extent of supporting habitat	Maintain the area of habitat which is likely to support the subfeature.
Structure and function: presence and abundance of key structural and influential species	[Maintain OR Recover OR Restore] the abundance of listed typical species, to enable each of them to be a viable component of the habitat
Structure: biomass	Maintain the leaf / shoot density, length, percentage cover, and rhizome mat across the feature at natural levels (as far as possible), to ensure a healthy resilient habitat.
Structure: non-native species and pathogens	Restrict the introduction of non-native species and pathogens, and their impacts.
Structure: rhizome structure and reproduction	Maintain the extent and structure of the rhizome mats across the site, and conditions to allow for regeneration of seagrass beds.
Structure: sediment composition and distribution	Maintain the existing distribution of sediment composition types across the feature/subfeature.
Structure: species composition of component communities	Maintain the species composition of component communities

Supporting processes: energy / exposure	Maintain the natural physical energy resulting from waves, tides and other water flows, so that the exposure (high, medium, low) does not cause alteration to the biotopes, and stability, across the habitat.
Supporting processes: light levels	Maintain the natural light availability to the seagrass bed.
Supporting processes: morphology	Maintain the natural physical form and coastal processes which shape the seagrass bed.
Supporting processes: physico-chemical properties	Maintain the natural physico-chemical properties of the water.
Supporting processes: sediment contaminants	Restrict surface sediment contaminants (<1cm from the surface) to below the OSPAR Environment Assessment Criteria (EAC) or Effects Range Low (ERL) threshold. (For example, mean cadmium levels should be maintained below the ERL of 1.2 mg per kg).
Supporting processes: sedimentation rate	Maintain the natural rate of sediment deposition.
Supporting processes: water quality - contaminants	Restrict aqueous contaminants to levels equating to High Status according to Annex VIII and Good Status according to Annex X of the Water Framework Directive, avoiding deterioration from existing levels.
Supporting processes: water quality - dissolved oxygen	Maintain the dissolved oxygen (DO) concentration at levels equating to High Ecological Status (specifically ≥ 5.7 mg per litre (at 35 salinity) for 95 % of the year), avoiding deterioration from existing levels.
Supporting processes: water quality - nutrients	Maintain water quality and specifically mean winter dissolved inorganic nitrogen (DIN) at a concentration equating to High Ecological Status (specifically mean winter DIN is < 12 µM for coastal waters), avoiding deterioration from existing levels.
Supporting processes: water quality - turbidity	Maintain natural levels of turbidity (eg suspended concentrations of sediment, plankton and other material) across the habitat.

Whitsand Bay is a 6 km stretch of sand and shingle with gullies that have been carved by strong tides and cross-currents. The site contains subtidal sand and coarse sediment habitats, as well as intertidal rocky habitats at Hannafore and on Looe Island which support a high diversity of seaweeds and invertebrates. The ocean quahog (*Arctica islandica*), a long-lived bivalve which is known to live for over 400 years has been recorded within sediment habitats in the site. Within the shallower part of the site the seagrass beds are likely to provide a nursery ground for ecologically and commercially important species such as cuttlefish. Further out to sea there are shipwrecks and small areas of subtidal rocky reef that support pink sea-fans (*Eunicella verrucosa*) and rare sea-fan anemones (*Amphianthus dohrnii*).

Management measures are being put in place by the regulators (Marine Management Organisation (MMO) and Inshore Fisheries and Conservation Authorities (IFCAs[1])) on a site by site basis. Natural England have advised the regulators about the vulnerability of the features included within the Designation Order and activities that are currently occurring within the site that will have a negative impact on the protected features.
Fact sheet:
http://publications.naturalengland.org.uk/publication/6628749109886976?category=1721481

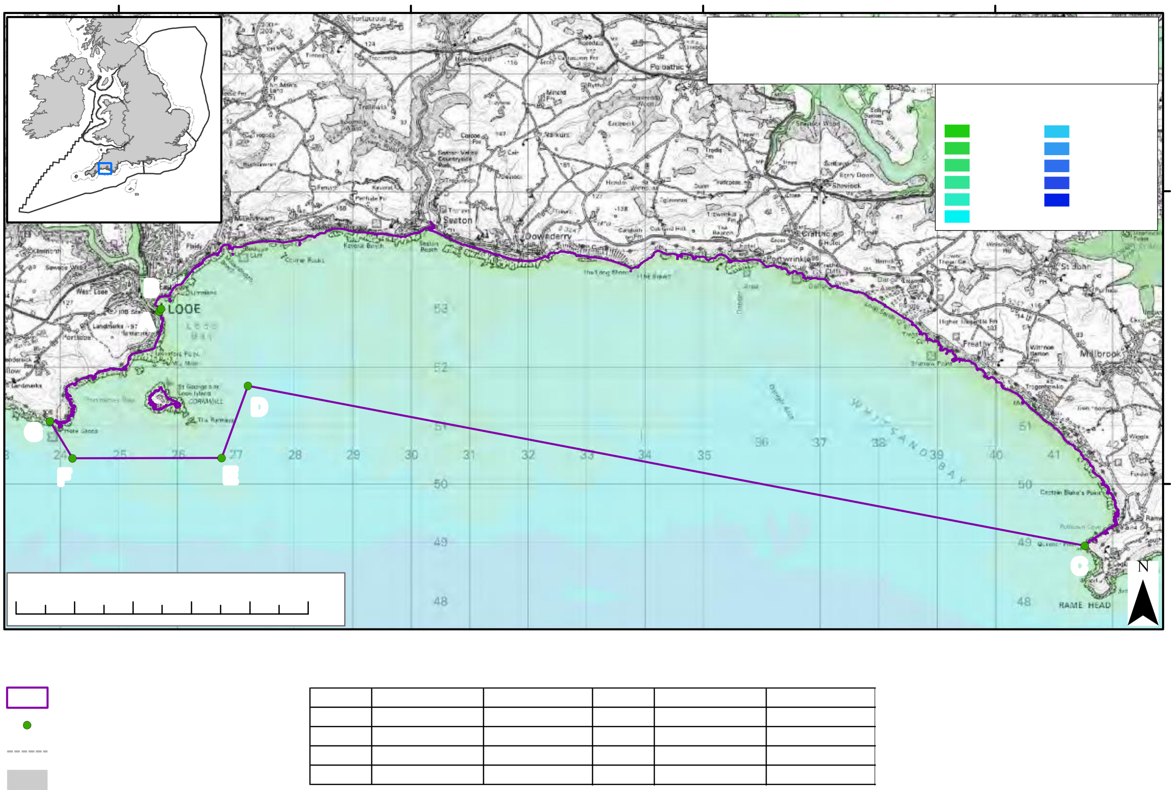

Figure 1 Map showing the location of Whitsand Bay and Looe MCZ (from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/259347/mcz-map-whitsand-and-looe-bay-boundary.pdf)

1.1 Background Information

The Looe Voluntary Marine Conservation Area (VMCA), supported by the Looe Marine Conservation Group was set up in 1995 to encourage education and learning about the marine environment in what was recognised as an area rich in marine habitats and species.

Included in the Looe VMCA are subtidal beds of the seagrass *Zostera marina*. In 2001, Cornwall Wildlife Trust carried out a desk study to collate information on the status of seagrass beds in Cornwall (Hocking and Tomsett 2001, cited Clark, 2011). A sparse and

[1] A recent IFCA bylaw introduced to this site fairly recently to ban almost all bottom towed gear

patchy area colonised by *Zostera marina* was recorded off East Looe in 1998 from an area estimated to be 20 to 30 m^2. This data was collected by Plymouth University in 1998 and by divers' reports over a number of years.

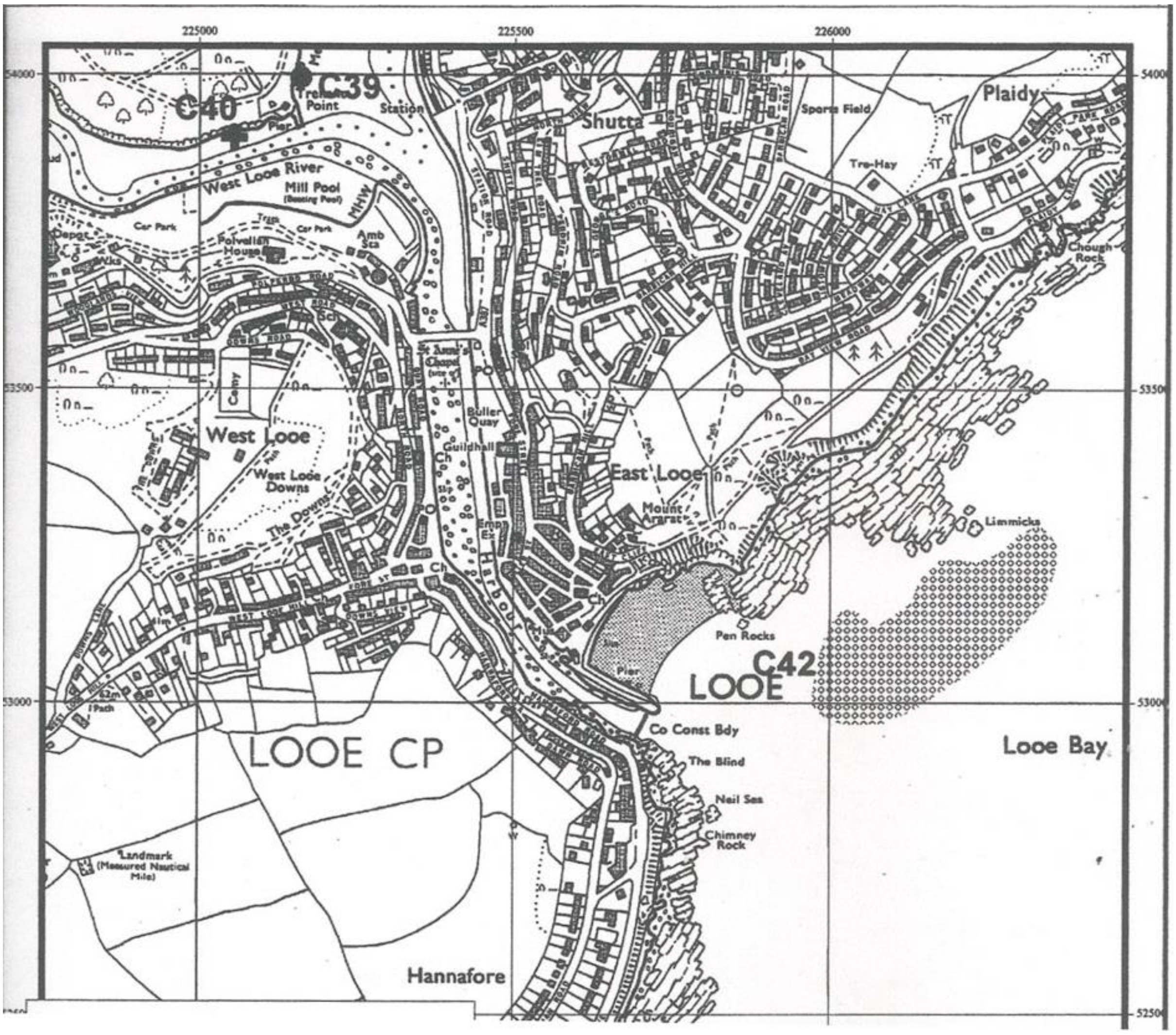

Figure 2 The patterned area in Looe bay indicates the extent that Zostera marina *was thought to cover in the report by Hocking and Tompsett (2001). Other small patches of intertidal* Zostera marina *are indicated up river. From Clark (2011)*

In October 2011, the Cornwall Wildlife Trust in conjunction with the Looe VMCA, Plymouth University, Cornwall College Newquay and the Environmental Records Centre for Cornwall and the Isles of Scilly undertook a drop-down video survey (DDV) to map the *Zostera* bed off East Looe (Clark, 2011, Cornwall Wildlife Trust, 2012). The results of the survey are depicted in Figure 3 and Annex A. The *Zostera* bed is depicted as extensive (110 ha or 1.1 km^2) but to be very patchy. Density of plants was estimated as 110 plants per m^2 with plants around one metre in length growing in a substratum of medium to coarse sand down to a depth limit of 11 m.

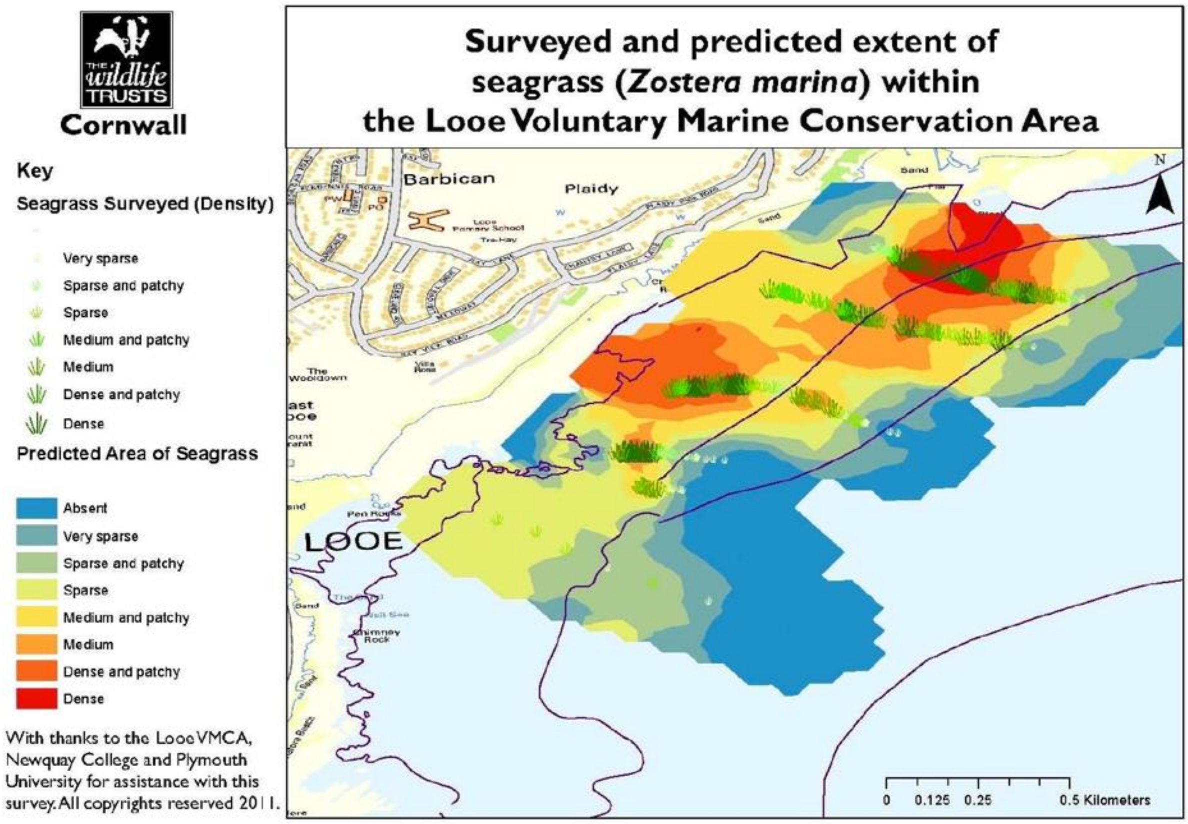

Figure 3 The surveyed and predicted extent of Zostera marina within the Looe VMCA from (Clark, 2011). The extent map was produced using the ROV surveying method and ArcGis ArcView 9. Predictive patterns of eel grass were produced using 'krigging'. Data was entered into Excel first and included a transect number with a GPS reading and density score.

1.2 Current studies

This report presents the results of a DDV survey undertaken by the Cornwall IFCA (Inshore Fisheries Conservation Authority) in 2015 (Latham and Trundle, 2015), followed by a diving survey by Natural England (NE) in 2107. The overall aim of these surveys was to create a baseline for monitoring *Zostera marina* in Whitsand Bay and Looe MCZ.

Specific aims and objectives of each survey are now described.

1.2.1 Aims and objectives of the 2015 IFCA DDV Survey

Aim: To provide data on the extent and distribution of eelgrass (*Zostera marina*) to inform Natural England dive surveys to assess the feature condition.

Objectives:
- Complete a DDV survey, consisting of a series of inshore and offshore transects across the area in which eelgrass has been previously recorded or predicted to occur
- Confirm presence and distribution of the eelgrass feature within the MCZ.

1.2.2 Aims and objectives of the 2017 NE Diving Survey

Aim: To undertake *in situ* surveys in order to assess eelgrass condition.

Objectives:
To obtain data along a series of 50 m transects and study the following:

- Density
- Presence of macro algae
- Collection of samples of seagrass plants for measurement of length, infection by the fungus *Labyrinthula zosterae*, colonisation by epiphytes, presence of eggs on leaves and incidence of flowering.

2 Methods

Methods for each of different elements of the survey are described below.

2.1 Inshore Fisheries and Conservation Authority (IFCA) drop down video (DDV)

The following data files accompany this part of the work and are held by Natural England:

- 20150730_Tow_analysis_combined_point.shp
- 20150731 Day 2_Tow Analysis_point.shp
- Zostera_extent_region.shp
- Zostera_high_density_region.shp
- Zostera_Medium_density_region.shp

The methodology of the DDV survey given below is taken from Latham and Trundle (2015). The Whitsand and Looe Bay MCZ Eelgrass survey was completed from Cornwall IFCA's survey vessel R/V Tiger Lily VI. This vessel included a purpose-built survey station within the wheelhouse, fitted with an uninterruptable power supply (UPS), NEMA inputs and dedicated GPS. All locations are recorded in Long/Lat WGS84, from the dedicated survey GPS (Furuno GP-32). All times recorded are UTC taken from a single source, the survey GPS.

The camera used for the DDV survey was an STR SeaSpyder drop camera system contained in a custom-built frame, allowing high resolution stills of the seabed to be taken using a surface controlled digital SLR camera. Separate real time video, with user-programmable overlay, allowed positional information, bearing and depth to be recorded on the video output.

The SeaSpyder camera was deployed from the starboard side davit of R/V Tiger Lily VI and lowered to the seabed. The video record was started during deployment. A waypoint (mark) was created in OLEX to indicate the start of the transect; this was repeated at the end of the transect. The SeaSpyder was 'flown' with the frame legs just above the seabed and periodically landed on the seabed to allow a high quality still image to be taken. Still images were captured at a frequency of one every 60 seconds; images separation varied slightly to ensure that the stills taken were of good quality (e.g. taken when the frame was stable and the lens unobstructed) this sometimes led to a delay. Immediately upon having captured a stills image a waypoint (mark) was created in OLEX.

The transects were arranged inshore to offshore in a south-easterly heading and are shown in Figure 4

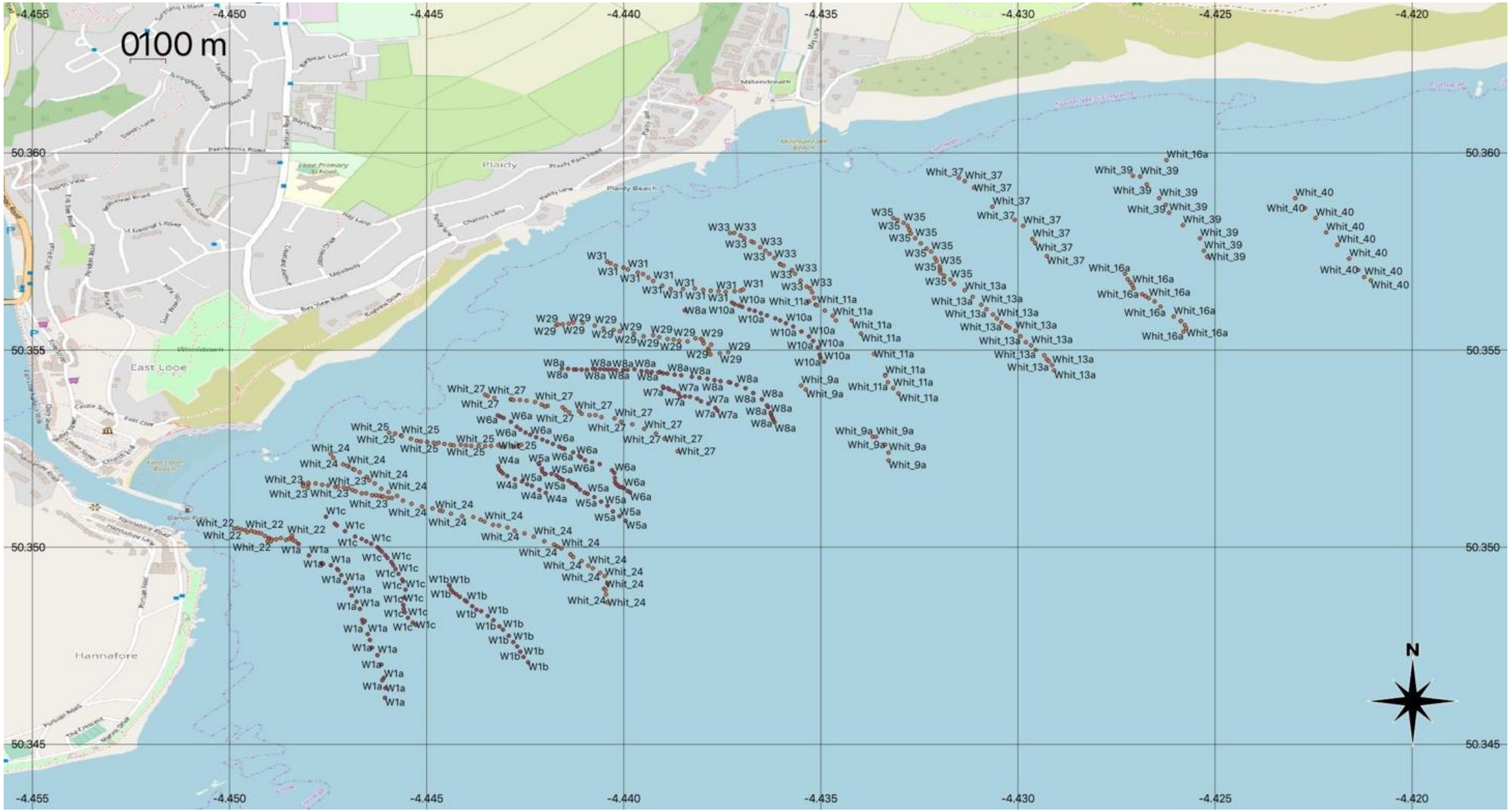

Figure 4 Map to show DDV transects. Each red dot is labelled by transect and represents a still image capture

OLEX navigation software was used to record the vessels track and waypoints/marks at the start and end of each transect and at the location of every stills image.

The following were recorded for each transect:

- Date
- Transect no.
- Start time
- Finish time
- Length of tow (time)
- No. stills
- Comments on substratum and biota.

The following were recorded for each still picture:

- Northing
- Easting
- Time
- Depth
- Transect no.
- Habitat, including Zostera % cagtegory: <5%, 5-50% and >50%

2.1.1 Data analysis

The DDV data was analysed by IFCA with the results contained in the report by Latham and Trundle (2015). A three-point abundance scale was used to determine density:

Table 2 Abundance categories of Zostera marina cover used by IFCA when analysing the drop-down video.

Abundance category
<5% cover
5 to 50% cover
>50% cover

The DDV data is contained in the IFCA following GIS files:

- 20150730_Tow_analysis_combined_point.shp
- 20150731 Day 2_Tow Analysis_point.shp
- Zostera_extent_region.shp
- Zostera_high_density_region.shp
- Zostera_Medium_density_region.shp

A contour map showing the distribution and abundance of seagrass was created using QGIS 3.4.5. The GIS data file used to produce the contour map is given is:

- 201507_tow_analysis_all_fb.shp

2.2 Diver transect methodology

Data files with the results from the diver transect work and leaf analysis data are contained in the following file held by NE:

- Whitsand Bay seagrass survey 2017 raw data.xlsx

The NE dive team carried out their survey of the seagrass bed between 20th and 21st June 2017.

The diving was carried out in accordance with the Approved Code of Practice for scientific diving projects (HSE, 2014) and the countryside agency diving rules (Holt, 2015). The divers were qualified according to the relevant 1997 HSE regulations and used air with standard SCUBA equipment (HSE, 1997). Divers worked in pairs with one diver having a permanently inflated surface marker buoy (SMB) and each diver carrying a delayed surface marker buoy (DSMB) for use in case of separation. Each diver also carried a communications unit allowing for voice communication from the surface and signalling to the surface from the divers.

The Category 2 MCA registered charter boat *Venture* skippered by Pete Fergus (and based in Sutton Harbour) transported the divers and acted as the cover vessel.

The NE dive team was as follows:

Diving Project Manager:	Tom Hardy, Natural England
Dive Supervisors:	Tom Hardy (TH), Laura Gannon (LG) and Gavin Black (GB) (all NE staff)
Divers / standby divers:	Kevan Cook (KC), Natural England
	Contractors: Mark Parry (MP; National Marine Aquarium)

A series of 50 m long transect were studied in the seagrass bed with the positioning of the transects chosen to include areas with a higher density of plants.

The transect study method is illustrated in Figure 5. A shot marker was deployed at each transect location and divers then deployed transect tapes on pre-determined compass bearings. Each diver carried a quadrat and worked together either side of the transect tape taking readings from within the quadrats every 5 m along the transect. The quadrats were placed adjacent to each other either side of the tape with the lower corner (right on the left side and left on the right) positioned on the appropriate tape mark.

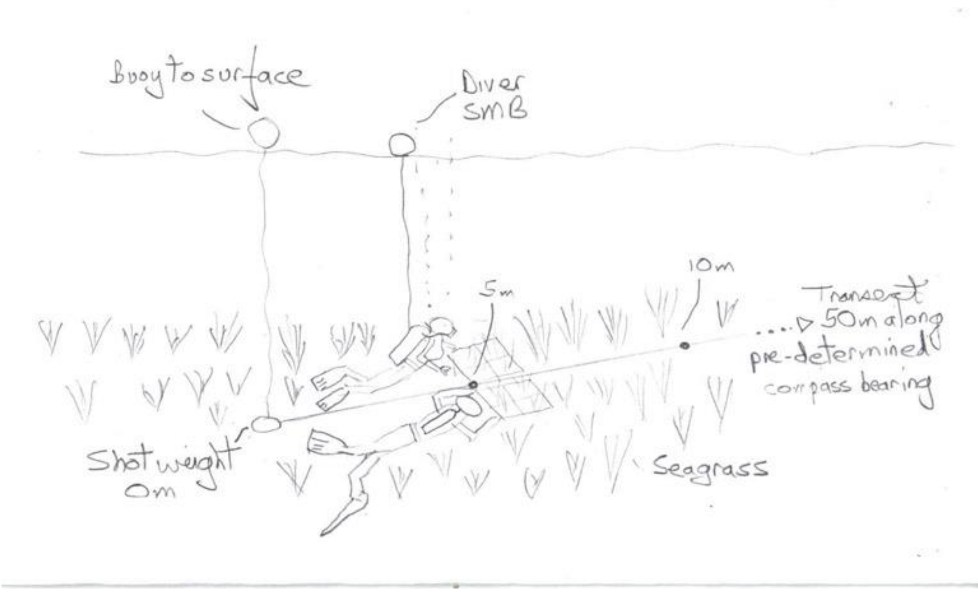

Figure 5 An illustration to show the transect study method carried out by divers

The following were recorded in each quadrat every 5 m:

- Cover of *Zostera marina* using the following scale:

Table 3 Zostera marina abundance categories recorded in situ during the dive survey

Zostera abundance	**% cover category**
0 - No *Zostera* Present	0%
1 - Minimal *Zostera* Present	1-4%
2 - Up to a quarter of Quadrat contains *Zostera*	5-25%
3 - Up to half the Quadrat contains *Zostera*	26-50%
4 - Over half the Quadrat contains *Zostera*	51-75%
5 - Almost all the Quadrat contains *Zostera*	76-100%

- Sediment type based on the following categories:

Table 4 Sediment categories recorded during the dive survey

Sediment Type	Code
Sand	S
Shingle / Shells	H
Rock	R
Mixed	M
Macro Algae	A

2.2.1 Quality Assurance

Prior to diving, the team were properly briefed regarding how to carry out the surveys.

2.2.2 Data analysis

Analysis of the data follows Curtis (2012), who demonstrated (statistically) how the different transects in a seagrass bed in Plymouth Sound differed significantly from each other. This was because some were at the edges of the beds, others were in dense areas and others differed for other reasons e.g. moorings were present. Because of this it was concluded that quadrats between diver transects could not be considered to be replicates of the same 'population'. In order to make a statement about density of the bed as a whole, a mean of means for all transects was calculated.

Curtis (2012) expressed densities in term of number per m^2. In the field, divers counted plants in 0.0625 m^2 quadrats (quarter of a square meter) and so (Curtis, 2012) multiplied results by 16 to give density per m^2.

The range of values for the different attributes (e.g. high and low densities) were taken from the raw data at each site.

Where proportions (i.e. percentages) have been calculated, the data was arcsine transformed prior to calculation[2] (Fowler, Cohen et al., 1998). The proportion data is also presented as untransformed percentages.

2.2.3 Plant collection and data recording

At 11 stations along the transect, all the *Zostera* shoots in a quarter of the (0.25 m^2) quadrat (i.e. 0.0625 m^2) were collected and placed in labelled bags. Whole shoots were collected by snipping them off at the base i.e. just above where they arise from the rhizome. It was important to keep enough of the plant below where the leaves emanated so the leaves remained on the plant.

Collecting and bagging *Zostera* shoots underwater can be tricky and bag management practices were carefully thought out prior to diving. Bags had to be big enough to contain folded plants up to 1 m long. The labelled bags were 'nested' in the correct order, with the outer one being the first one to use and so on. 'Zip' fastened bags were used to prevent the plants from escaping but care had to be taken not to cut the plants when closing zips. The full bags were transferred to a mesh bag for safe transporting.

Back at the survey base, the samples were processed by the team with the following being recorded:

- Presence of flowers / seeds
- Eggs present on leaves
- Maximum length of leaves in a plant
- Infection in individual leaves by *Labyrinthula zosterae* and cover of individual leaves by epiphytes measured on the following scale:

[2] Data suitable for calculating means and standard deviations should be normally distributed. In distributions which are proportions the left and right hand tails are truncated because all values must lie on a scale with absolute limits of 0 and 1. Arcsine transformation of the data ensures that these statistical methods can be validly applied.

Table 5 Scale used for recording infection of *Zostera marina leaves by Labyrinthula zosterae* and cover of leaves by epiphytes (hydroids, bryozoans, algal crusts etc.)

0 - Uninfected	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 inftected	76-100%

Leaves infected by *Labyrinthula zosterae* and colonised by epiphytes is shown in Figure 6.

Figure 6 Zostera marina leaves showing various degrees of infection by Labyrinthula zosterae by Francis Bunker

2.2.4 Data analysis

The data from the dive survey was analysed using tools in Excel and is contained in the file:

- Whitsand Bay seagrass survey 2017 raw data.xlsm

3 Results

The results for each of the areas studied are now considered in turn.

3.1 Drop down video (DDV)

A total of 9 hours and 25 minutes of video were recorded during the 26 transects over the 2 survey days; 5 hours 46 minutes on the 30th July 2015 and 3 hours 39 minutes on the 31st July 2015. In addition to the video data, approximately 540 still images were captured.

A map showing the transects together with positions at which still images were taken is shown in Figure 4 and a summary of the analyses of the DDV transects is given in Table 6.

Table 6 Table with summary information on transects across the Whitsand Bay Zostera bed.

Date	**Transect**	**Start**	**Finish**	**Length**	**No. Stills**	**Comments**
30/07/2015	W21	07:46:00	08:10:00	00:23:59	21	Fine sand with ripples, worm casts, *Ulva* spp. and drift macroalgae.
30/07/2015	W23	08:15:00	08:40:00	00:24:55	23	Fine sand with ripples. Sparse seagrass (occ. plants), becoming sparse and patchy seagrass bed with occasional dense stands.
30/07/2015	W25	08:43:00	09:06:00	00:23:06	22	Sparse, patchy seagrass bed on fine sand, becoming denser but remaining patchy.
30/07/2015	W27	09:10:00	09:38:00	00:28:47	25	*Laminaria hyperborea* with understorey reds on rock/ boulder/ cobble. Fine sand with occ. seagrass patches and drift m/algae. Large patches of coarse seabed with *Saccorhiza polyschides*, *Saccharina latissima* and m/algae mid- and outer- transect.
30/07/2015	W29	09:46:00	10:12:00	00:26:26	23	Kelp (*L. hyperborea*, *S. polyschides*) with understorey reds on rock/ boulder/ cobble. Fine sand with occ. seagrass. Patchy seagrass bed at transect outer end.
30/07/2015	W31	10:19:00	10:38:00	00:19:39	17	Fine sand in shallow water (<1.5m). Occ. seagrass plants/ stands becoming patchy bed.
30/07/2015	W33	10:42:00	11:01:00	00:18:23	17	Fine sand with occ. seagrass, denser/ patchy bed mid-transect, sparser at outer transect end.
30/07/2015	W35	11:05:00	11:23:00	00:18:03	17	Sparse, patchy seagrass bed becoming denser on fine sand. Some barren patches.
30/07/2015	W37	11:29:00	11:47:00	00:18:14	17	Fine sand. Kelp (*L. hyperborea, S. polyschides*) with understorey reds on patches of rock/ boulder/ cobble. Sparse seagrass returning to fine sand at outer transect end.
30/07/2015	W39	11:51:00	12:07:00	00:16:24	15	Kelp (*L. hyperborea, S. polyschides*) with understorey reds on rock/ boulder/ cobble. Pot back line. Fine sand w. drift m/algae.
30/07/2015	W40	12:11:00	12:30:00	00:19:01	17	*S. polyschides*, *S. latissima* and *L. hyperborea* with understorey m/algae on rock outcrops/ boulder/ cobble/ coarse seabed.
30/07/2015	W16a	13:10:00	13:26:00	00:16:05	13	*S. polyschides*, *S. latissima*, *L. hyperborea* and m/algae on boulder/ cobble/ coarse seabed. Fine sand with patches of coarse sediment/ pebbles and m/algae.
30/07/2015	W13a	13:37:00	13:55:00	00:18:26	18	Fine sand w. very occ. seagrass, drift m/algae and evidence of infauna. Coarse sediment/ pebble/ cobble seabed with kelp (*S. polyschides*, *S. latissima*, *L. hyperborea*) and m/algae.
30/07/2015	W11a	14:04:00	14:24:00	00:19:25	18	Fine sand with occ. seagrass and infauna burrows, becoming sparse, patchy seagrass bed before disappearing. Sediment becoming coarser with pebbles/ cobbles and m/algae.
30/07/2015	W9a	14:30:00	14:46:00	00:15:33	15	Fine sed. w. infauna burrows/ siphons, drift algae and occ. seagrass. Pebble/ cobbles w. m/algae and *Chorda filum* towards transect end.
30/07/2015	W24	15:05:00	15:44:00	00:39:40	36	Fine sed. w. infauna burrows/ siphons, drift algae and occ. seagrass. Patchy seagrass becoming bed, dense in patches. Fine sand, becoming coarse sed./ pebble w. m/algae at transect end.

Date	**Transect**	**Start**	**Finish**	**Length**	**No. Stills**	**Comments**
30/07/2015	W21	07:46:00	08:10:00	00:23:59	21	Fine sand with ripples, worm casts, *Ulva* spp. and drift macroalgae.
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30/07/2015	W27	09:10:00	09:38:00	00:28:47	25	*Laminaria hyperborea* with understorey reds on rock/ boulder/ cobble. Fine sand with occ. seagrass patches and drift m/algae. Large patches of coarse seabed with *Saccorhiza polyschides, Saccharina latissima* and m/algae mid- and outer- transect.
31/07/2015	W1a	07:54:00	08:19:00	00:24:27	22	Fine sand with ripples with occ. seagrass and m/algae-covered rock.
31/07/2015	W6a	08:37:00	09:09:00	00:31:45	31	Coarse/ pebble/ cobble seabed with kelp and algal turf, becoming fine sand with patchy seagrass bed.
31/07/2015	W8a	09:29:00	10:07:00	00:37:40	35	Short initial section of coarse/ pebble/ cobble seabed with kelp and algal turf. Fine sand with patchy, sometimes dense, seagrass bed.
31/07/2015	W10a	10:15:00	10:32:00	00:16:54	16	Fine sand w. coarse/ shell fractions, infauna and drift m/algae. Sparse, patchy seagrass; some denser patches.
31/07/2015	W2a	10:45:00	11:03:00	00:18:18	17	Fine sand w. drift m/algae interspersed w. patches of coarser sed. w. m/algae. Occ. seagrass, becoming more frequent, patchy becoming denser bed. Pot back line?
31/07/2015	W1b	11:08:00	11:28:00	00:20:01	19	*S. polyschides, S. latissima, L. hyperborea* and understorey m/algae on rock outcrop/ boulder/ cobble/ coarse seabed. Changes to fine sed. w. coarse fraction and m/algae. Patchy seagrass, occ. dense towards end of transect.
31/07/2015	W5a	11:38:00	11:59:00	00:21:08		Kelp (*S. polyschides, S. latissima, L. hyperborea*) and understorey m/algae on rock outcrop/ boulder/ cobble/ pebble/ coarse sediment. Mixed (coarse sed./ fine sand) w. drift m/algae becoming fine sand w. infaunal burrows/ siphons. Sparse, patchy seagrass, becoming denser but patchy.
31/07/2015	W4a	12:03:00	12:14:00	00:10:39	29	Fine sand w. drift m/algae and infauna burrows/ siphons. Patchy, sparse seagrass.
31/07/2015	W1c	12:20:00	12:45:00	00:25:23	23	Fine sand w. kelp (*S. polyschides, S. latissima, L. hyperborea*) and m/algae on rock/ boulders. Patchy seagrass bed w. associated m/algae.
31/07/2015	W7a	12:51:00	13:04:00	00:12:46	12	Fine sand w. sparse, patchy seagrass, shell fragments, infauna burrows/ siphons and (drift?) m/algae. Denser seagrass bed at outer extent of transect.
Total	**26**			**09:25:06**	**518**	

A contour map showing the distribution of the density categories of *Zostera marina* is shown in Figure 7 (see also Annex A). *Zostera* bed was approximately 1400 m long and 480 m wide (at the widest and longest points).

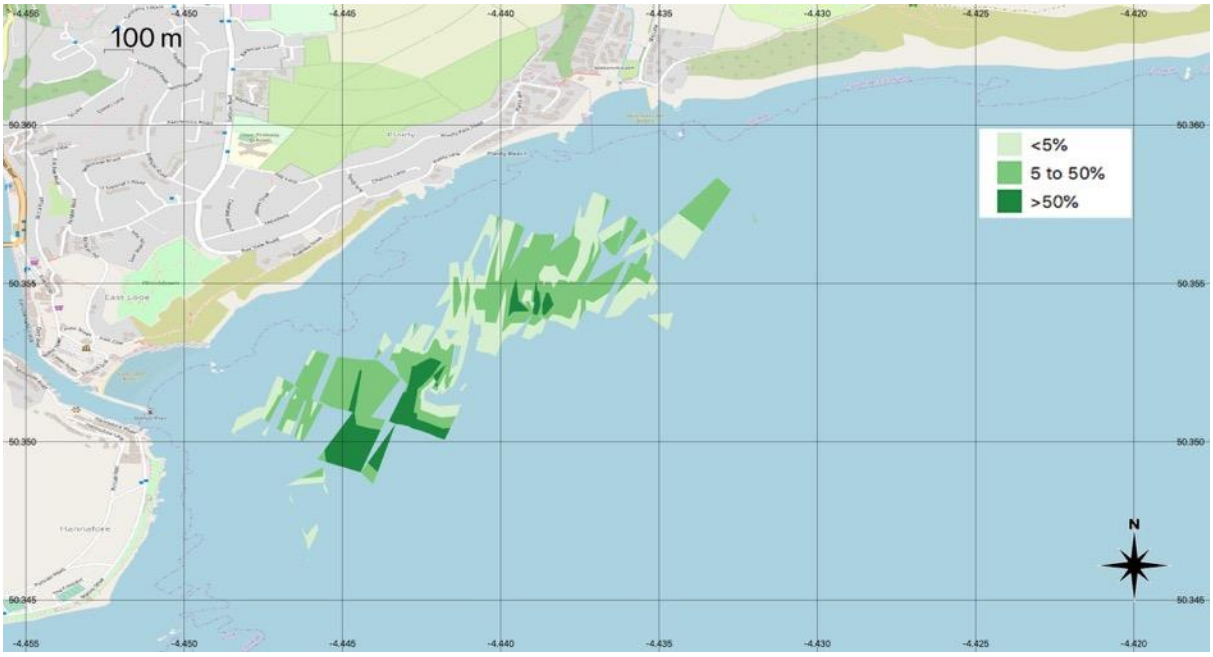

Figure 7 Contour map showing the density of Zostera marina in Whitsand Bay, June 2017 based on the results of the IFCA video survey. Colours represent percentage categories (see key on map)

The areas of each of the three % cover categories recorded from the DDV analysis and calculated from the GIS contour map are given in Table 7.

Table 7 A summary of results from DDV surveys of the Whitsand Bay Zostera bed in 2017

	2017	
Category	Area (m2)	% of area
<5%	106.706	37.8
5 – 50%	138.427	49.0
>50%)	37.318	13.2
Total area all seagrass	282.451	
Total area of bed (> or = to 5% cover)	175.745	

3.2 Studies carried out by diving

A total of 11 transects were studied by diving. A map showing the location of the transects is given in Figure 8.

Figure 8 Map showing positions of transects surveyed by divers

3.2.1 Densities and lengths of plants

The mean number of plants per square meter was estimated by averaging the mean density calculated for each transect and multiplying by 16 and this is presented in Table 8. The mean maximum plant length was calculated by averaging the mean plant length for each transect and this is also presented in Table 8.

Table 8 Calculations of densities and plant lengths based on the diver study transects.

mean no plants m^2 (mean of means for all transects). Range for all 11 transects in brackets	mean maximum plant length in mm (mean of means for all transects). Range for all transects in brackets
51 (1-100)	42 (34-52)

3.2.2 Incidence of plant flowering

Zostera marina plants with flowers and / or seeds were recorded in all transects, with the average incidence of flowering being approximately 8%. A summary of the 2017 data collected is shown in Table 9.

Table 9 Incidence of Zostera marina flowering

No. plants examined	No. plants with flowers	mean % plants with flowers	mean arcsin of % plants with flowers
382	31	8	16.2

3.2.3 Infection by *Labyrinthula zosterae*

The leaves collected by divers at each site were examined for infection by the fungus *Labyrinthula zosterae*. The percentage of the leaves infected was calculated and the degree of infection estimated on the following scale:

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

The data collected is presented in Table 10.

Table 10 Infection by Labyrinthula zosterae of leaves collected by divers at each of the study sites.

Percentage leaves infected (mean of means for all transects) and range	Infection score mean of means for all transects and range
25 (0-46)	0.3 (0.0 - 0.6)

3.2.4 Cover of leaves by epiphytes

Conspicuous epiphytes on *Zostera* included filamentous red and brown seaweeds, encrusting red seaweeds, hydroids, bryozoans and ascidians. The cover by epiphytes of the leaves collected and examined was scored on the same scale as that used for *Labyrinthula zosterae* infection (see section 3.2.3 above).

Summary data on epiphytisation is given in Table 11.

Table 11 Epiphytisation of Zostera leaves collected by divers at each of the study sites.

Percentage leaves with epiphytes (mean of means for all transects) and range	Epiphyte Score mean of means for all transects and range
46 (32 - 57)	0.6 (0.4 – 0.9)

4 Discussion

4.1 Appraisal of methods

Monitoring seagrass beds by DDV and diving was discussed in detail in Bunker and Green (2019) and some of the salient points are revisited here. There are both advantages and drawbacks with each method when it comes to obtaining data that can be compared between sampling events. Obtaining quantitative data on the distribution and abundance of subtidal *Zostera marina* is difficult due to the vagaries of underwater visibility and sea conditions which affect both DDV and divers. It is important to undertake these surveys in good weather with good underwater visibility.

Both the DDV and diver surveys are based on estimation of percentage cover of seagrass in quadrats. When considering the results, limitations of surveyor's abilities to accurately estimate percentage cover of seagrass should be recognised and this is particularly true of *in situ* observations by divers. Inconsistency with respect to how different surveyors estimate percentage cover of organisms is well known (Baker and Little, 1989, Moore, Bunker et al., 2015). As well as inter-surveyor variability, perception of cover is affected by the way seagrass is arranged in a quadrat e.g. when the current is running and the seagrass is flattened compared to when the water is still and the seagrass is upright. Patchiness can make estimations problematical. In order to help compensate for this, it is important that both the DDV team and the divers use reference photographs when doing estimates (see Environment Agency (2018)). It is not known whether such reference photos were used in the analysis of the IFCA survey data.

Abundance of seagrass in the transects was recorded on an abundance scale (see Table 3). Scales of abundance are not ideal for collecting monitoring data as the results cannot readily be analysed statistically. It would be better to record estimates of percentage cover underwater and later convert to abundances if thought necessary.

Curtis (2012) highlighted the problem of calculating statistics using the data from all transects. This was because each transect differed significantly from the others. In future surveys it would be useful to have set positions for the transects in order to improve chances of comparison.

Another diver-lead sampling regime would be to follow the one proposed by Unsworth, Bertelli et al. (2014) where the seagrass status is assessed within randomly assigned quadrats radiating out from pre-determined seagrass sampling points spread in a stratified fashion throughout the whole seagrass meadow. If such a regime were followed the problem of calculating statistics from independent transects could be solved.

4.2 Area of the seagrass bed

The area colonised by *Zostera* calculated in the previous studies (highlight in section 1.1) and current studies is given in Table 12.

Table 12 Estimated area covered by seagrass in the Whitsand Bay and Looe MPA in three years.

	1998	2011	2015
Total area of all seagrass (m^2)	20 to 30	1100	282.451
Total area of bed (m^2) ie > or = to 5% cover)	?	?	175.745

There are problems with comparison of data between years, largely due to different methods being used each time. The 2001 desk-study (Hocking and Tomsett 2001, cited Clark, 2011) showed only a rough area in which seagrass had been found. The 2011 study and the 2015 study both used DDV but different methods for both recording and analysing the collected data. The 2011 survey employed fewer transects and calculated predictive patterns of seagrass distribution and density using ArcGIS and a process known as krigging (see Figure 3). The 2015 survey employed many transects and data points and the areas and densities were calculated using QGIS and the Contour plug-in (as employed in Bunker and Green (2019). Different abundance categories were used to draw the maps and assess cover in 2011 and 2015.

Both the 2011 and the current study created maps showing the area covered by seagrass using GIS to calculate cover of the *Zostera marina*. Not only were different methods used to achieve this each time but with such a patchy Zostera bed, the maps produced should only be used as a guide to cover and density of seagrass and cannot be used for accurate monitoring. Having stated this, gross changes in cover and abundance would show up over time but it is recommended that the same method be used to produce the maps.

To qualify as a *Zostera* spp. 'bed', the OSPAR definition states that plant densities should provide at least 5% cover (Tullrot, 2009) . This means that much of the area where seagrass was recorded does not achieve 'bed' status (see Table 12).

4.3 Density and shoot length

The mean density of plants was calculated at 51 per m^2 and this is low compared to densities recorded in Plymouth Sound in 2018 (Bunker and Green, 2019) where densities ranged from 64 to 119 m^2. An open coast bed off Torbay surveyed in 2019 had densities of 20 to 60 m^2 which are comparable with those of Whitsand Bay (Field, 2019). Clark (2011) quoted a figure of 110 plants per m^2 based on the 2011 study which is double that found in 2015. Whether this represents a real decline or is simply due to where the quadrats were placed on this patchy seagrass bed is unknown.

The 2001 desk-study (Hocking and Tomsett 2001, cited Clark, 2011) suggested that shoot length of the seagrass was estimated to be 1m (and it appears that the plants were not actually measured). The 2011 study (Clark, 2011) was carried out in spring when the shoot length was not yet developed. The mean maximum length of plants as measured in 2017 was 42 mm which is comparable to measurements taken at the same time of year (July) in Plymouth Sound (Bunker and Green, 2019). It is likely that the 2001 desk-study overestimated the length of plants. It was not ascertained whether or not shoot length was affected by depth.

4.3.1 Incidence of flowering

Flowering was recorded in 8% of the plants examined during the survey. This is slightly higher than was generally found in Plymouth Sound where incidence of flowering was around 5% (Bunker and Green, 2019). The statistical significance of this difference has not been calculated.

Philips, Grant et al. (1983) studied *Zostera marina* populations from the Pacific coast of North America and found that in subtidal areas where salinity fluctuation is minimal, dense stands of perennial plants reproduced vegetatively. This contrasted with intertidal areas where seasonally low salinities enhanced seed germination, where there was a higher incidence of flowering. A recent study in temperate China by Xu, Wang et al. (2018) examined the contribution of sexual reproduction to population recruitment. At a site protected from strong currents and waves, sexual reproduction in *Zostera marina* populations was more important than in an open coast situation. It was postulated that temperature regime may induce shifts in sexual recruitment strategies in *Zostera marina*. Blok, Olesen et al. (2018) suggested that global warming will result in an increased capacity for sexual reproduction at northern latitudes. Paulo, Diekmann et al. (2019) studied the hypothesis that the contribution of sexual propagation varies during the recovery of a seagrass meadow. They compared the proportion of sexual versus vegetative propagation of a perennial *Zostera marina* meadow before its disappearance due to winter storms and after recovery. They demonstrated the importance of sexual reproduction in meadow recovery and persistence.

The importance of collecting data on sexual reproduction in the seagrass beds is underlined by the above studies.

4.3.2 Infection by *Labyrinthula zosterae*

Muehlstein, Porter et al. (1991) identified the fungus *Labyrinthula zosterae* as the pathogen associated with wasting disease in *Zostera marina* which allegedly devastated seagrass beds in the 1930's. A recent study by Brakel, Werner et al. (2014) found little evidence that *L. zosterae* negatively impacted *Zostera* plants. On the contrary, infected plants showed enhanced leaf growth and kept infection to a low level and genetic studies indicated that *Zostera marina* was probably able to control host infection. The conclusion was that in their study area (the Wadden Sea and the Baltic), *L. zosterae* was not associated with substantial virulence under non-stress conditions. A more recent study in the Baltic by Brakel, Jakobsson-Thor et al. (2019) examined the effects of predicted climate change on *L. zosterae* / *Zostera marina* interactions. They found that *L. zosterae* was unable to infect *Zostera marina* under high temperature (27 ℃) in combination with low salinity (12 psu). Their work supported the idea that *L. zosterae* doesn't pose an immediate risk for eelgrass beds in the Baltic Sea, nor a future one (under the predicted salinity decrease and warming).

Infection by *L. zosterae* in the Looe seagrass bed recorded in 2017 was low (25% with a mean infection score of 0.3), compared to that recorded in Plymouth Sound in 2018 (44% with a mean infection score of 0.7). Continued monitoring of *L. zosterae* is useful in case of changes of condition that could result in this currently benign pathogen becoming virulent.

4.3.3 Cover of leaves by ephiphytes

Plant and animal epiphytes are a characteristic and diverse component of the seagrass community. Some species are endemic to seagrasses, such as the red encrusting seaweed

Rhodophysema georgii (Irvine, 1983) and the hydroid *Laomedea angulata* (Cornelius, 1995). Others are common species which are small enough to live on or feed on the seagrass community. A study of seaweed epiphytes found in seagrass beds in Wales was carried out by Edwards, Bunker et al. (2003).

A review of epiphyte-seagrass relationships with an emphasis on the role of micrograzing was undertaken by Orth and Montfrans (1984). The authors describe how the pioneer pennate diatom *Cocconeis scutellum* colonise *Zostera marina* leaves forming a mat which is in-turn colonised by a variety of micro-organisms, mainly bacteria, which are incorporated into a mucous matrix. It is thought that dissolved organic carbon released by the seagrass blades may enhance the growth of bacteria. Detritus becomes incorporated into the periphyton and a thick crust develops with algal growth on seagrass blades benefiting from nutrients released by seagrasses e.g. phosphates.

The epiphyte crust acts as a barrier to photosynthesis. Borum and Wium-Andersen (1980) demonstrated that less than 10% of incoming light was transmitted through a thick old crust at leaf tips whereas greater than 90% of ambient light was available for photosynthesis to lightly epiphytised (younger) basal portions of the blades. Grazing by molluscs, polychaetes and crustacea help keep fouling in check as well as rapid growth of new leaves and the shedding of old leaves. A study in France, (Jacobs and Noten, 1980 cited Orth and Montfrans, 1984) found new leaves grew every 13 days in May and 28 days in December.

Orth and Montfrans (1984) state that the diatom and bacteria component of the periphyton is responsible for a considerable percentage of production of seagrass bed ecosystems. On a per unit area basis, epiphytes contribute an average between 18% and 50% of the combined *Z. marina* leaf production. This production is available for consumption by the numerous grazers found in seagrass habitats, including molluscs, polychaetes and crustacea. The grazing is beneficial to the seagrass, as it helps remove the periphyton crust. Ruesink (2016) pointed out that epiphyte load was only of concern when it slows seagrass growth either as a result of lack of 'top-down' and / or 'bottom up' control shifts the relationship to a point where seagrass can no longer out-grow its competitors. The development of an epiphyte indicator of nutrient enrichment and finding threshold values for seagrass epiphyte load was advocated by Nelson (2017). He considers epiphyte load on submerged aquatic vegetation to be a useful biological indicator of water quality conditions with respect to nutrients.

Nelson (2018), in a study evaluating factors controlling the abundance of epiphytes on *Z. marina* considered that both seagrass and seagrass epiphytes may become increasingly light limited in the upper estuary and so epiphyte loads may have proportionally more impact in estuarine regions. In eutrophic conditions, macroalgae epiphytic on the seagrass *Posidonia australis* were found to impede its growth and has been known to cause disappearance of seagrass beds in polluted areas (Larkum, 1976 cited Orth and Montfrans, 1984). Prado (2018) found how epiphyte patterns clearly matched in situ measures of nutrient availability and were consistent with decreased shoot densities in discharge sites.

In the Looe seagrass bed, the incidence of epiphytes on leaves was 46%, with a score of 0.6 which was much lower than recorded in Plymouth Sound in 2018 where 87% of leaves bore epiphytes with an average score of 2.0.

The types of epiphytes that occur on seagrasses are thought to be an indicator of climate change. Brodie, Williamson et al. (2014) predict than with an increase in CO_2 in the oceans, seagrasses will proliferate, and associated epiphytes switch from calcified algae to diatoms and filamentous species. It would be useful to devise a way of cataloguing the species occurring in the epibiota to see if this changes over time. In Plymouth sound, the epiphytes are known to vary from bed to bed (Saunders, Attrill et al., 2003).

4.4 The condition of the subtidal seagrass bed in Whitsand and Looe Bay MCZ.

The importance and benefits of seagrass beds to marine ecosystems is well known and documented and have a long history of study. Recent summaries regarding conservation of seagrasses and their importance are given in Unsworth, McKenzie et al. (2018) and (Nordlund, Unsworth et al., 2018). Globally, seagrass beds are under threat with an estimated 29% of the known areal extent having disappeared since seagrass areas were initially recorded in 1879, making them amongst the most threatened habitats on earth along with mangroves, coral reefs, and tropical rainforests (Waycott, Duarte et al., 2009). A recent study by Nahirnick, Costa et al. (2020) linked a long-term decline (1932 to 2016) of three *Zostera marina* beds off the coast of British Columbia to coastal development. This emphasises the need for monitoring seagrass in Marine Protected Areas.

Natural fluctuations in the areal extent and density are to be expected and this requires separating these from actual decline and degradation. It is only by long term monitoring and investigating the environmental parameters that impinge on the health of seagrass communities that they can be effectively conserved.

Comparisons of this survey's data to that of 2011 (Clark, 2011) are difficult due to changes in methodology. The results of this survey underline the fragmented nature of the Looe seagrass bed. If the Looe bed is inherently patchy due to its open coast situation then the condition of the bed would be favourable. Certainly similarities in densities between those reported for Whitsand Bay and those recorded for Torbay (Field, 2019) lead to the conclusion that patchy seagrass at a low density could be normal for the open coast of Devon and Cornwall (see section 3.2.1). It is not possible to tell without further monitoring.

Other indices studied e.g. plant length, infection by *Labyrinthula zosterae* and epiphytism indicate that the seagrass is generally healthy.

4.5 Summary and conclusions

- The seagrass bed is of a patchy and fragmented nature with a large proportion of the area colonised by seagrass being less than 5% cover and so not qualifying for seagrass bed status in the OSPAR definition (Tullrot, 2009). It should still be considered as an important habitat that needs protection and a component part of the MCZ.

- Area estimates of seagrass habitat are difficult particularly due to patchiness within a bed and decrease in density with depth. Methods used to estimate area of coverage in the Whitsand and Looe Bay MCZ have been different on each occasion (1998, 2011 and 2015) and this makes any accurate comparison between years impossible. For monitoring it is important to use that the same methodology on each sampling occasion and it is recommended that the method developed by the Environment Agency in Plymouth Sound (Bunker and Green, 2019) be used in future.

- Whether or not the status of this bed can be considered as favourable is unknown and will remain so until the results of future monitoring is known.

- The dual approach of DDV and *in situ* recording by divers provides a good way of monitoring the different important features of seagrass beds. The survey methodologies currently employed together with ideas for improving them are presented in section 4.1. In particular, a revision of the diving methodology, changing from transect based surveys to one of stratified random sampling within the seagrass beds would provide results on density with more statistical power.

- Infection by the 'wasting disease' causing fungus *Labyrinthula zosterae* is present but low compared to that measured in Plymouth Sound in 2018 (Bunker and Green, 2019).

- The epiphyte populations recorded on the seagrass leaves were low and would not be considered to be having a deleterious effect on seagrass health. It is recommended that future monitoring studies should include more detailed studies of the epifloral and fauna by taxonomic experts.

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ANNEX A

Seagrass bed extent - Whitsand and Looe Bay MCZ - 2011 Cornwall Wildlife Trust and 2015 Cornwall IFCA survey data