Update 2015
Distribution mapping and health assessment of honeycomb worm, *Sabellaria alveolata*, reefs on Heysham Flat, Lancashire

Report to the North Western Inshore Fisheries and Conservation Authority

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Cover picture: aerial photo of *Sabellaria alveolata* reef on Heysham Flat. Credit: Royal Society for the Protection of Birds (RSPB), 2015.

1. Acknowledgements

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In addition to these formal acknowledgements, I would like to wholeheartedly thank everyone who helped to collect data for the study and the scientists at NWIFCA for coordinating surveys and for training surveyors.

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List of symbols

> (≥)	greater than (greater than or equal to)
< (≤)	less than (less than or equal to)
±	plus or minus
χ^2	Chi-square statistic of Kruskal-Wallis test
m	metre
m^2	square metre
n	total number
p	p-value
%	percent
τ	Tau statistic of Kendall's tau coefficient

List of acronyms and abbreviations

ANOVA	analysis of variance
BST	British Summer Time
cont.	continued
EMS	European marine site
GPS	Global Positioning Satellite
QGIS	Quantum Geographical Information System
MCZs	Marine Conservation Zones
MLS	minimum landing size
NWIFCA	North Western Inshore Fisheries and Conservation Authority
pers. comm.	personal communication
SE	standard error
spp.	species (plural)
SSSI	Site of Special Scientific Interest
UAV	Unmanned Aerial Vehicle

2. Introduction

This report serves as an update to two previous annual reports: Distribution mapping health and assessment of honeycomb worm, *Sabellaria alveolata*, reefs on Heysham Flat, Lancashire by Sian Egerton in 2014 (Egerton, 2014) and by Vicki Foster in 2015 (Foster, 2015). Copies of these documents can be found at www.nw-ifca.gov.uk or can be requested by emailing livingseasnw@cumbriawildlifetrust.org.uk. These two previous reports continue on from surveys to map the health and distribution of *S. alveolata* on Heysham Flat which began in 2011. This report will incorporate the data collected between 2011 and 2015.

This report has followed similar layouts to Egerton (2014) and Foster (2015) for ease of cross-referencing between reports. The report written by Egerton (2014) provides a detailed background, introduction and methodology which are identical to this update. To avoid repetition all sections which did not require updating or alterations have not been included in this report. This excludes basic information such as location maps which are needed to interpret this updated report as well as a brief summary of population dynamics of *S. alveolata* and the blue mussel, *Mytilus edulis* on Heysham Flat.

2.1. Population dynamics of *Sabellaria alveolata* and *Mytilus edulis* on Heysham Flat

Egerton (2014) provides a thorough introduction regarding the distribution, environmental requirements, population dynamics and associated biodiversity of *S. alveolata* in European waters. Egerton (2014) also details the competition between *S. alveolata* and *M. edulis* which is an integral relationship to understand the distribution and health of *S. alveolata* in this study. The resounding conclusion in reports from both Egerton (2014) and Foster (2015) is that both species appear to be ephemeral on Heysham Flat with large variations in distribution and health from year to year.

It has been documented that *S. alveolata* has settled and colonised different areas of Heysham Flat each year. These settlements do not last long (often months or less) and are highly impacted by the dense settlement of undersize *M. edulis* each summer. *M. edulis* is a characteristically competitive species and is well documented to completely colonise areas of hard substrate all around the world, as is seen in areas around Morecambe Bay (Seed & Suckanek, 1992). This is important to their survivability as seasonally *M. edulis* is highly affected by stormy weather with large settlements being washed out of the area on Heysham Flat during winter months. Conversely during the winter months *S. alveolata* is recorded to survive well and create new settlements after reproducing in the summer months (Wilson, 1971). After the primary settlement phase, *S. alveolata* goes through a further three phases of growth, stagnation and destruction as documented in this report (Gruet, 1986).

3. Survey location

The location of the survey, Heysham Flat, is on the North West coast of England situated in Morecambe Bay in Lancashire centrally located at latitude: 54.0590, longitude: -2.9031 (Figure 1). The geological features of Heysham Flat are comprised of rocky skear, a boulder and rocky substrate, surrounded by an expansive dense sandy bay. Heysham Flat is accessible by foot from the mainland at low tide. On a designated area on Heysham Flat there is a seasonal hand gathering seed mussel (*Mytilus edulis*) fishery (NWIFCA, 2015b).

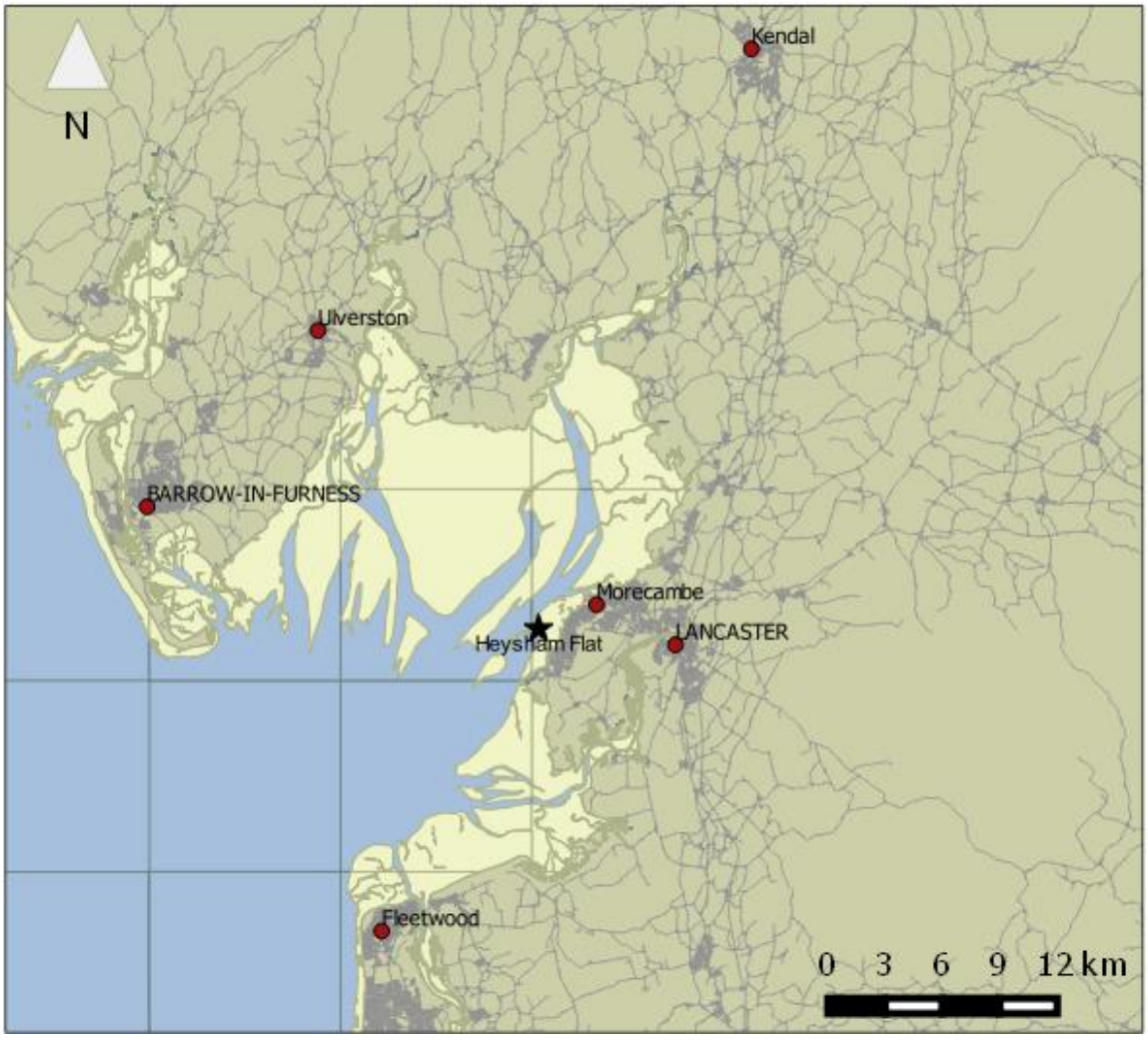

Figure 1 - Map of Morecambe Bay in North West England depicting the location of survey: Heysham Flat. Figure created in QGIS overlaid on Ordnance Survey maps (Ordnance Survey, 2015)

Morecambe Bay is a designated European marine site (EMS) (English Nature, 2000) with *S. alveolata* reef being listed as a key sub-feature (JNCC, 2008). *S. alveolata* reef is also a biodiversity action plan habitat and is found on the skear at Heysham Flat. NWIFCA Byelaw 6 prohibits the use of bottom towed gear on reef features including an area on Heysham Flat

(Figure 2) (NWIFCA, 2014). In addition to this protection, the main area of *S. alveolata* is also closed to the aforementioned hand gathering seed mussel fishery.

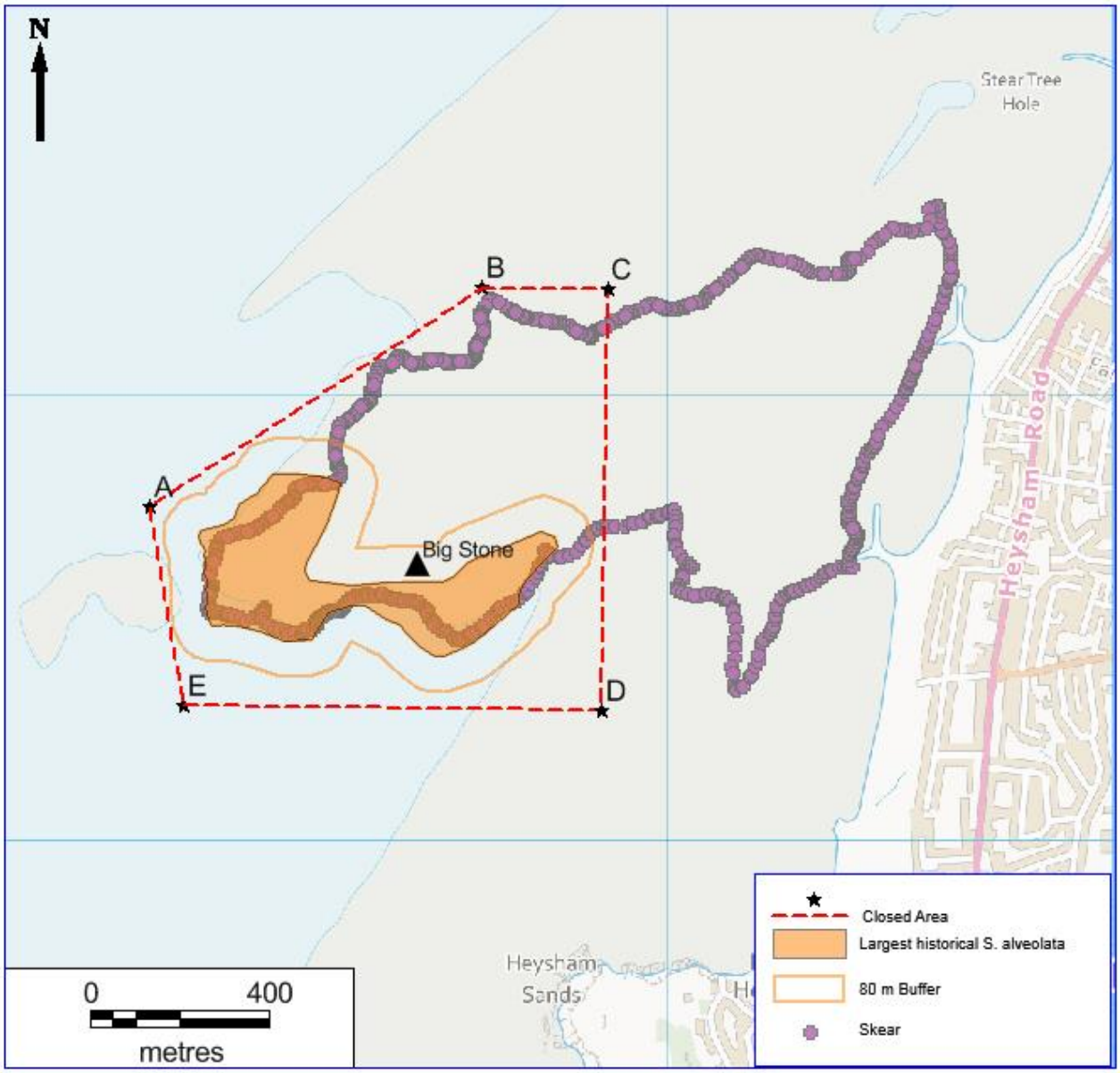

Figure 2 - Descriptive map of Heysham Flat and skear depicting area closed to bottom towed gear inside points A-E classed in this report as EMS Heysham Flat Area. This encompasses the largest historical area of *S. alveolata.* The channel, called Dallam Dyke, can be seen to the left of the historical area of *S. alveolata* (NWIFCA, 2014).

4. Field surveys

4.1. Survey organisation

Field surveys to assess the distribution and health of *S. alveolata reefs* on Heysham Flat have remained consistent since annual seasonal surveys began in 2011 with minor changes in methodology and survey points. Previous reports by Egerton (2014) and Foster (2015) have extensively detailed the organisation of survey. These reports built upon and improved the survey organisation that was established in the 2011 to 2013 surveys.

4.1.1. Dates, tides and surveying hours

As with previous surveys of the *S. alveolata* distribution and health on Heysham Flat, the 2015 surveys were planned for extreme low tides mainly less than one metre in the spring and summer. This was to allow for the maximum area of Heysham Flat to be accessed in one survey. All surveys were conducted at least two hours before low tide and no later than one hour after low tide in daylight hours for safety reasons and access logistics. A full list of survey dates and times from surveys from 2011 to 2015 is displayed in Table 1.

Table 1 - Survey dates and times of surveys from 2011 to 2015. 2015 surveys are highlighted in light blue.

Season	Date	Time of sunrise (BST)	Time of sunset (BST)	Time of low tide (BST)	Height of low tide (m)	Time of high tide (BST)	Height of high tide (m)
Summer 2011	30/08/11	06:17	20:08	07:05/19:15	0.6/0.8	12:50	10.1
Autumn 2011	27/09/11	07:07	18:58	06:00/18:10	0.8/0.9	11:40	10.0
Spring 2012	03/08/12	05:30	21:05	07:15/19:30	0.8/1.1	12:50	9.5
Summer 2012	20/08/12	06:00	20:29	08:05	0.9	13:50	9.7
Autumn 2012	15/10/12	07:41	18.13	05:55/18:05	1.1/1.2	11:40	9.9
Spring 2013	02/04/13	06:40	19:15	10:40	1.8	16:30	8.6
Summer 2013	27/06/13	04:41	21:48	09:25	0.7	15:00	9.4
Summer 2013	24/07/13	05:13	21:23	19:50	0.8	00:40	10.2
Autumn 2013	10/10/13	07:31	18:25	09:40/22:05	2.0/2.1	03:05/15:30	9.3/9.1
Spring 2014	28/04/14	05:40	20:38	05:45/18:10	1.1/0.9	11:20/23:45	9.7/9.6
Summer 2014	15/07/14	04:59	21:36	08:30/20:50	0.5/0.9	14:10	9.9
Spring 2015	23/03/15	06:06	18:31	07:35/19:55	0.5/0.6	13:10	10.4
Summer 2015	06/07/15	04:48	21:45	09:30/21:50	1.0/1.5	15:15	9.3
Summer descriptive 2015	03/09/15	06:24	19:58	09:35/22:00	0.9/1.3	15:20	9.6

4.1.2. Surveyors

The 2015 spring survey was conducted by: NWIFCA staff Senior Scientist, Mandy Knott; Science Officer, Abigail Leadbeater; Enforcement Officer Nick Walters and Head of Enforcement, Andrew Deary.

The 2015 summer survey was conducted with assistance from Cumbria Wildlife Trust's and the Wildlife Trust for Lancashire, Manchester and North Merseyside's Marine Training Programme, hereby known as the North West Wildlife Trusts. Trainee Marine and Coastal Conservation Officers Catherine Oliver, Kathryn Borrowdale, Sally Tapp and Christina Pullan assisted NWIFCA surveyors Mandy Knott and Sarah Temple.

The 2015 summer descriptive survey was conducted by Catherine Oliver and Sally Tapp from the North West Wildlife Trusts.

4.2. Methodology - amendment

All methodologies remain the same as the surveys conducted in previous years. Recommendations for future studies from Egerton (2014) were adopted by the 2014 and 2015 study to survey 84 centralised fixed stations to ensure a standardised representation of changes of *S. alveolata* distribution and health between seasons. These recommendations were continued for surveys conducted in 2015. For reference, a guide for the classification of health and formation categories of *S. alveolata* used during surveys can be found in Appendix I.

In addition to the surveys conducted in spring and summer 2015, another survey was conducted in September 2015, herein referred to as 'summer descriptive 2015.' The purpose of the summer descriptive survey was to collect additional data not already mapped on the skear where *S. alveolata* was known to be present. These data were collected due to recommendations from the Senior Scientist at NWIFCA and from the 2014 *S. alveolata* update report (Foster, 2015). The summer descriptive data were not used for mapping or statistical analysis in this report as it is biased data and therefore including it would distort the findings from the survey. For the purpose of this report, data from the 2015 summer descriptive survey were not to be classed as seasonal data. A map of all stations surveyed between 2011 and 2015, including stations surveyed in the 2015 summer descriptive survey is depicted in Figure 4. This map serves as only an illustrative view of the survey area and it should be noted that Morecambe Bay is undergoing significant changes in terms of sediment dynamics which means that the mean low water mark is constantly changing.

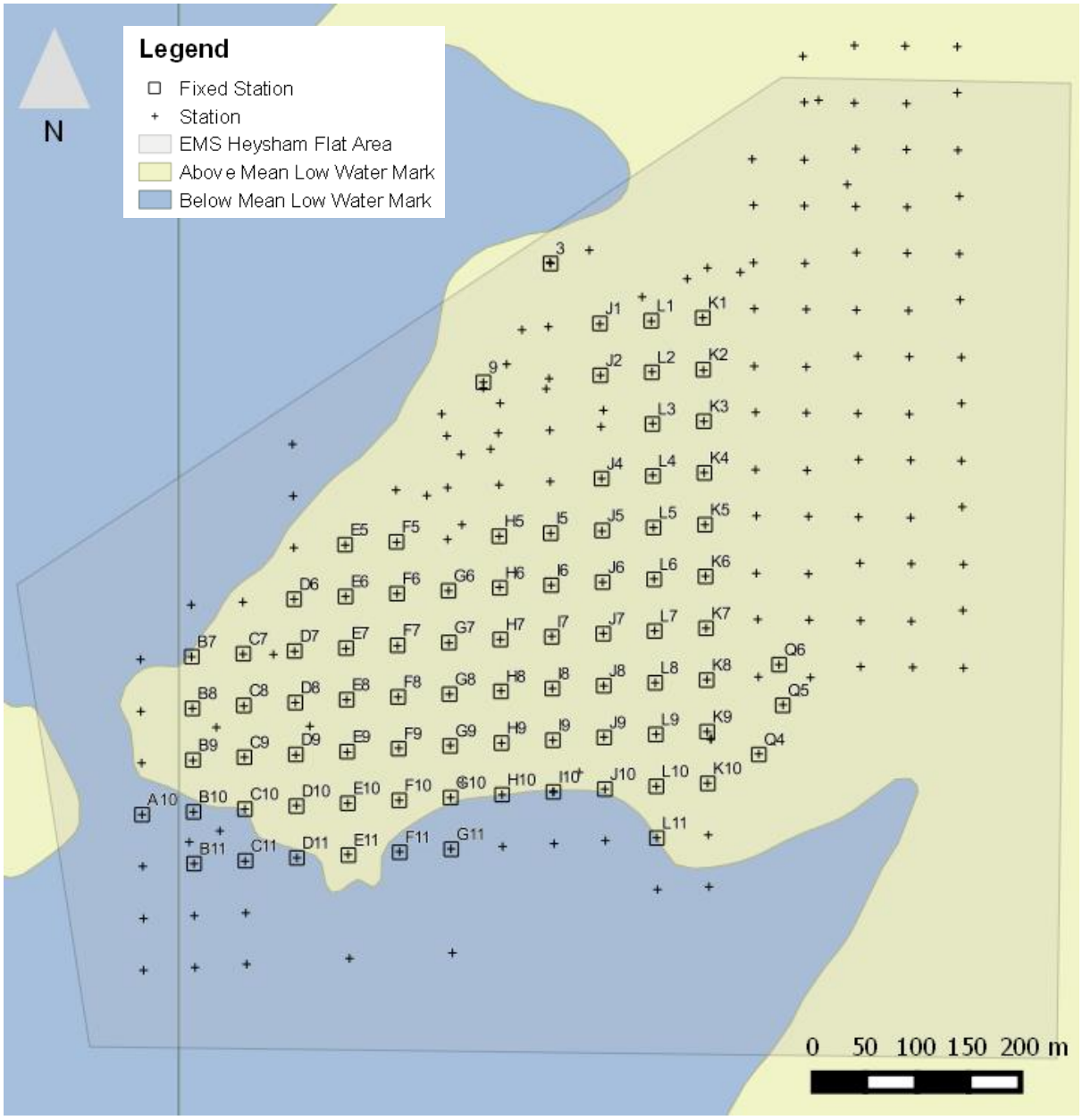

Figure 4 - Descriptive map depicting sampling stations (crosses) on Heysham Flat. Fixed stations are boxed and labelled. Figure created in QGIS overlaid on Ordnance Survey maps (Ordnance Survey, 2015).

4.3. Data analysis - amendment

As with the update report by Foster (2014) analysis focused on investigating results from the following:

- Distribution (ie. percentage cover) of *S. alveolata* at all stations
- Distribution of *S. alveolata* at fixed stations
- *S. alveolata* formation at fixed stations

- *S. alveolata* condition at fixed stations
- Distribution of *M. edulis* at fixed stations
- Relationship between *S. alveolata* and *M. edulis* at all stations
- Biodiversity on Heysham Flat at all stations.

The 2015 summer descriptive survey was not included in any analysis as it was only used for descriptive evidence.

4.3.1. Statistical analysis

Two main types of statistical tests were carried out, those to test for differences between seasons and those to test for relationships between variables.

Statistical analysis to test for differences

Seasonal data for *S. alveolata* percentage cover at fixed stations was compared to assess statistical differences between seasons. A Fligner-Kileen test of homogeneity of variance was applied to the data to assess for violations of assumptions. This test showed violations and therefore the data were classed as non-parametric. Differences in the percentage cover of *S. alveolata* across all fixed stations were therefore tested using a Kruskal-Wallis analysis of variance test (ANOVA). Post-hoc pairwise comparison tests using the Bonferroni correction was then applied to assess differences of the mean ranks from each season. The same statistical tests were used to assess differences between both adult and undersize *M. edulis* cover and seasons at fixed stations.

Statistical analysis to test for relationships

Due to the non-parametric nature of the data, Kendall's tau coefficient test was used to assess the correlation between the following data:

- *M. edulis* and *S. alveolata* distribution at all stations
- *S. alveolata* and species richness at all stations
- Adult *M. edulis* distribution and species richness at all stations
- Undersize *M. edulis* distribution and species richness at all stations.

All statistical analyses were conducted using the software R, version 3.2.2 (R Development Team, 2015), in the integrated development environment R studio, version 0.99.486. (R Studio Team, 2015).

4.3.2. Mapping data

Similar to the report by Foster (2015), maps were created using QGIS, version Lyon 2.12.2 (QGIS Development Team, 2015), with data overlaid on Ordnance Survey maps (Ordnance Survey, 2015). Using season data from 2011 to 2015 thematic maps were created to depict the following data:

- Distribution of *S. alveolata* at all stations
- Distribution of *S. alveolata* at fixed stations
- *S. alveolata* formation at fixed stations
- *S. alveolata* condition at fixed stations
- Distribution of *M. edulis* at fixed stations.

On all maps, areas with ≥30% and ≥70% coverage of *S. alveolata* were depicted to visually highlight important areas and also to assess any correlations or differences between seasons. All maps depict the European marine site (EMS) Heysham Flat designated area along with every station with data from 2011 to 2015 to provide a visual comparison of the extent of points surveyed within the designated area (NWIFCA, 2014).

5. Results

The distribution mapping and health assessment of *S. alveolata* has been recorded on Heysham Flat since 2011 with a cumulative total of 210 stations surveyed between 2011 and 2015. Due to the dynamic nature of *S. alveolata* in the survey area it was difficult to gain a representative overview of the changes occurring so in summer 2014 84 fixed stations were established to make it easier to seasonally compare data (Foster, 2015). The number of stations surveyed each season is displayed in Table 2.

Table 2 - Number of stations surveyed each season from 2011 to 2015 including number of fixed stations surveyed where 'Spr' = spring, 'Aut' = autumn, 'Sum' = sum, 'Sum Desc' = summer descriptive.

Survey Year	**2011**	**2012**		**2013**			**2014**		**2015**		
Survey Season	Aut	Sum	Aut	Spr	Sum	Aut	Spr	Sum	Spr	Sum	Sum Desc
No. stations surveyed	49	86	62	63	104	51	38	97	98	82	11
No. unique annual stations (replicates removed)	49	148			173		103			109	
No. fixed stations surveyed	49	79	0	0	78	44	26	84	81	81	0

Table 2 highlights that the years with low survey power were autumn 2011 (49 stations), autumn 2013 (51 stations) and spring 2014 (38 stations). For these seasonal surveys, due to low survey power, data analysis was not as good a representation as other seasons. In autumn 2012 and spring 2013 no fixed stations were surveyed and therefore will not be included in the fixed station analysis.

In 2015 three surveys were conducted, two full surveys in spring and summer and also a descriptive survey with 11 stations surveyed in areas not surveyed during the fixed survey. Due to the dynamic nature of the distribution of *S. alveolata* around the skear a summer descriptive survey was needed to gain a wider understanding of the abundance and health of *S. alveolata* on Heysham Flat. In spring 2015 it was not possible to survey station L4, L3 and L9 as they were submerged in water which deemed the stations unsafe to survey as was the situation in summer 2015 with stations L6, L3 and L9.

5.1. Seasonal distribution of *Sabellaria alveolata*

Due to the dynamic and ephemeral nature of *S. alveolata* on Heysham Flat, the seasonal distribution of *S. alveolata* was analysed twice. One analysis focused on all stations and the other analysis focused on only fixed stations. The purpose of displaying all stations that were surveyed each season was to depict the movement of *S. alveolata* around the skear seasonally as a descriptive representation. By using fixed stations it was easier to compare data across all seasons for more accurate analysis. Raw data from all 2015 surveys relating to *S. alveolata* distribution and health assessment can be found in Appendix II.

5.1.1. Seasonal distribution of *Sabellaria alveolata* at all stations

The overview of all 10 seasons surveyed shows a fluctuation of the percentage cover of *S. alveolata* between seasons (Figure 5). Although this analysis is not accurately representative due to varying numbers of stations surveyed, Figure 5 shows a cycle of high mean percentage cover of *S. alveolata* across seasons. In spring 2013 and summer 2014, mean percentage cover of *S. alveolata* was less than 5%. In seasons following these lows percentage cover increases by at least 10%. In autumn 2012 and spring 2013 a different section of the skear was surveyed from other seasons, the reasons for this are explained in Egerton (2014).

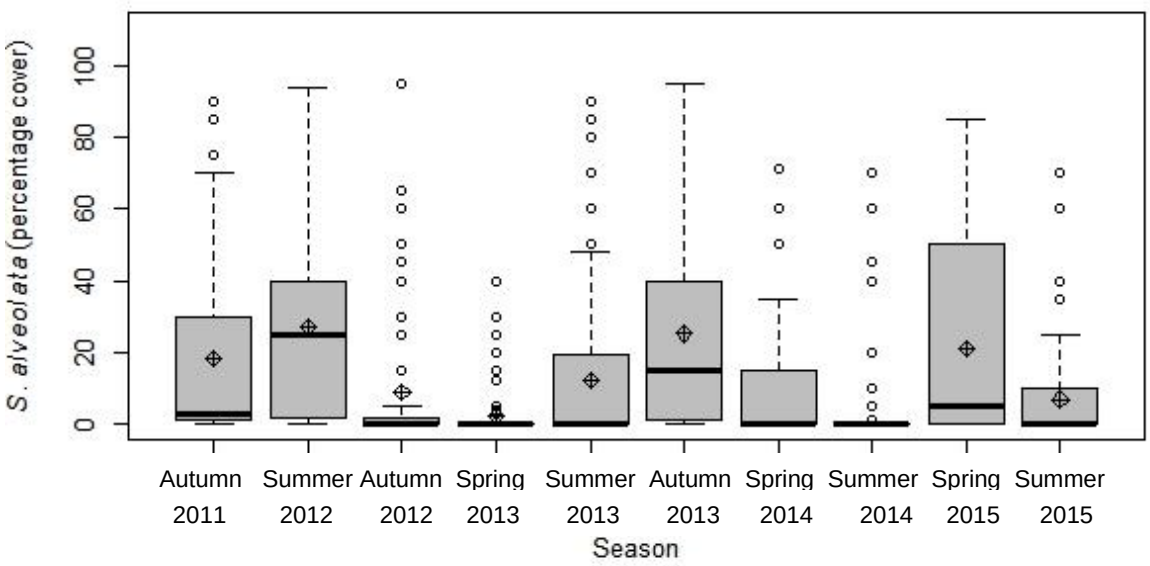

Figure 5 - Boxplot depicting average percentage cover of *S. alveolata* at all stations on Heysham Flat. Crossed diamonds represent the mean.

Figure 6 (a) – j)) shows maps of the survey area with the distribution of *S. alveolata* depicted at all of the stations surveyed in each season.

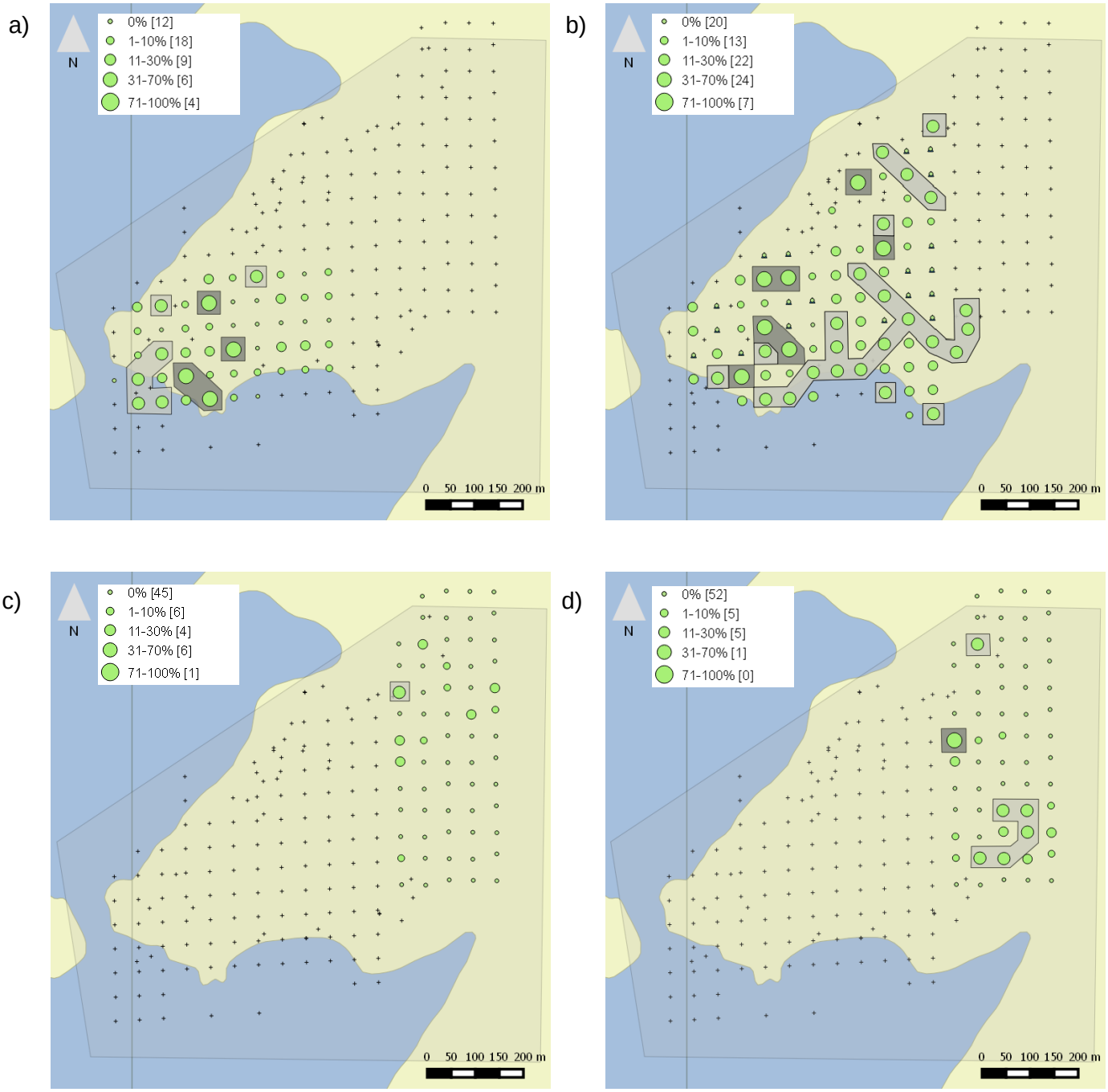

Figure 6 - Maps of Heysham Flat depicting mean percentage cover of *S. alveolata* at all stations per season. The maps are labelled as: a) autumn 2011, b) summer 2012, c) autumn 2012, d) spring 2013.

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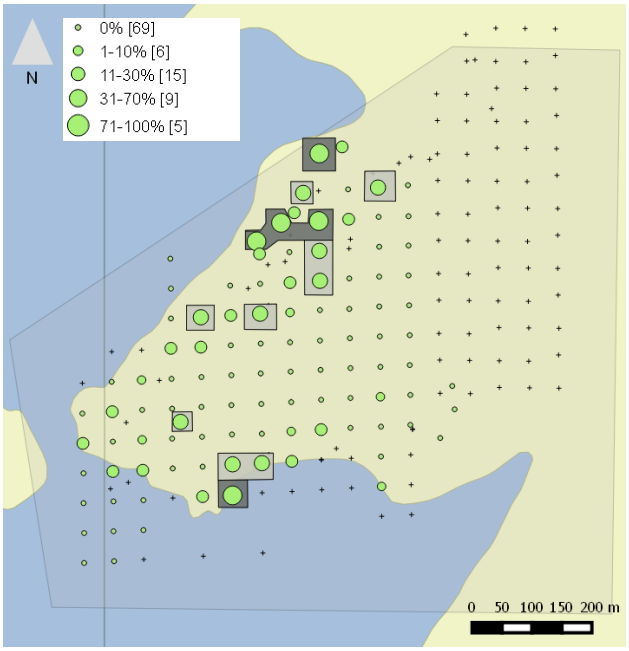

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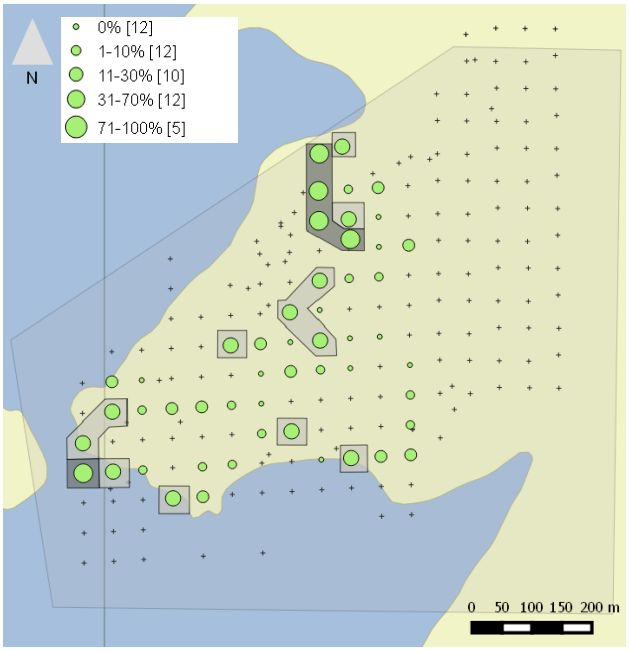

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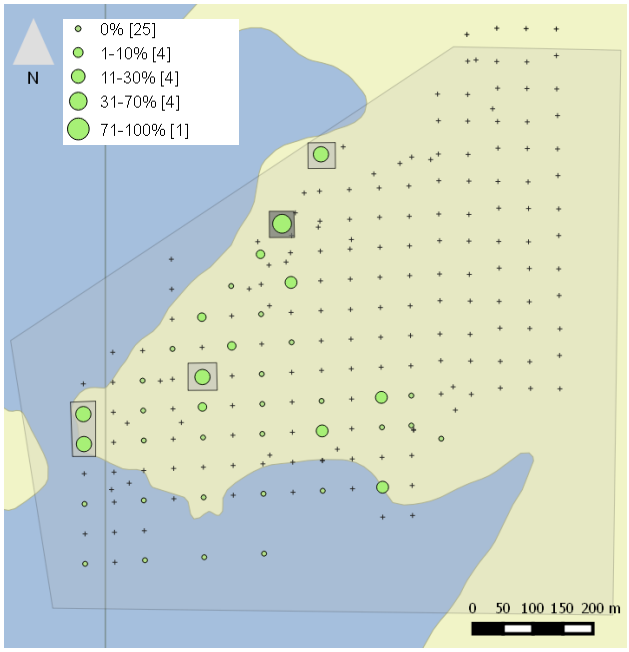

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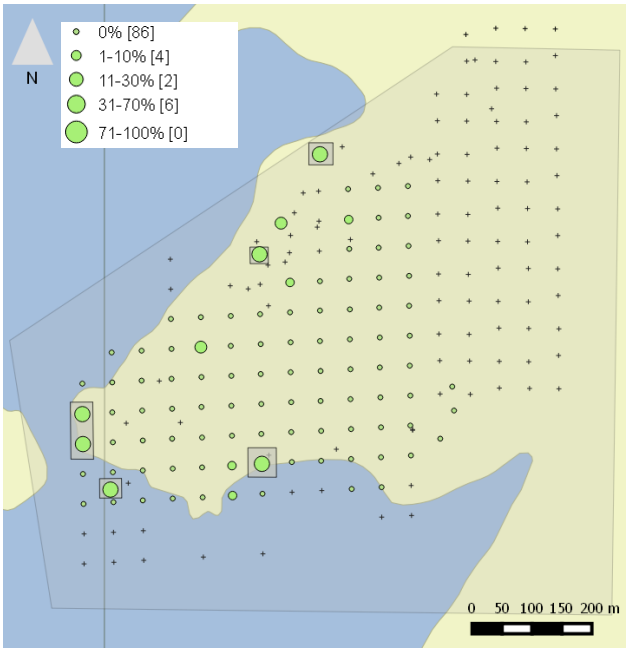
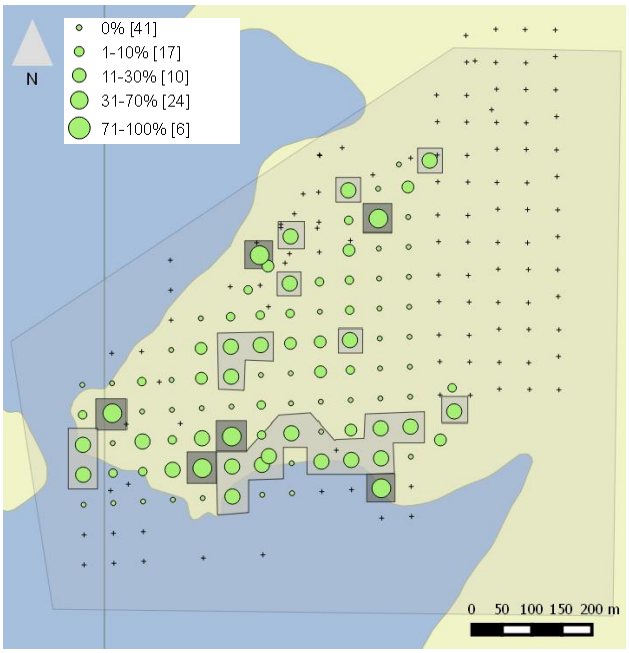


Figure 6 cont. - Maps of Heysham Flat depicting mean percentage cover of *S. alveolata* at all stations per season. The maps are labelled as: e) summer 2013, f) autumn 2013, g) spring 2014, h) summer 2014.

i)



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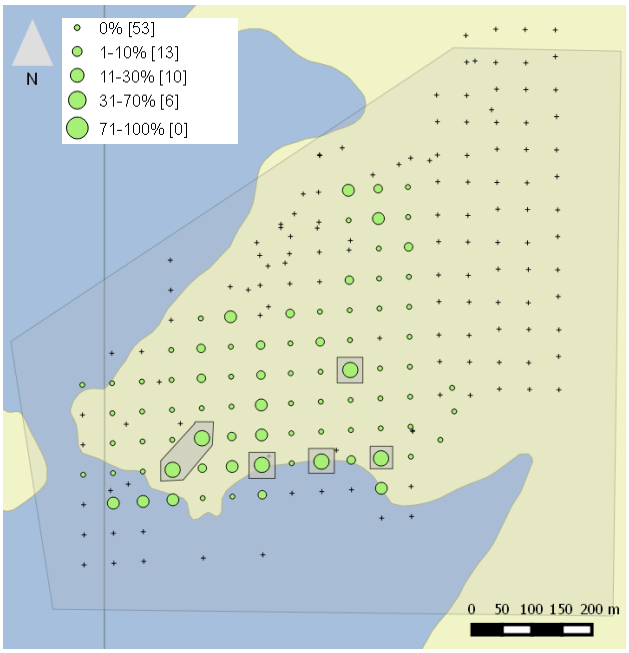


Legend

S. alveolata Cover

- 0%
- 1 - 10%
- 11 - 30%
- 31 - 70%
- 71 - 100%
- ≥ 30% S. alveolata Cover
- ≥ 70% S. alveolata Cover
- EMS Heysham Flat Area
- Station Not Surveyed

Figure 6 cont. - Maps of Heysham Flat depicting mean percentage cover of *S. alveolata* at all stations per season. The maps are labelled as: i) spring 2015, j) summer 2015.

Visually in Figure 6 seasons with the greatest distribution of *S. alveolata* over Heysham Flat are from summer 2012 (Figure 6 b)), summer 2013 e), autumn 2013 f) and spring 2015 i). The largest connected patch of *S. alveolata* with coverage ≥30% and ≥70% is visually seen in summer 2012 b) and spring 2015 i). At each season, a patch of ≥30% cover is present on the southern section of the skear except for seasons where this area was not surveyed and in spring 2014 where little *S. alveolata* was recorded at all.

5.1.2. Seasonal distribution of *Sabellaria alveolata* at fixed stations

Table 3 depicts a summary of the number of fixed stations surveyed highlighting the mean cover of *S. alveolata* across all stations each season and the general trends in *S. alveolata* distribution showing 0% cover and ≥ 30% cover.

In 2015 83 (99%) out of 84 fixed stations were surveyed in spring and 81 (96%) stations were surveyed in summer. Spring 2015 data showed a recovery of *S. alveolata* at fixed stations with 29% of the fixed stations surveyed depicting ≥30% *S. alveolata* cover. 41% of fixed stations were reported to have 0% cover, the lowest figure since autumn 2013. Summer 2015 data showed that 7.4% of stations had ≥30% *S. alveolata* cover with 64.2% of stations having 0% cover.

Table 3 - Seasonal percentage cover of *S. alveolata* on Heysham Flat between 2011 and 2015. Significant differences between means were calculated using Kruskal-Wallis post-hoc pairwise comparison tests using the Bonferroni correction.

	n (% of fixed stations)	Mean *S. alveolata* cover (%) (± 1 SE)	Standard deviation in *S. alveolata* cover (%)	Median *S. alveolata* cover (%)	Stations with 0% *S. alveolata* (% of stations surveyed)	Stations with ≥30% *S. alveolata* (% of stations surveyed)	Significant differences between means * <0.05 ** <0.001
Autumn 2011	49 (59.8)	18.4 ± 3.8	26.8	3	12 (24.5)	13 (26.5)	Summer 2013** Summer 2015*
Summer 2012	79 (94)	26.4 ± 2.9	26.1	25	19 (24.1)	32 (40.5)	Summer 2013**
Summer 2013	78 (92.9)	7.7 ± 1.9	17	0	52 (66.7)	7 (9)	Autumn 2013* Spring 2015*
Autumn 2013	44 (52.4)	18.4 ± 3.6	23.7	4.5	12 (27.3)	11 (25)	Summer 2015*
Spring 2014	26 (31)	9.5 ± 3.6	18.1	0	14 (53.8)	3 (11.5)	-
Summer 2014	84 (100)	2 ± 1	9.2	0	75 (89.3)	2 (2.4)	Summer 2015*
Spring 2015	83 (99)	19.6 ± 2.8	25.7	2	34 (41)	24 (29)	-
Summer 2015	81 (96)	7.1 ± 1.6	14.4	0	52 (64.2)	6 (7.4)	-

Distribution of *S. alveolata* has varied between the years of 2011 and 2015 (Figure 7). In autumn 2011 59.8% of fixed stations were surveyed of which 24.5% of these had 0% cover of *S. alveolata* and 26.5% had ≥30% cover. The summer of 2012 had the highest mean

26.4% (± 2.9 SE) of all of the years surveyed with the highest percentage of stations surveyed with ≥30% or more coverage of *S. alveolata* at a figure of 40.5%. Summer 2013 saw a drop in mean percentage cover (7.7% ± 1.9) with 9% of stations having ≥30% cover. This increased again in autumn 2013 to 18.4% (± 3.6) with 25% of stations having ≥30% cover to then decrease to very low means in 2014 with spring depicting 9.5% ± 3.6 percentage cover with 11.5% of the fixed stations surveyed having ≥30% cover. In spring 2014 there was a low survey effort with 26 fixed stations surveyed in total. In summer 2014 there was a mean of 2% ± 1 *S. alveolata* cover, of which only 2.4% was ≥30% cover and of the 84 fixed stations surveyed 89.3% had 0% cover, the lowest of any season.

Analysis of the non-parametric data to identify differences between the mean percentage cover across the seasons found a statistical difference (Kruskal-Wallis analysis of variance (ANOVA), χ^2 (7) = 123.58, $p < 0.001$). Post hoc pairwise comparisons were calculated using Bonferroni correction to calculate differences between the mean ranks of percentage cover of *S. alveolata* between seasons. These indicated that autumn 2011 (18.4% ± 3.8 SE) was significantly greater than summer 2013 (7.7% ± 1.9, $p < 0.001$) and summer 2015 (7.1% ± 1.6, $p < 0.05$). Summer 2012 (26.4% ± 2.9) was also greater than summer 2013 (7.7% ± 1.9, $p < 0.001$). In turn summer 2013 (7.7% ± 1.9) was significantly less than autumn 2013 (18.4% ± 3.6, $p < 0.05$) and spring 2015 (19.6% ± 2.8, $p < 0.05$). There was a high mean percentage cover of *S. alveolata* in autumn 2013 (18.4% ± 3.6) which was significantly greater than in summer 2015 (7.1% ± 1.6, $p < 0.05$). But the mean percentage cover of *S. alveolata* in summer 2014 (2 ± 1) was significantly less than summer 2015 (7.1% ± 1.6, $p < 0.05$).

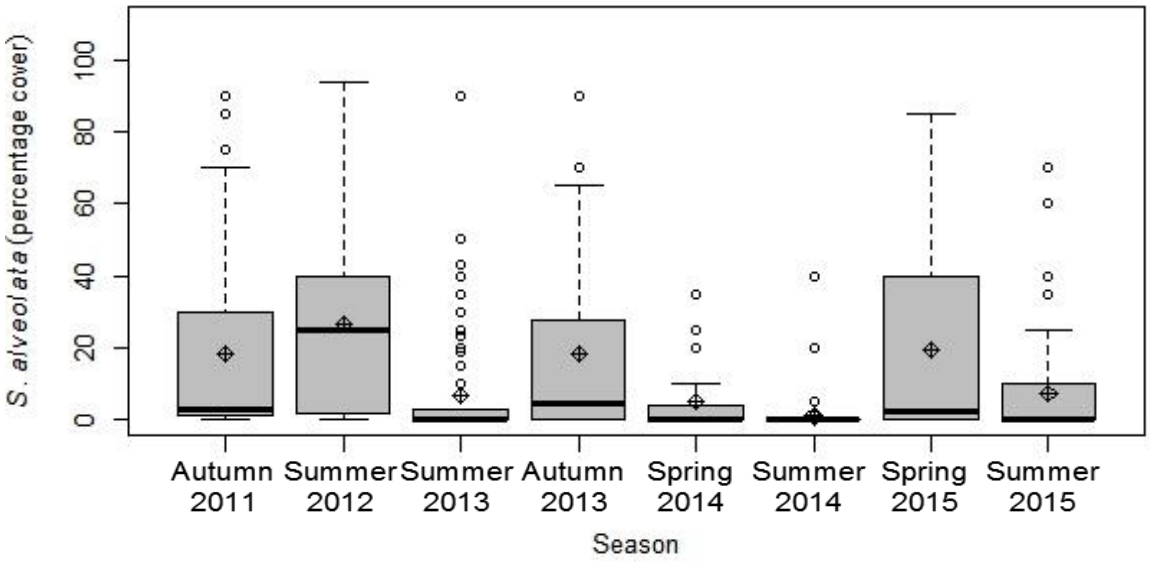


Figure 7 - Boxplot depicting average percentage cover of *S. alveolata* at fixed stations per season on Heysham Flat. Crossed diamonds represent mean values.

The distribution of this data is depicted in Figure 8 (a) – g)) where maps of the study area show the distribution of *S. alveolata* on Heysham Flat at fixed stations highlighting areas with ≥30% and ≥70% *S. alveolata* cover.

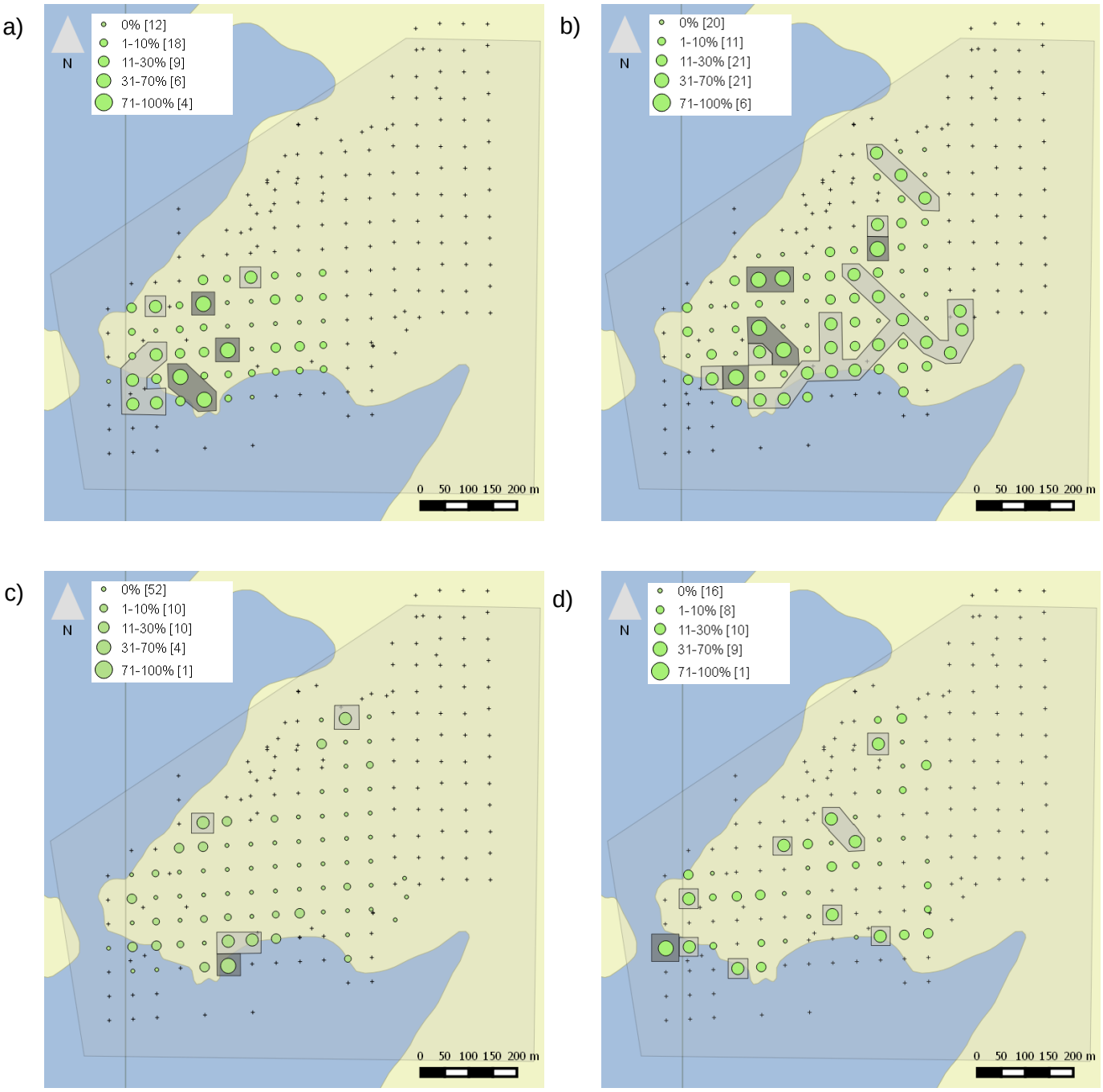
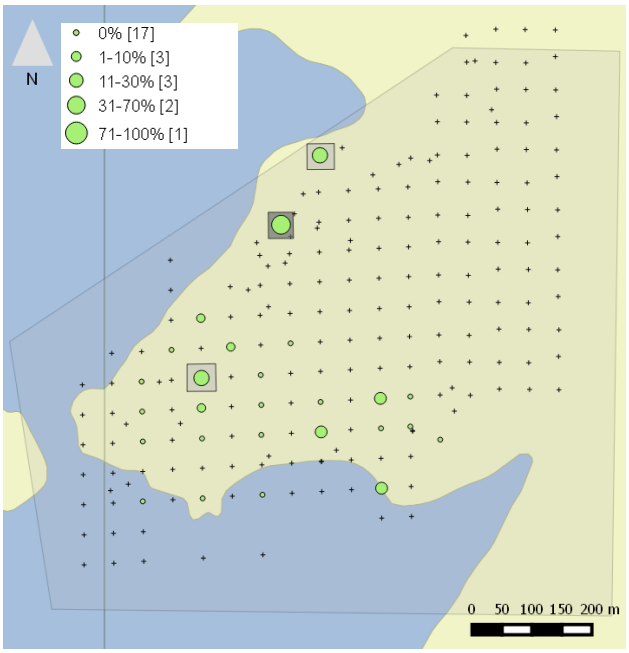
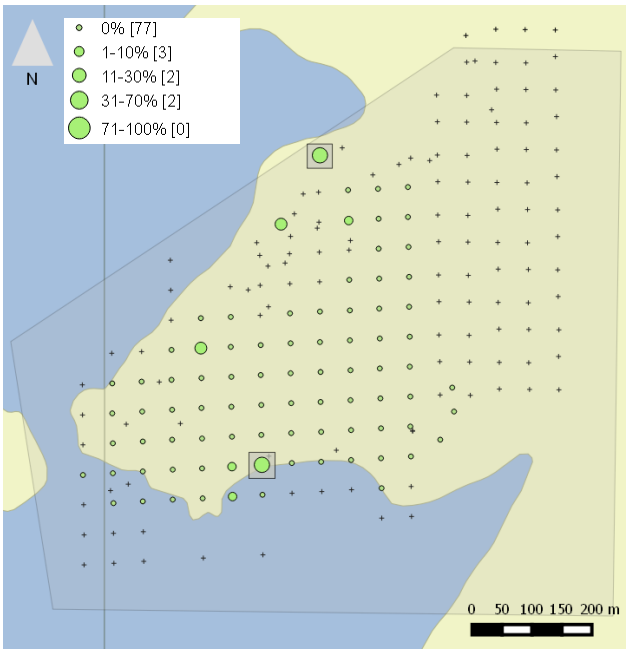


Figure 8 - Maps of Heysham Flat depicting mean percentage cover of *S. alveolata* at fixed stations per season. The maps are labelled as: a) autumn 2011 b) summer 2012, c) summer 2013 and d) autumn 2013.

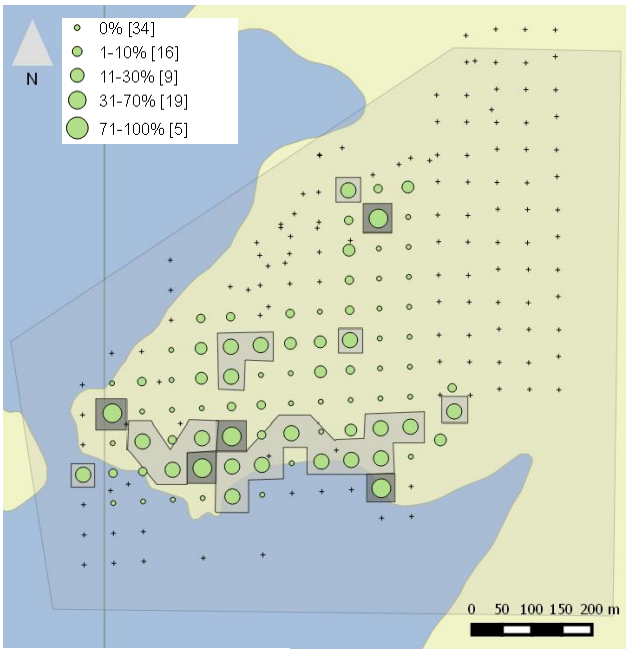
e)



f)



g)



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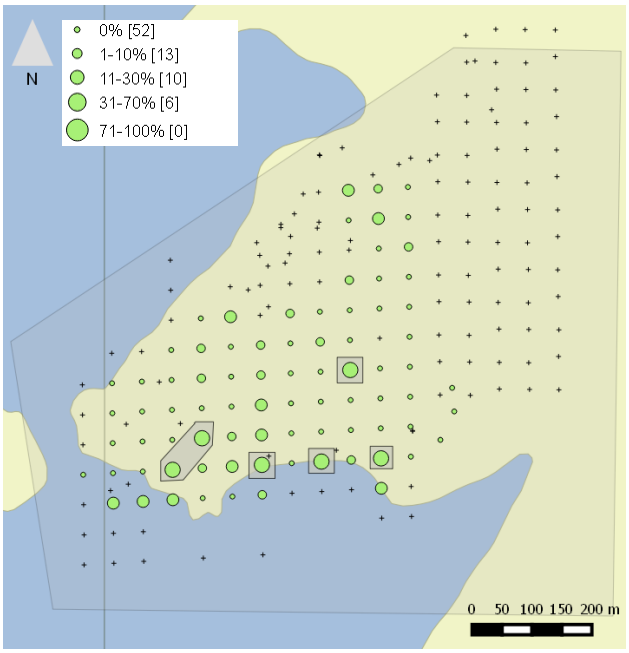


Legend

S. alveolata Cover

- 0%
- 1 - 10%
- 11 - 30%
- 31 - 70%
- 71 - 100%
- ≥ 30% S. alveolata Cover
- ≥ 70% S. alveolata Cover
- EMS Heysham Flat Area
- Station Not Surveyed

Figure 8 cont. - Maps of Heysham Flat depicting mean percentage cover of *S. alveolata* at fixed stations per season. The maps are labelled as: e) spring 2014.f) summer 2014, g) spring 2015 h) summer 2015.

5.2. Seasonal formation and health of *Sabellaria alveolata*

The health and formation of *S. alveolata* was recorded at fixed stations for each season. Data was not available for station K4 in summer 2012, station K8 in autumn 2013, station D10 in summer 2013 and station I1 in summer 2014 and therefore these points were removed for this analysis.

5.2.1. Seasonal formation of *Sabellaria alveolata*

Between the years of 2011 and 2015, the main formation of *S. alveolata* recorded at the fixed stations was patchy (Figure 9). The patchy formation has remained higher than all other formations ranging from 40% to 76% across all seasons.

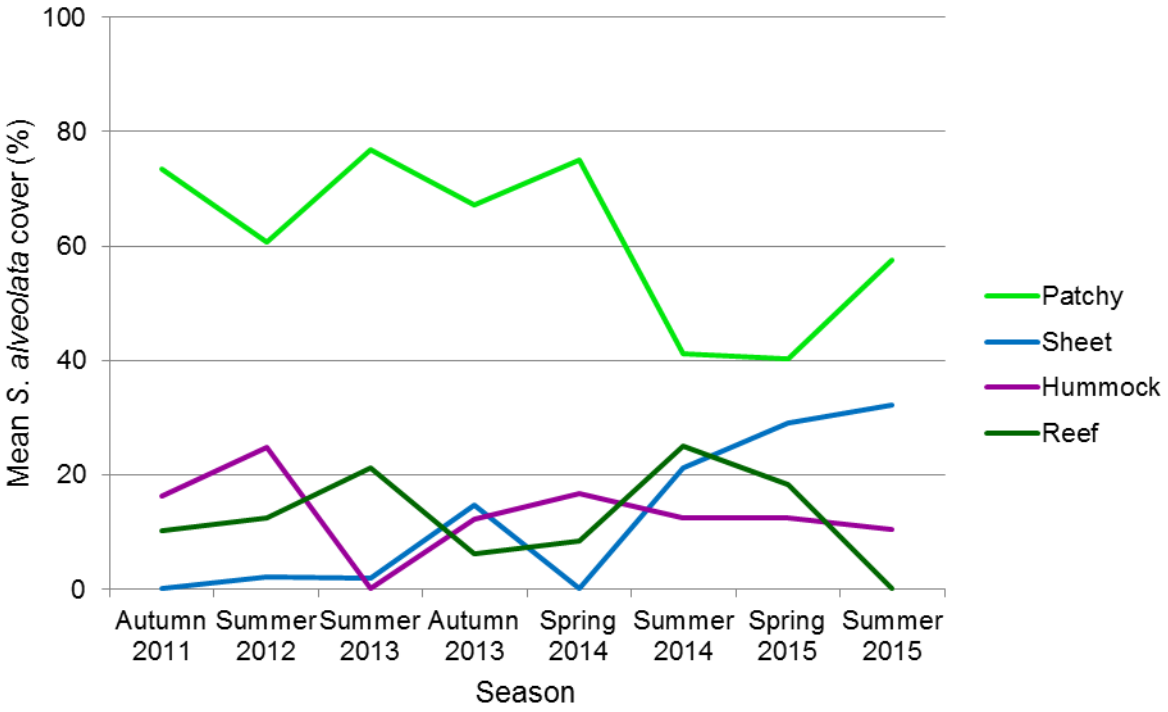


Figure 9 - Line graph depicting the mean percentage cover of *S. alveolata* associated with different reef formations per season.

The percentage of *S. alveolata* found in sheet, hummock and reef formations have remained consistently low across all seasons. Summer 2015 saw a 25% decrease in reef formation since the previous year but with sheet formation rising by 11% in the same time period. Hummock formation has remained steady over all seasons with a 0% low in summer 2013 which has grown to 10.3% in summer 2015.

To depict this information graphically, the formation of *S. alveolata* at fixed stations per season is shown on maps in Figure 10 (a) – g)). These maps also highlight areas with ≥30% and ≥70% of *S. alveolata* cover for visual comparison in distribution hotspots.

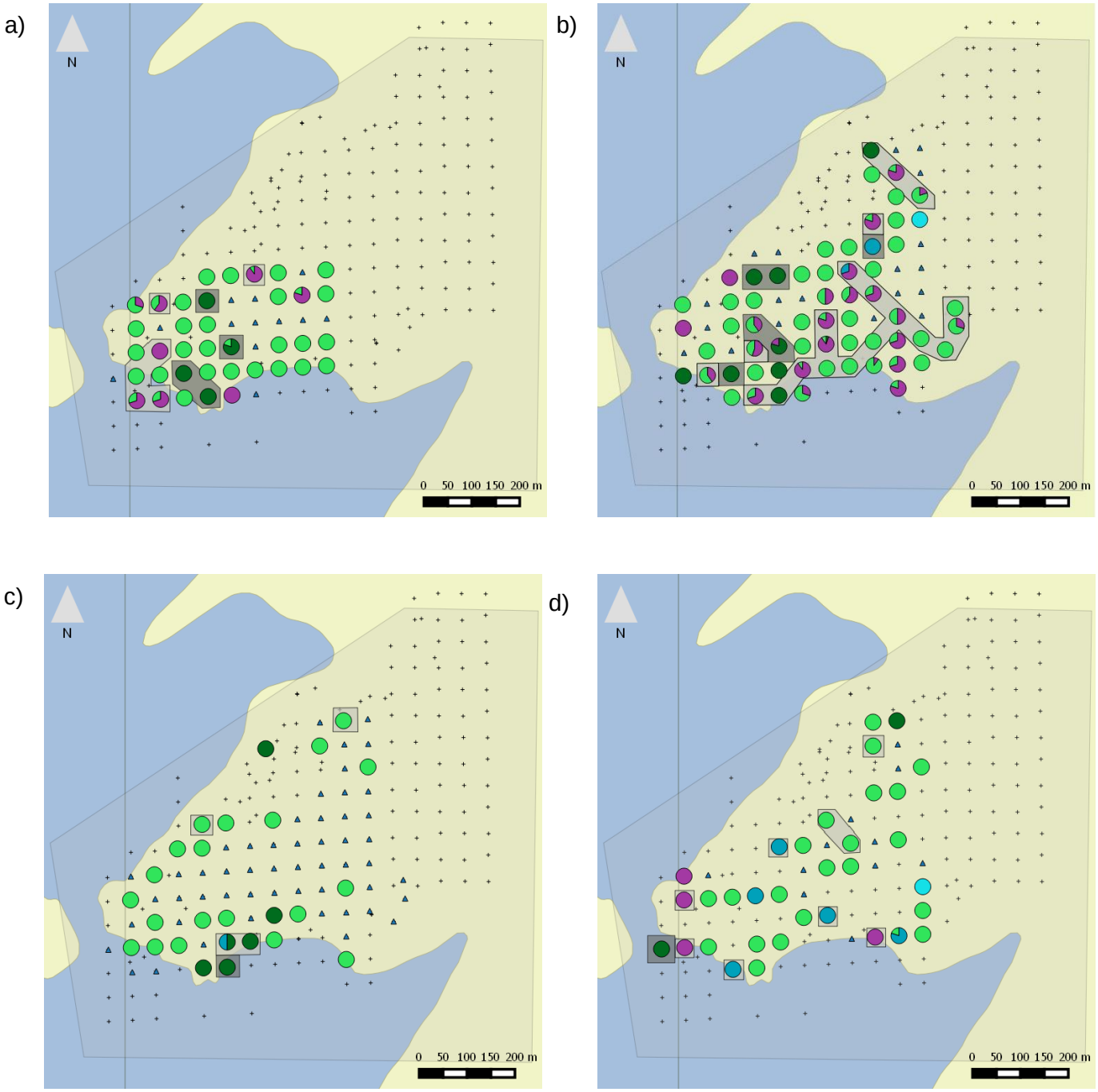
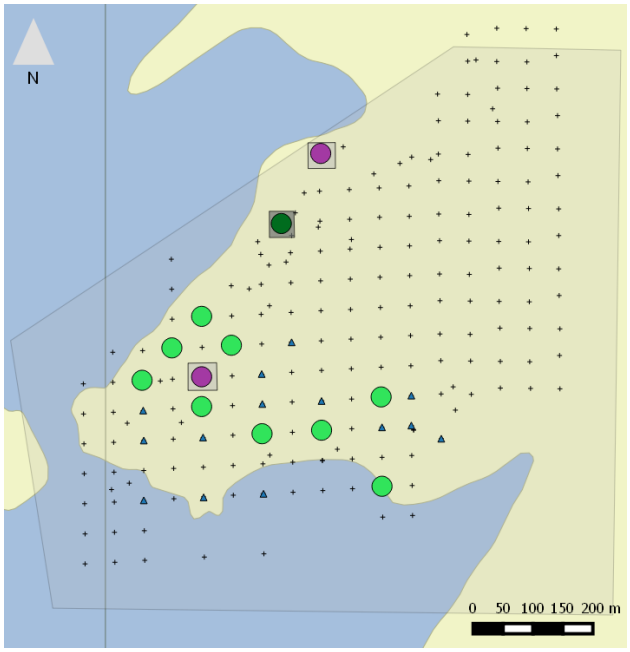


Figure 10 - Maps of Heysham Flat depicting distribution of formation types of *S. alveolata* at fixed stations per season. The maps are labelled as: a) autumn 2011 b) summer 2012, c) summer 2013 and d) autumn 2013.

e)



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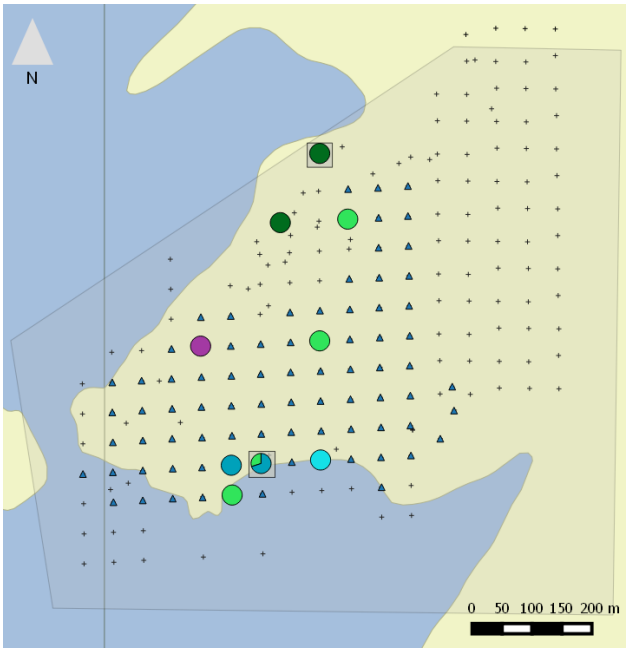
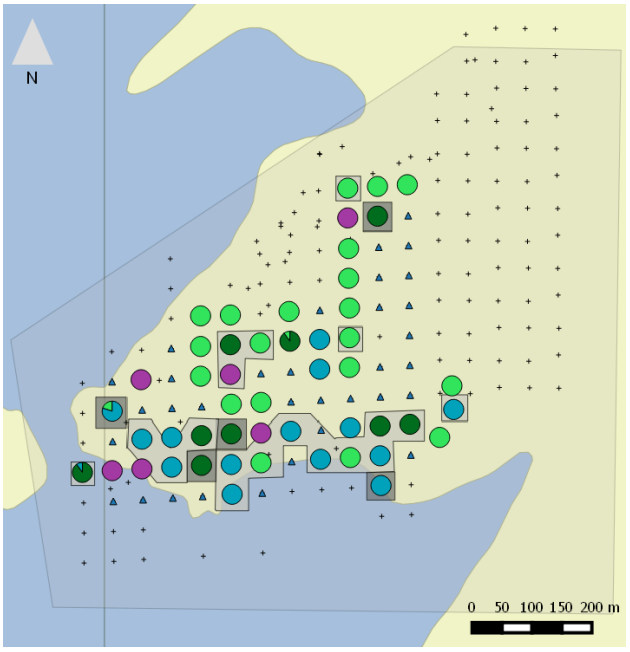


g)



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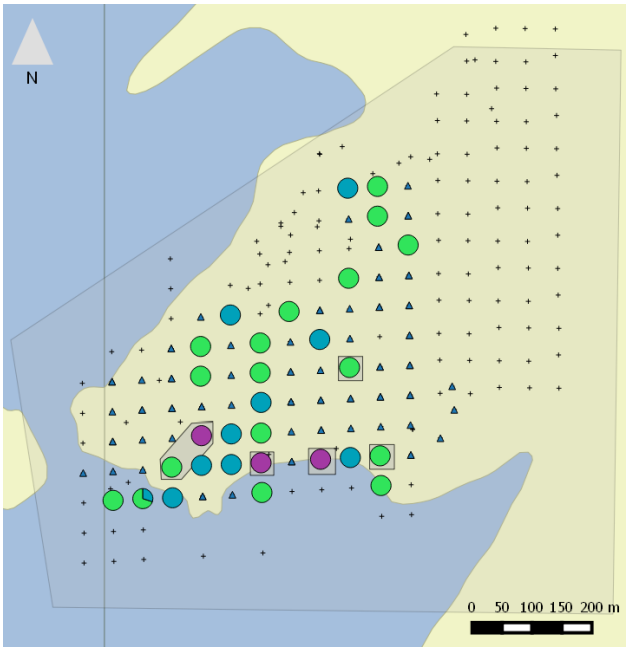


Legend

S. alveolata Formation
- Patchy
- Sheet
- Hummock
- Reef
- Unknown
- S. alveolata Absent
- ≥ 30% S. alveolata Cover
- ≥ 70% S. alveolata Cover
- EMS Heysham Flat Area
- Station Not Surveyed

Figure 10 cont. - Maps of Heysham Flat depicting distribution of formation types of *S. alveolata* at fixed stations per season. The maps are labelled as: e) spring 2014 f)summer 2014, g) spring 2015, h) summer 2015.

5.2.2. Seasonal health of *Sabellaria alveolata*

The health of *S. alveolata* has shown a variable pattern between all seasons from 2011 to 2015 (Figure 11). Autumn 2011 showed a high in crisp aperture of 51.7%, this has declined steadily to 1.9% in summer 2015. In autumn 2013, 69.2% of *S. alveolata* was recorded as dead which was a peak across all seasons. In summer 2015, the percentage of dead *S. alveolata* decreased to 21.6%. Newly settled *S. alveolata* showed a peak in summer 2012 of 61.5% which decreased to 0.5% in spring 2014 and 0.3% in spring 2015 but increased to 47.9% in summer 2015.

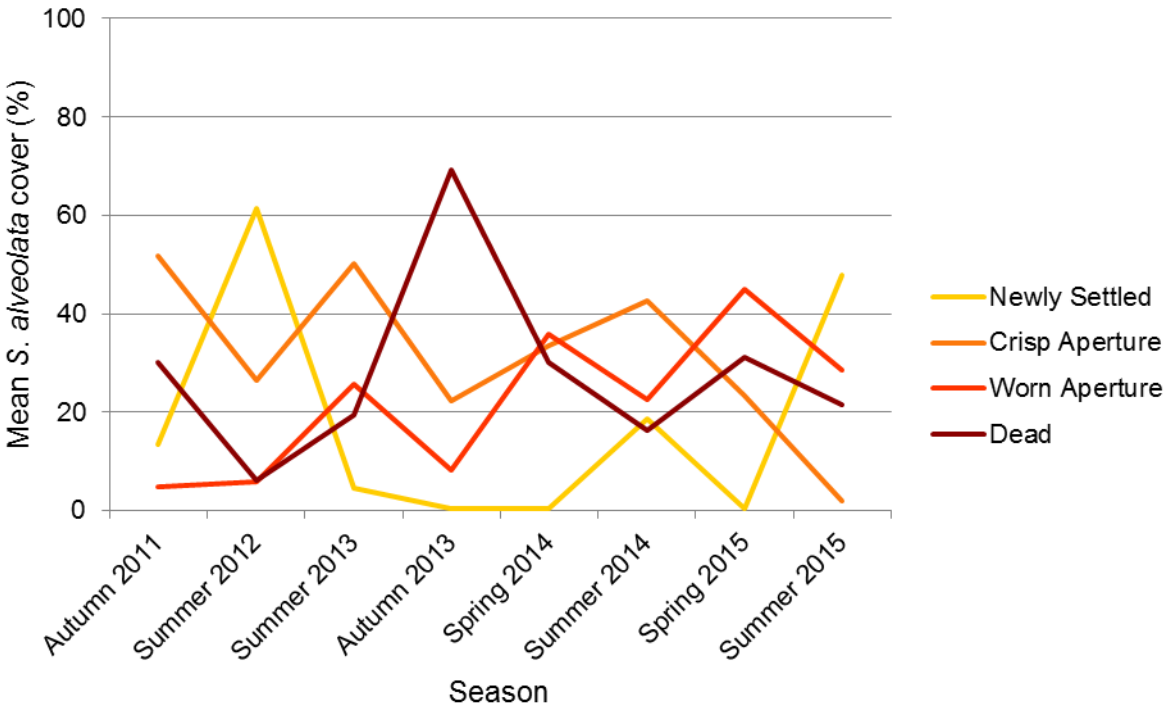


Figure 11 - Line graph depicting the mean percentage cover of *S. alveolata* associated with different health types per season.

Whist percentage of crisp apertures has steadily increased between 2011 and 2015, the opposite pattern is evident for percentage cover of worn apertures of *S. alveolata*. In autumn 2011, percentage of worn apertures was recorded at 4.7%, this steadily rose to a peak in spring 2015 of 45% and in summer 2015 this fell to 28.6%.

To depict this information graphically, the formation of *S. alveolata* at fixed stations per season is shown on maps in Figure 12 (a) – g)). These maps also highlight areas with ≥30% and ≥70% of *S. alveolata* cover for visual comparison in distribution hotspots.

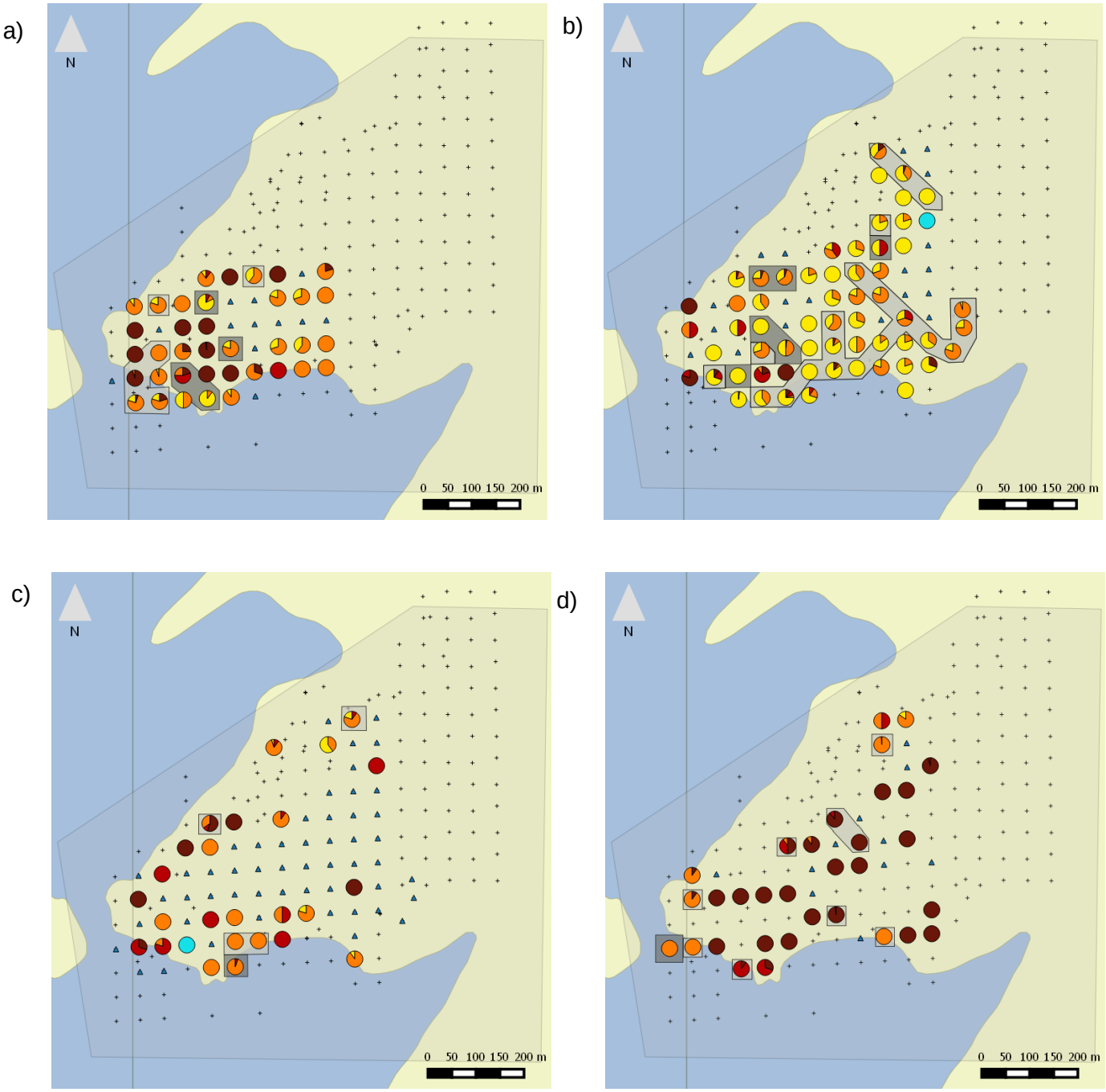
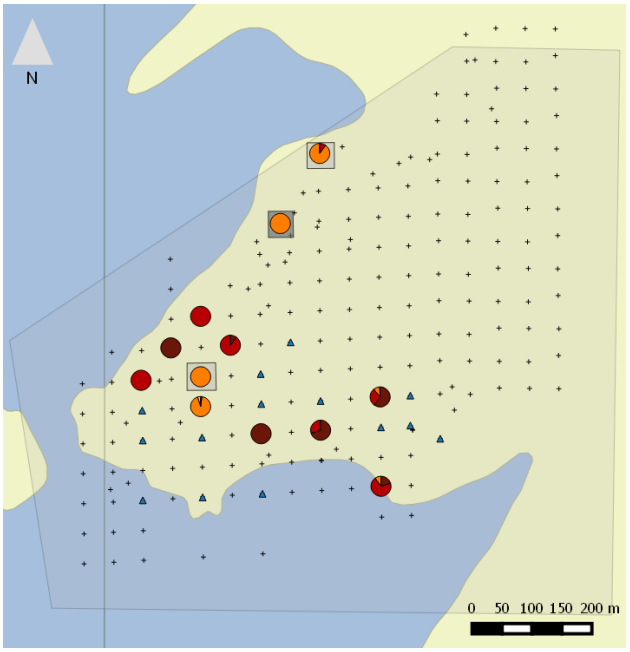


Figure 12 - Maps of Heysham Flat depicting health types of *S. alveolata* at fixed stations per season. The maps are labelled as: a) autumn 2011 b) summer 2012, c) summer 2013 and d) autumn 2013.

e)



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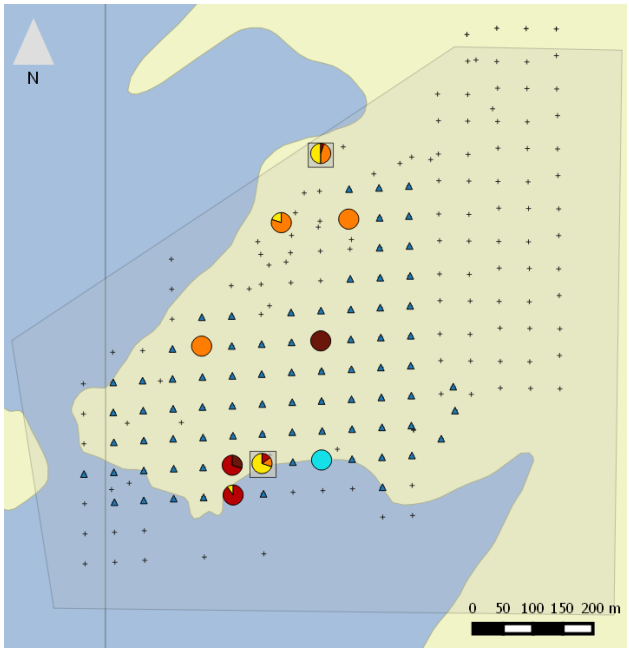
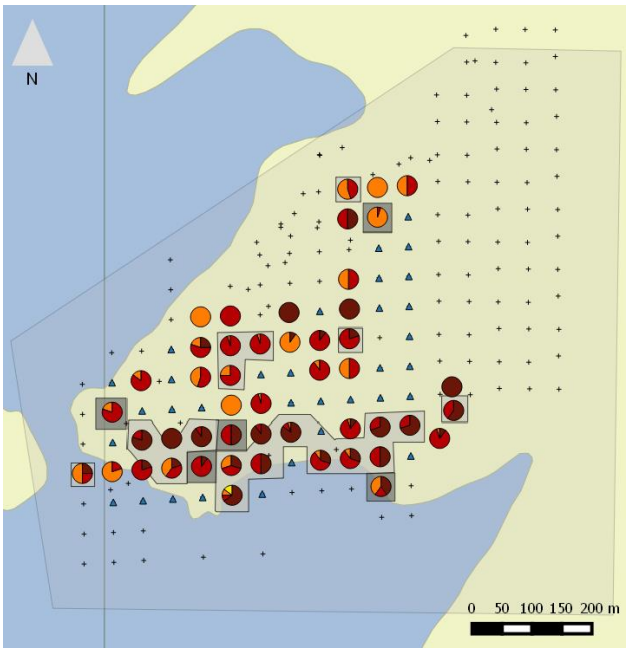


g)



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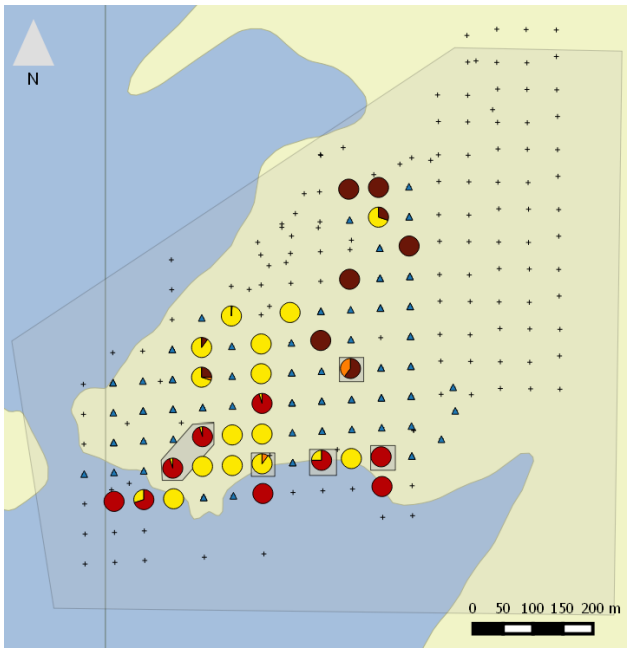


Legend

S. alveolata Condition

- Newly Settled
- Crisp Aperture
- Worn Aperture
- Dead
- S. alveolata Absent
- ≥ 30% S. alveolata Cover
- ≥ 70% S. alveolata Cover
- EMS Heysham Flat Area
- Station Not Surveyed

Figure 12 cont. - Maps of Heysham Flat depicting distribution of health types of *S. alveolata* at fixed stations per season. The maps are labelled as: e) spring 2014 f) summer 2014, g) spring 2015 and h) summer 2015.

5.2.3. Correlation between the health and formation of *Sabellaria alveolata*

To assess the correlation between the health and formation of *S. alveolata* the mean proportion of all formation types (± SE) were compared against health categories at fixed stations (Figure 13). This included the analysis of any stations with more than one formation and condition type.

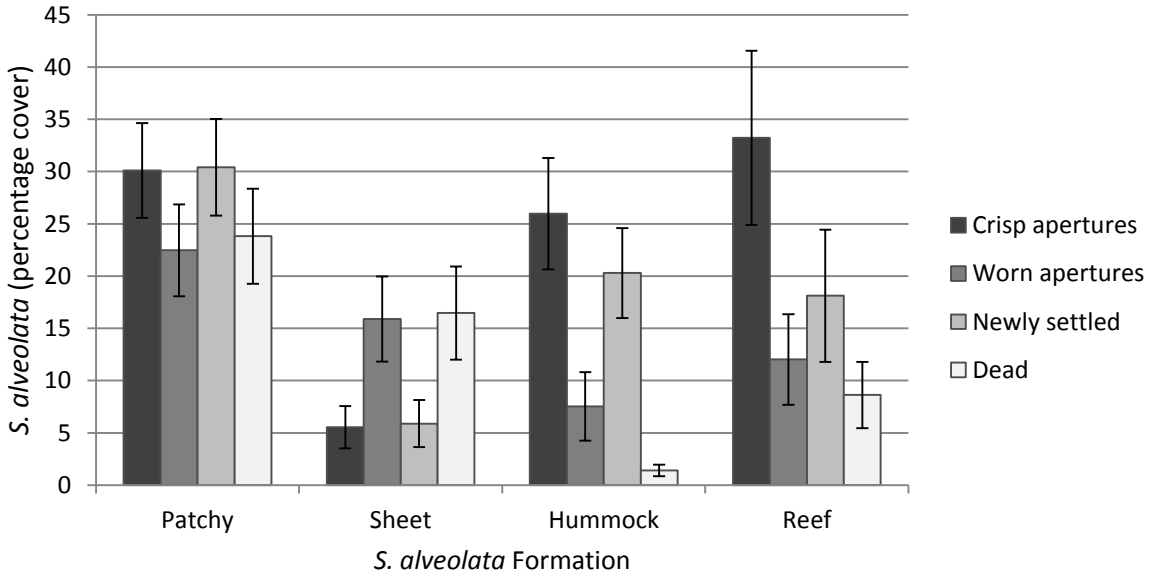


Figure 13 - Bar chart depicting the mean proportion (± SE) of health categories of *S. alveolata* associated with different reef formations across all fixed station samples.

From the *S. alveolata* formation analysis, patchy was found to be the most prominent formation. Of the patchy *S. alveolata*, crisp (30.1%) and new (30.4%) formation types were recorded as the highest and worn as the lowest at 22.5%.

Sheet and hummock formation were the least prominent formation types. The findings suggest that sheet formation had the least percentage of crisp apertures (5.6%) or be newly settled (5.9%). In a hummock formation, the health of the *S. alveolata* had mostly crisp apertures (26%) and was newly settled (20.3%). The lowest correlation was between hummock formation and dead at 1.4%. The reef formation was found to have the highest proportion of crisp apertures (33.2%) and the lowest proportion of dead *S. alveolata* (8.6%).

5.3. Seasonal distribution of *Mytilus edulis*

The percentage cover of *M. edulis* (edible blue mussel) was categorised into either individuals above 45mm, which is the minimum landing size (MLS) in NWIFCA's Byelaw 3 or below 45mm which is classed as undersize or seed *M. edulis* (NWIFCA, 2012). Raw data from all 2015 surveys relating to *M. edulis* and other substrate cover can be found in Appendix III.

The mean percentage cover of adult *M. edulis* is shown in Figure 14 which shows low prevalence of adult *M. edulis* on Heysham Flat. Very low percentage coverage was reported for summer and autumn 2013 where nearly 80% in both seasons reported 0% cover of adult *M. edulis*. In summer 2013, the largest coverage recorded was 6% with an average of 0.3%. The highest mean cover was reported to be 6% in spring 2015 followed by 4.8% is summer 2012 and 3.3% in autumn 2011. In 2015 the percentage cover of *M. edulis* increased from a low of 0.15% in summer 2014 to 6% in spring 2015 with the highest coverage at one fixed station was recorded to be 55% which is not depicted in Figure 14 as an outlier.

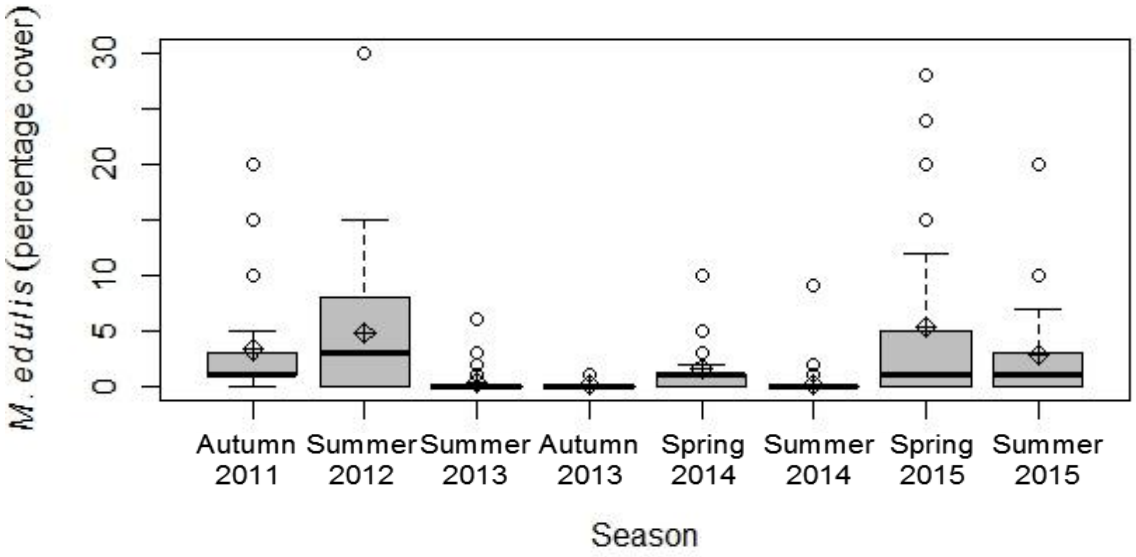


Figure 14 - Percentage cover of adult *M. edulis* at fixed stations on Heysham Flat per season. Crossed diamonds = means.

Kruskal-Wallis ANOVA confirmed that there was a statistical difference between the mean ranks of the percentage cover of adult *M. edulis* between seasons χ^2 (7) = 152.23, p <0.001. Post-hoc pairwise comparisons using Bonferroni correction found that autumn 2011, summer 2012 and spring and summer 2015 had significantly higher mean ranks than summer 2013, autumn 2013 and summer 2014 ($p < 0.001$). Spring 2014 was also found to be significantly higher than summer 2014 ($p < 0.05$).

Undersize *M. edulis* percentage coverage on Heysham Flat was more abundant than the adult population (Figure 15).

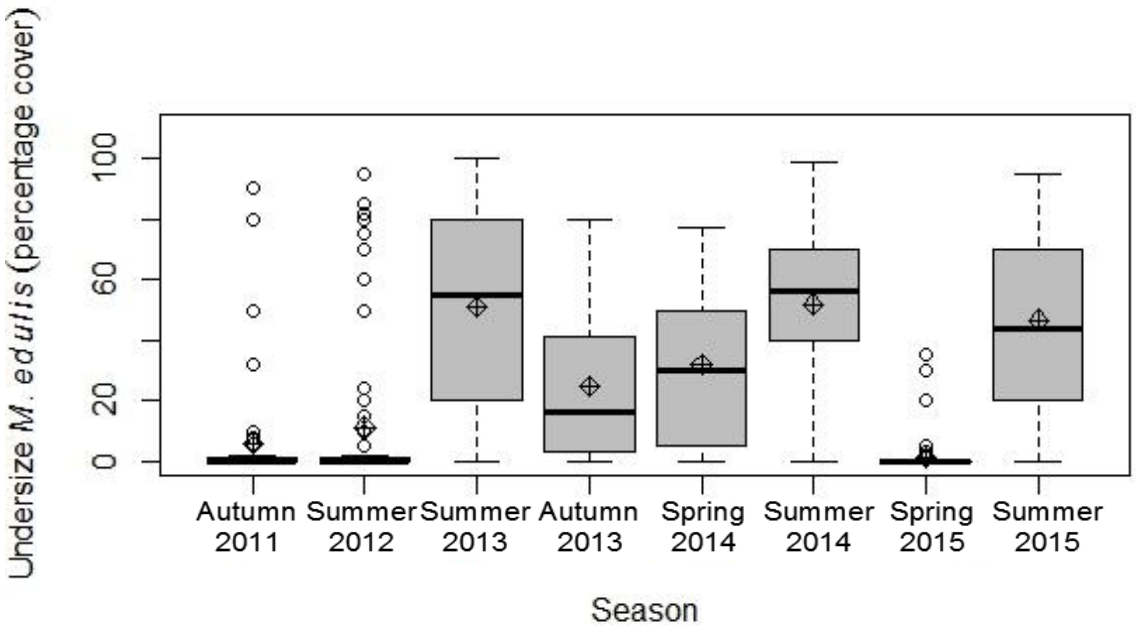


Figure 15 - Percentage cover of undersize *M. edulis* at fixed stations on Heysham Flat per season. Crossed diamonds = means.

Despite the large variation in records of undersize *M. edulis* in autumn 2011 and summer 2012, the mean for both seasons did not exceed 12% cover which was larger than the 4% in spring 2015 but all were the lowest values recorded between 2011 and 2015. The highest mean percentage cover of undersize *M. edulis* was recorded as 51% in summer 2014. This saw a mean decrease in percentage cover of 49.7% to spring 2015 and then an increase of 45.4% to summer 2015 (46.7%). In spring 2015, 68 stations recorded 0% cover of undersize *M. edulis*, this dropped to 1 station with 0% cover in summer 2015. In summer 2015 50 fixed stations surveyed (62% of all stations surveyed in that season) had ≥30% cover of undersize *M. edulis*.

Kruskal-Wallis ANOVA confirmed that there was a statistical difference between the mean ranks of the percentage cover of undersize *M. edulis* between seasons χ^2 (7) = 240.09, p <0.001. Post-hoc pairwise comparisons using Bonferroni correction found that autumn 2011 and summer 2012 had significantly lower mean ranks than all seasons except spring 2014 and spring 2015 (p < 001). Spring 2013 was significantly higher than autumn 2013 (p < 0.05) and spring 2015 was significantly lower than all seasons except autumn 2011 and summer 2012 (p < 001).

In Figure 16 (a) – g)) maps of the study area show the distribution of undersize *M. edulis* at fixed stations on Heysham Flat highlighting areas with ≥30% and ≥70% *S. alveolata* cover.

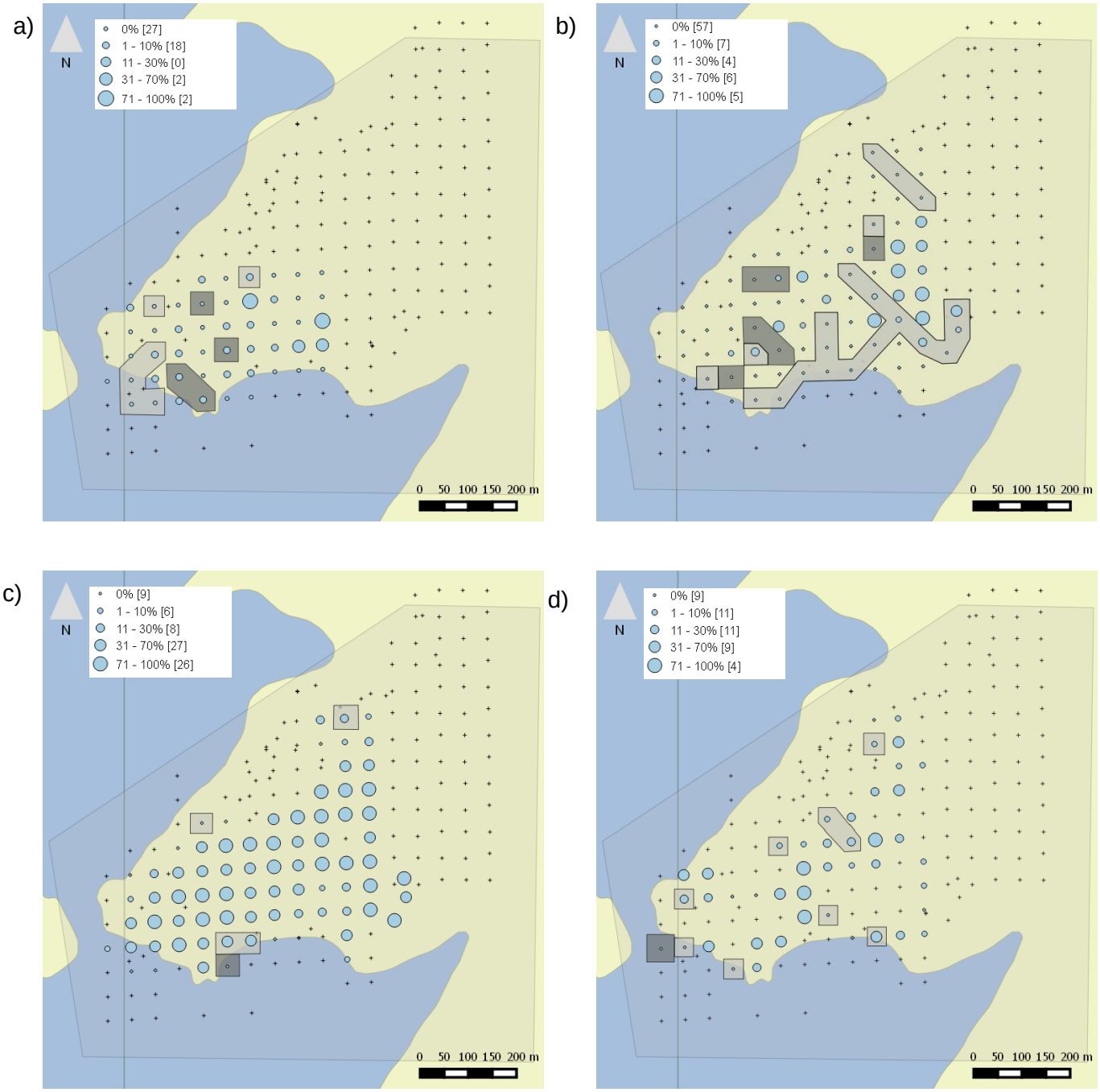
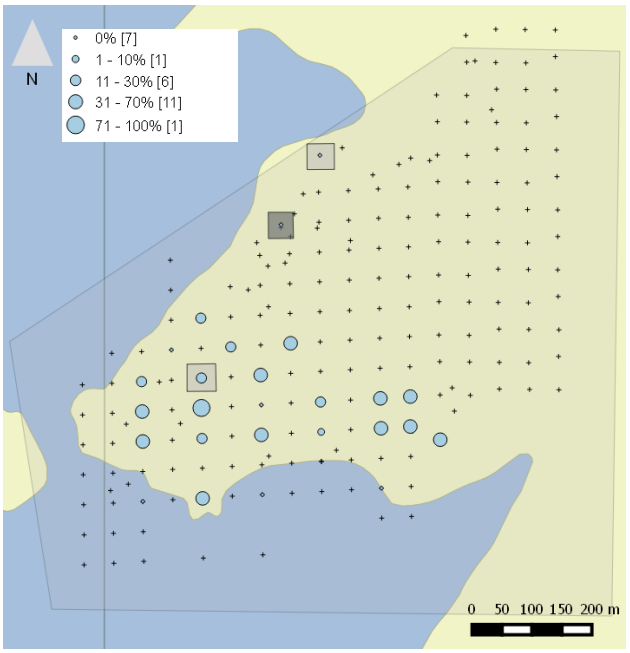
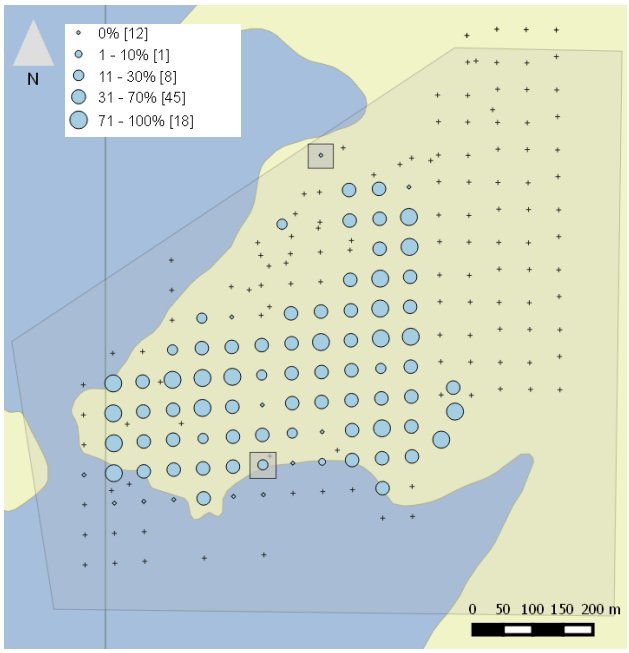


Figure 16 - Maps of Heysham Flat depicting percentage cover of *M. edulis* at fixed stations per season. The maps are labelled as: a) autumn 2011 b) summer 2012, c) summer 2013 and d) autumn 2013.

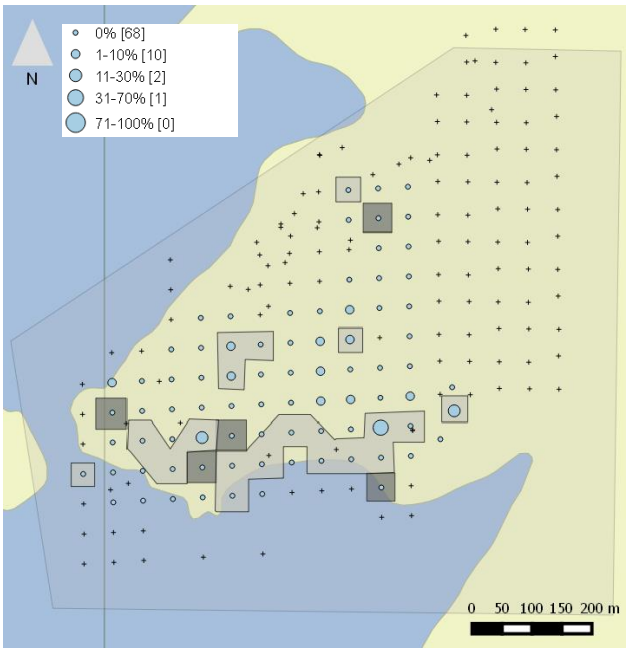
e)



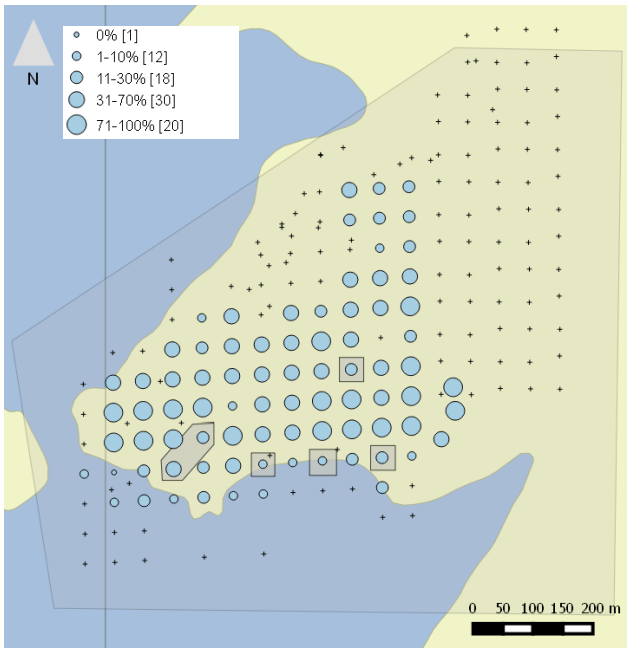
f)



g)



h)



Legend

Seed M. edulis Cover

- 0%
- 1 - 10%
- 11 - 30%
- 31 - 70%
- 71 - 100%
- ≥ 30% S. alveolata Cover
- ≥ 70% S. alveolata Cover
- EMS Heysham Flat Area
- Station Not Surveyed

Figure 16 cont. - Maps of Heysham Flat depicting percentage cover of *M. edulis* at fixed stations per season. The maps are labelled as: e) spring 2014 f) summer 2014, g) spring 2015, h) summer 2015.

5.3.1. Relationship between *Sabellaria alveolata* and *Mytilus edulis*

The coverage of *S. alveolata* and *M. edulis* was compared at all fixed stations between 2011 and 2015 as the report thus far has focused on fixed stations and therefore it will be easier to draw comparisons from. In the 529 cumulative stations surveyed over the five years of surveying undersize *M. edulis* was absent in 196 stations (37.1%). Figure 17 depicts a linear regression of the correlation between percentage cover of *S. alveolata* and undersize *M. edulis*

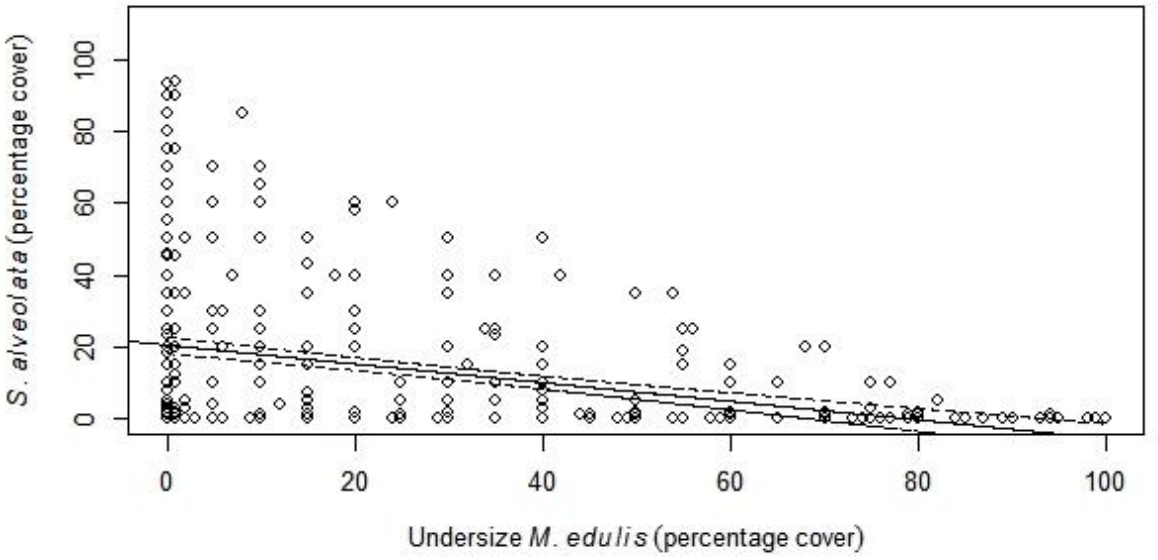


Figure 17 - Scatter plot depicting the correlation between percentage cover of *S. alveolata* and percentage cover of undersize *M. edulis.* The solid line depicts linear regression with the dotted lines showing 95% confidence region.

A Kendall's tau coefficient test was used to assess if there was a correlation between percentage cover of *S. alveolata* and undersize *M. edulis* and a negative significant correlation was found, $\tau = -0.337$, $p < 0.001$.

When assessing if there was also a correlation between the percentage cover of *S. alveolata* and adult *M. edulis*, a weak but significant correlation was found, $\tau = -0.164$, $p < 0.001$ (Figure 18). However due to the nature of this data with 54% of the stations not having any records of adult *M. edulis*, this data is not strong enough to draw conclusions from, this is evident from the skewed nature of data depicted in Figure 18.

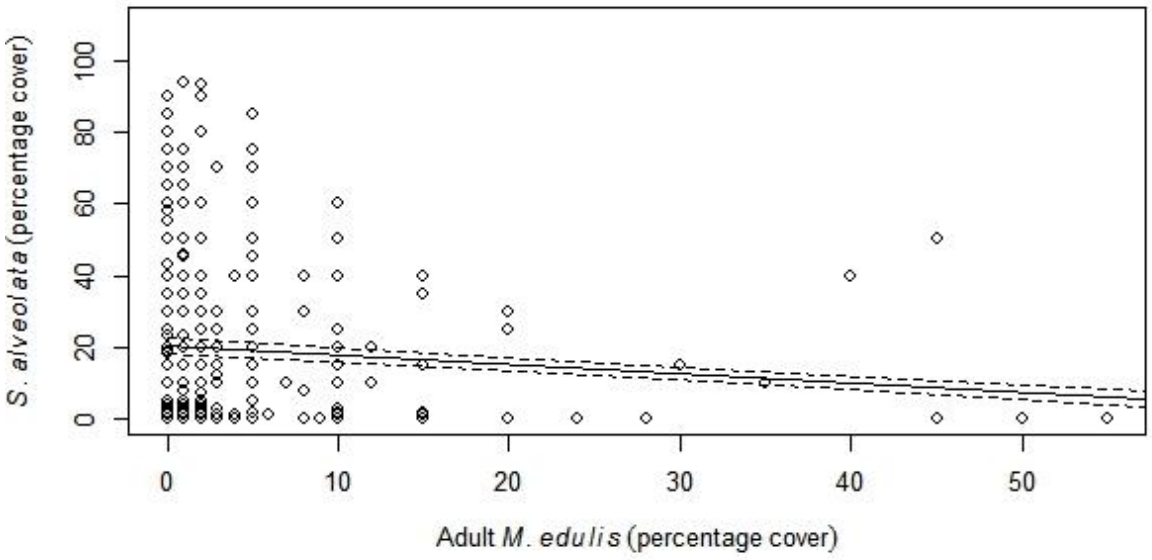


Figure 18 - Scatter plot depicting the correlation between percentage cover of *S. alveolata* and percentage cover of adult *M. edulis.* The solid line depicts linear regression with the dotted lines showing 95% confidence region.

5.4. Descriptive surveys of *Sabellaria alveolata* on Heysham Flat

Due to the new methodology implemented by Foster (2015), a descriptive survey was officially conducted in summer 2015 to assess areas of Heysham Flat not surveyed during fixed surveys. An additional descriptive survey of the condition of Heysham Flat was undertaken by the NWIFCA in May 2015 which provided the report with additional descriptive data.

5.4.1. Descriptive surveys of *Sabellaria alveolata* on Heysham Flat

In 2015 a summer descriptive survey was conducted to survey points on Heysham Flat to collect descriptive data of points not surveyed at fixed stations and at a later time in the year. Figure 19 represents the data collected on this survey with seven out of 11 stations having ≥30% cover of *S. alveolata*. Figure 19 depicts that in the descriptive survey 2015 there were areas of healthy *S. alveolata* still present on Heysham Flat. On the southern side of the skear, most of the *S. alveolata* appears to be covered in *M. edulis*.

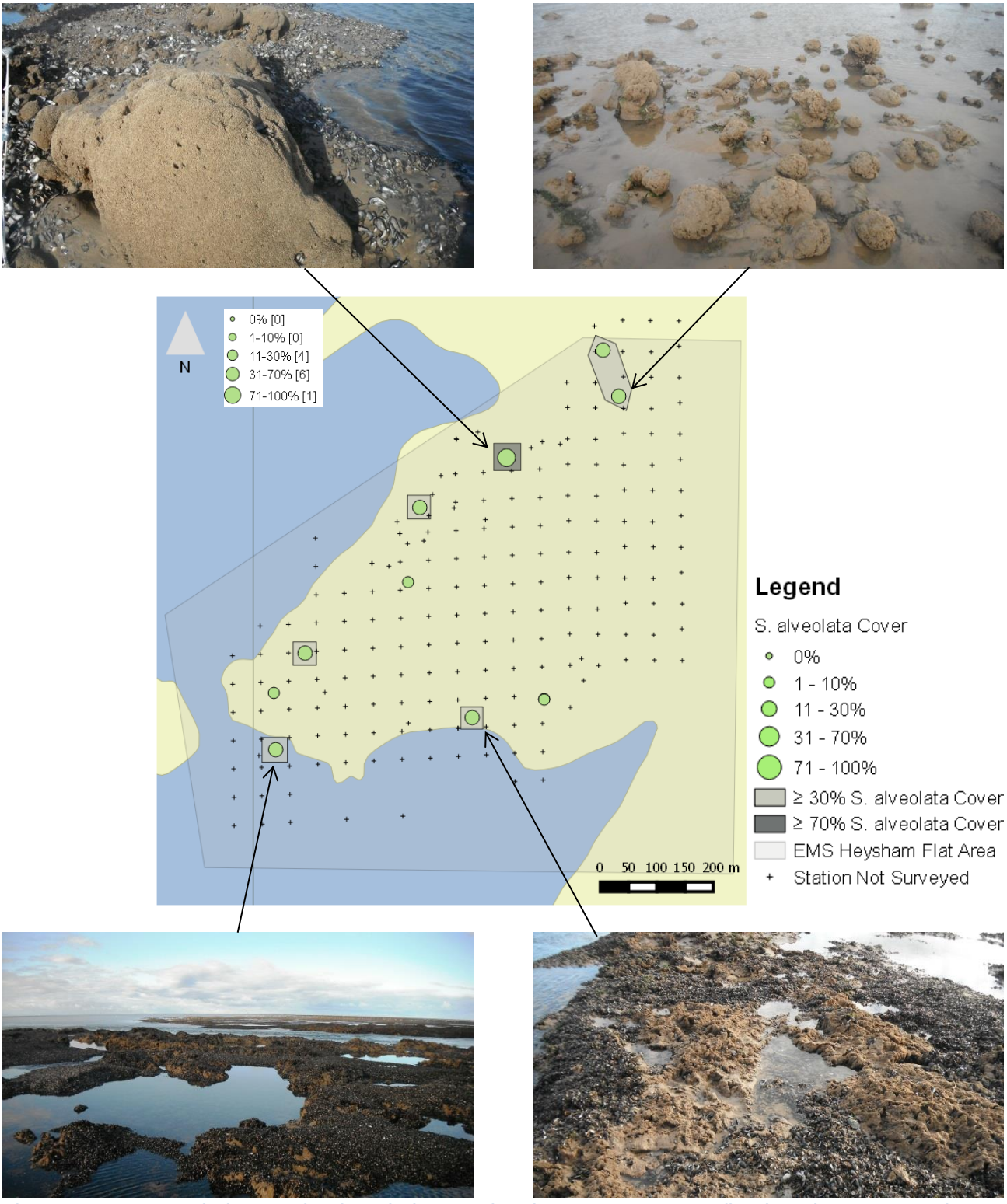


Figure 19 - Map and photos of a descriptive *S. alveolata* surveys not at fixed stations on Heysham flat in summer 2015.

Whist also assessing the health and condition of the *S. alveolata* surveyed in the summer descriptive survey in 2015, it was found that none of the *S. alveolata* was newly settled. It was also found that 50% of the stations surveyed were either 100% dead or up to 50% of the quadrat recorded as dead (Figure 20). Of the formation types, 50% was reported as hummock with only the south western station was reported to be reef.

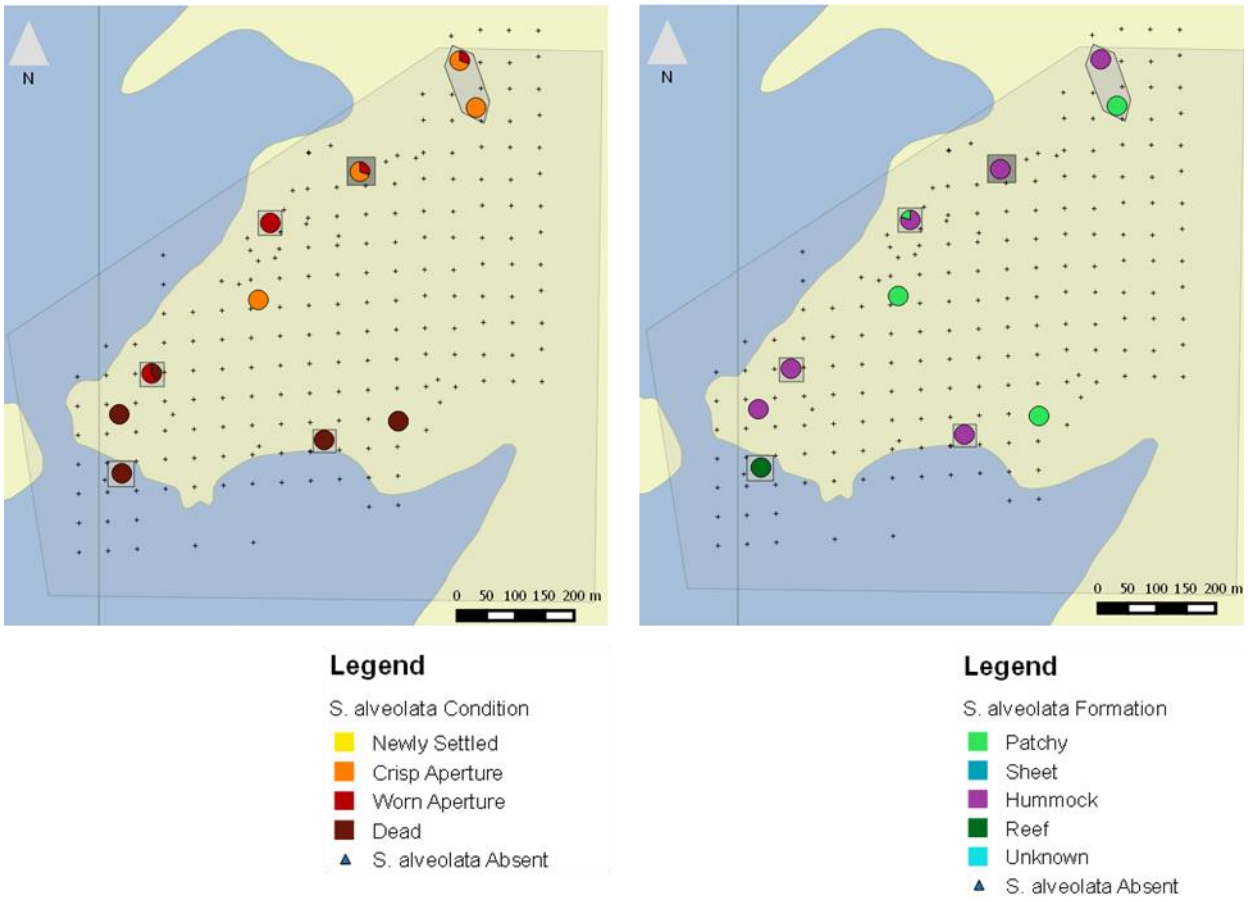


Figure 20 - Maps depicting the Health and formation of *S. alveolata* surveyed during the summer 2015 descriptive survey on Heysham Flat.

5.4.2. Ariel descriptive surveys of Heysham Flat

On the 20th May 2015, the NWIFCA used a helicopter to visually assess Heysham Flat from an aerial perspective. Figure 21 depicts photos taken of *S. alveolata* on Heysham Flat. Photo a) and b) shows new submersed patches of healthy reef in the channel which had not been seen in recent history and photo c) shows the settlement of *S. alveolata* on the outer skear which is reported to be a new settlement. By summer 2015 this area was reported to be smothered in a new settlement of *M. edulis* (pers. comm., Mandy Knott).

a)

b)

c)

Figure 21 - Aerial photos of *S. alveolata* settlements on Heysham Flat. Photos taken 20th May 2015 by Mandy Knott at NWIFCA.

5.5. Biodiversity on Heysham Flat

At every station surveyed, species in addition to *S. alveolata* and *M. edulis* were recorded as notes. This data ranged in the quality of taxonomic identification skills of the surveyor with records ranging from common names such as 'periwinkle' to species names such as *Lanice conchilega* (sand mason worm). For the purpose of the analysis, each species recorded was listed as one distinct species, meaning that paddle worm eggs were recorded as paddle worm and not two separate species. Records of dead shells were removed (cockle and pacific oyster) as the biodiversity comparison was solely interested in live species and it is likely that these shells were washed in from other areas in Morecambe Bay.

Of the 529 cumulative stations surveyed at fixed stations between 2011 and 2015, 270 stations (51%) did not contain any *S. alveolata*. A total of 24 different species were present at stations where *S. alveolata* was recorded. These species are detailed in Appendix IV. Of the stations with *S. alveolata* present, 411 distinct records were recorded over a period of five years at all stations surveyed. Of the 259 stations that had records, 119 (46%) stations

had more than one species present, five stations had three species present and one station had six species present. The most common species recorded in association with *S. alveolata* was *Lanice conchilega* with 134 distinct records followed by barnacles including species such as *Balanus crenatus*, identified in summer 2015 with 126 records.

Kendall's tau coefficient test was conducted to assess if there was a correlation between percentage cover of *S. alveolata* and species richness. A significant correlation was found, $\tau = 0.249$, $p < 0.001$. A linear regression of this analysis is depicted in Figure 22 which shows that the higher percentage cover of *S. alveolata* recorded, more species are present. This analysis does not discriminate between the condition or formation of the *S. alveolata.*

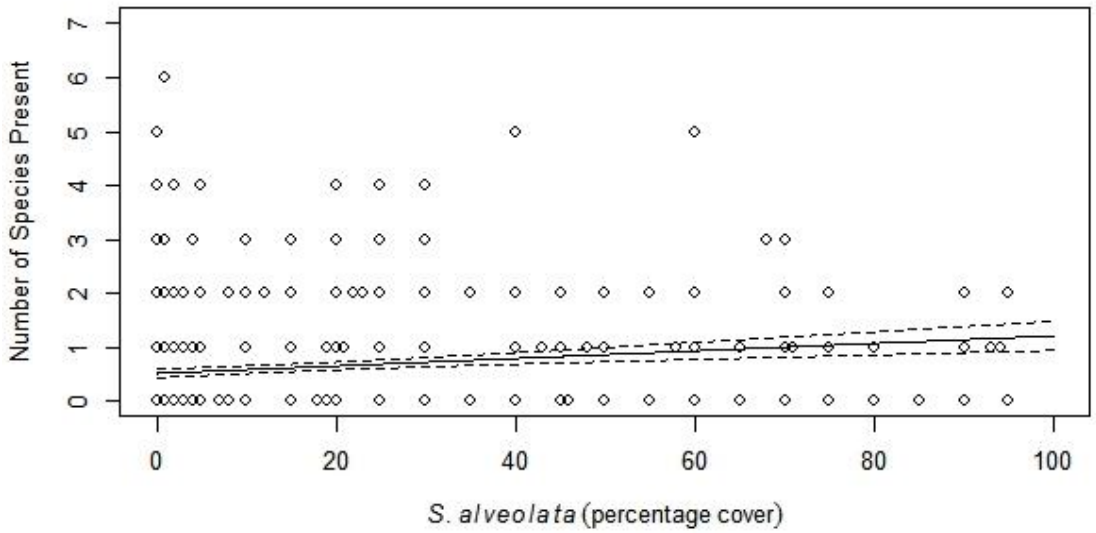


Figure 22 - Scatter plot depicting the correlation between percentage cover of *S. alveolata* and species richness. The solid line depicts linear regression with the dotted lines showing 95% confidence region.

Biodiversity was also compared with adult and undersize *M. edulis* percentage cover. Due to a typically low percentage cover of adult *M. edulis* being recorded on the skear, as they do not get a chance to develop, no strong conclusions can be drawn from these data. Figure 23 depicts the percentage cover of adult *M. edulis* compared against species richness whereby it can be seen that the 95% confidence region on the linear regression suggests lack of correlation. However a Kendall's tau coefficient test was used to assess if there was a correlation between percentage cover of adult *M. edulis* and species richness and a positive significant correlation was found, $\tau = 0.252$, $p < 0.001$.

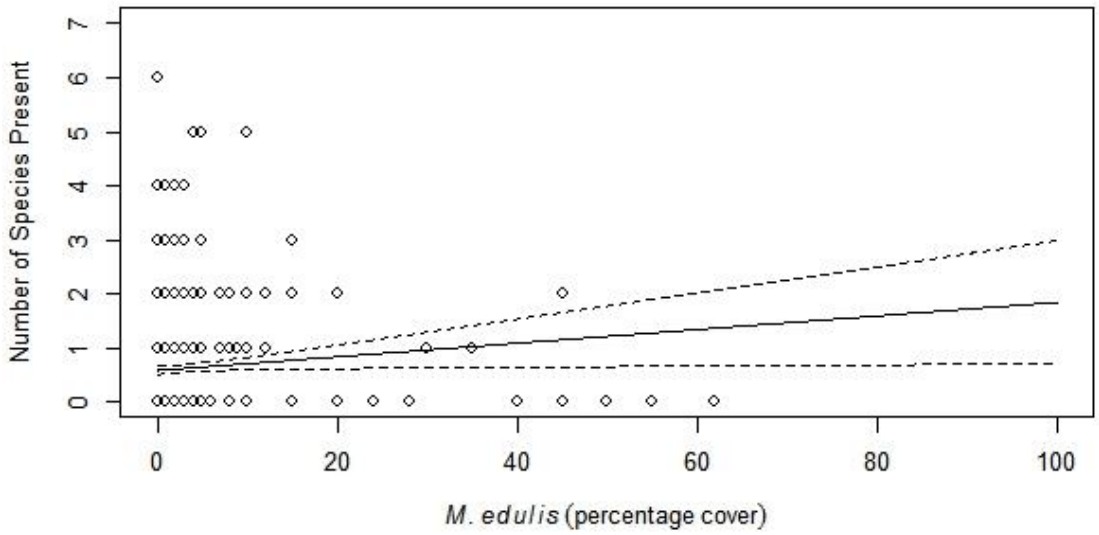


Figure 23 - Scatter plot depicting the correlation between percentage cover of adult *M. edulis* and species richness. The solid line depicts linear regression with the dotted lines showing 95% confidence region.

When comparing undersize *M. edulis* to species richness the opposite correlation was found where an increase in abundance of undersize *M. edulis* negatively affected the species richness (Figure 24). A Kendall's tau coefficient test was used to assess if there was a correlation between percentage cover of undersize *M. edulis* and species richness and a weak negative significant correlation was found, $\tau = -0.076$, $p < 0.05$.

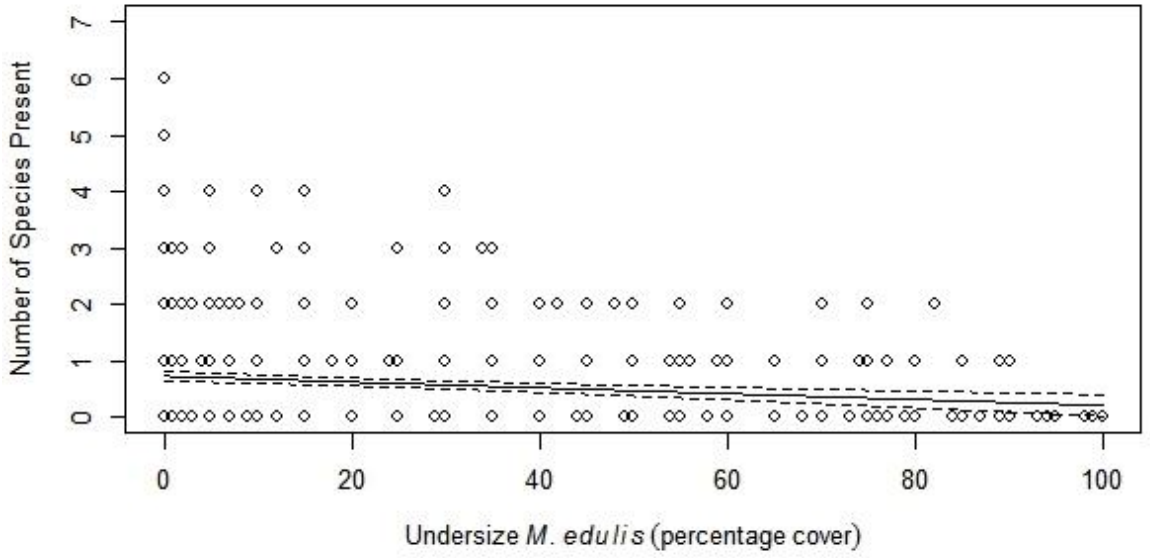


Figure 24 - Scatter plot depicting the correlation between percentage cover of undersize *M. edulis* and species richness. The solid line depicts linear regression with the dotted lines showing 95% confidence region.

6. Discussion

Heysham Flat supports a complicated dynamic competition between two ephemeral species: *S. alveolata* and *M. edulis*. Both species require a hard substratum to settle upon which is provided by the rocky skear on Heysham Flat. This area is especially important as it is surrounded by a homogenous sandy/ mud environment. The skear not only supports these two species but also an array of other intertidal marine species including predator bird species which feed on the *M. edulis* and infauna. Due to the instability of the bed and the abundance of *M. edulis* a designated area of the skear has been open to a seasonal hand gathering fishery for undersize mussel in recent years. The *S. alveolata* reef is not affected by this as the main area of *S. alveolata* is protected from fishing activity by conditions in an authorisation issued by the NWIFCA. Further to the authorisation, the S. alveolata reef is cordoned off in a pegged out area. Whilst the distribution and health of *S. alveolata* on the entirety of Heysham flat is not exclusively affected by these external influences and different uses of the area, this report points to these variables as contributing towards the species particularly dynamic and cyclical nature.

6.1. *Sabellaria alveolata* distribution

The distribution of *S. alveolata* on Heysham Flat has shown to vary significantly between seasons surveyed at fixed stations. Between 2011 and 2015 three spikes in mean percentage cover amidst low mean percentage cover suggest that *S. alveolata* exists in a cyclical pattern, which is a cycle of development and decay. This finding is consistent with other surveys on *S. alveolata* in the UK and France, where it was found that this species exhibits a cyclical pattern of the abundance of the species in periods of up to five years (Gruet, 1985; Gruet, 1986; Perkins, 1988). This suggests that in this study either there was a higher than average cycle of development and decay or data collected did not accurately represent the mean percentage over of *S. alveolata* on Heysham Flat.

Between spring 2014 and spring 2015 the percentage coverage of *S. alveolata* was reported to have increased by 17%. This is interesting as this contributes towards the cyclical theory however anecdotal evidence reported by Foster (2015) suggested that surveys conducted in 2014 represented only a very brief snapshot in time regarding the distribution and health of *S. alveolata* that year. Foster (2015) reported that during observations of Heysham Flat in early 2014 the distribution of *S. alveolata* was “doing exceptionally well” and was the highest coverage it had been since the Senior Scientist at NWIFCA had seen it. This reinforces what we know about the distribution and health of *S. alveolata* on Heysham Flat – it is an exceptionally dynamic species. With this knowledge it makes it difficult to draw conclusions from the data set to compare between years.

As growth of *S. alveolata* usually happens over the winter months and into early spring and *M. edulis* populations are highly negatively affected by winter storms, it would suggest that the highest percentage cover of *S. alveolata* should occur in the spring before the next settlement of *M. edulis* spat (Wilson, 1976). This pattern was best reported in spring 2015 where mean percentage cover of *S. alveolata* exceeded the mean percentage cover of *M. edulis* by 19.6%. As in previous summers, in August 2015 the hand gathering seed mussel fishery was opened due to the *M. edulis* spat reaching around 10mm in size which is big enough to fish. This fishery was closed in November 2015. In previous years these undersize mussels if not fished have been washed away in the winter seasons. Therefore distribution of *S. alveolata* is not thought to be affected by the hand gathering seed mussel fishery. There are no concerns over defragmentation of the historical area of reef via trampling by fishers as this area is not designated to fish in.

S. alveolata has been documented to be affected by temperature changes as well as being killed by prolonged periods of frost (Cunningham, *et al*., 1984). The species grows best in warm temperatures due to an increased metabolism (Gruet, 1982). Conversely growth is restricted below 5°C and *S. alveolata* does not survive long periods of cold temperatures (Wilson, 1971). No extreme frosts have been recorded in Morecambe Bay since the winter of 2010 (Met Office, 2013). Findings from this report suggest that the opposite has occurred: apart from in summer 2012, *S. alveolata* distribution was lowest in summer but increasing soon after this season in both summer 2013 and summer 2014. By plotting percentage cover of *S. alveolata* and *M. edulis* against mean seasonal air temperatures from the North West of England between 2011 and 2015, it is apparent that *S. alveolata* growth increases towards winter and then drops again in colder winter conditions (Figure 25). Due to the dynamic nature of the distribution of *S. alveolata* on Heysham Flat, the notion of a 'trend' occurring has to be interpreted with caution as the distribution of *S. alveolata* has the ability to change within a very short period of time. There are also significant gaps in the data set with no surveys being conducted in winter due to undesirable tides and limited daylight hours and therefore there may be very different patterns occurring than is suggested in this report.

It is true that mean low temperatures in winter does not necessarily represent harsh winters, therefore the number of frost days has been taken into consideration and plotted on Figure 25. The year with the highest number of frost days was in 2012 (41.5 days) which was also the coldest winter. In summer 2013 the mean *S. alveolata* percentage cover was 7.7% which was the third lowest after values recorded in summer 2014 and summer 2015. Although statistical comparison between number of frost days and mean percentage cover of *S. alveolata* cannot be conducted due to insufficient data, it could be concluded that on Heysham Flat, low temperatures is not the biggest contributor towards the decomposition of *S. alveolata* but it can be argued that *M. edulis* is.

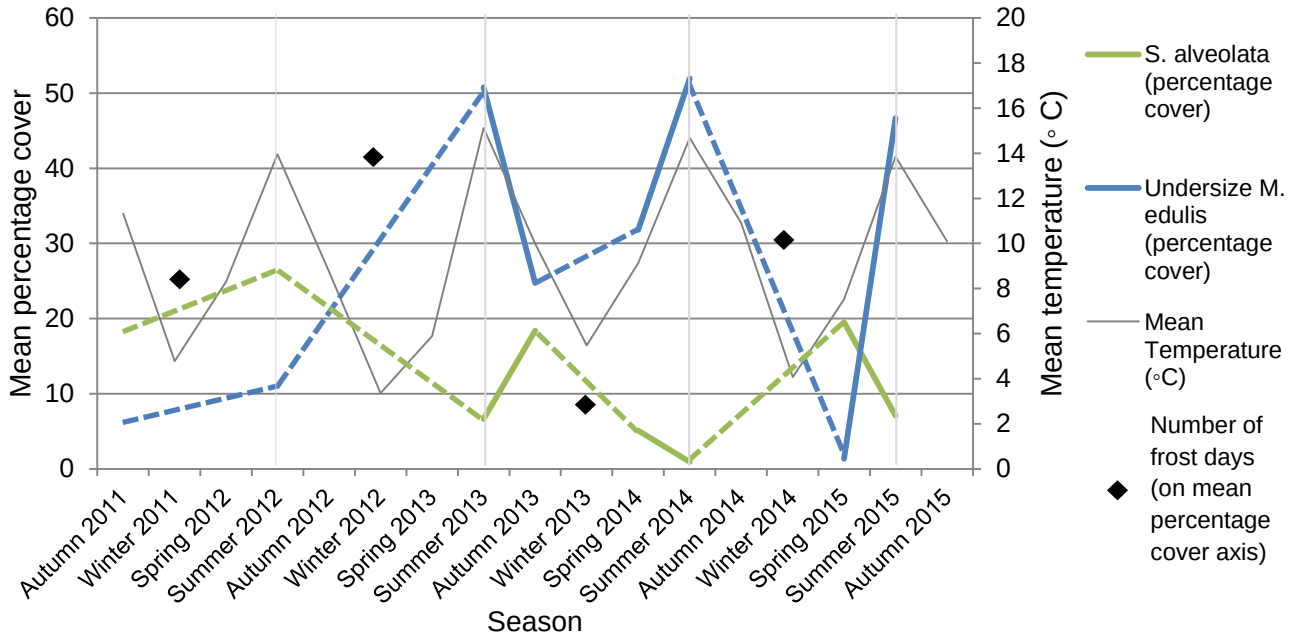


Figure 25 - Graph depicting percentage cover of *S. alveolata* and *M. edulis* against seasonal mean air temperatures from North West of England between 2011 and 2015 (Met Office, 2016a). Blue and green dashed lines represent trends between when data was collected at fixed stations. Faint grey vertical lines highlight summer each year. Black diamonds represent number of frost days (Met Office, 2016b).

6.2. Health and formation of *Sabellaria alveolata*

By drawing conclusions from surveys conducted in spring and summer 2015, it is apparent that the large distribution of *S. alveolata* that was recorded in spring of 2015 had mostly worn apertures or was recorded to be dead. In summer 2015 this large settlement was replaced by a small amount of newly settled *S. alveolata* which was recorded to be patchy. This is likely to have been smothered later in summer by *M. edulis*. These findings are recurrent throughout the five years of surveying Heysham Flat. In summer 2012 61% of the *S. alveolata* recorded was newly settled which was 60% patchy. This trend is again depicted in Figure 13 where the mean proportion of *S. alveolata* sampled at fixed stations was predominately patchy and of that the highest recorded health category was newly settled. Using the same comparison, when the *S. alveolata* was recorded as in a reef formation, 33% of this had crisp apertures which is expected as the reefs are held together by healthy and strong *S. alveolata* (Gruet, 1985).

The cyclical nature of *S. alveolata* on Heysham Flat can be explored further by looking at the health and formation of the species. Despite results indicting that there was a mean cover of 18.4% of *S. alveolata* in Autumn 2013, 69.2% of this *S. alveolata* was recorded as dead and 11% was recorded to have worn apertures. This could explain why the percentage cover of *S. alveolata* had decreased to 9.5% by spring 2014. Of course over a period of six months where no surveys were carried out over winter, many other factors could have contributed

towards the record low levels of *S. alveolata* recorded in spring 2014.

6.3. *Mytilus edulis* distribution

The relationship between percentage cover of *S. alveolata* and *M. edulis* over the past five years has shown to have a weak negative correlation. This implies that with an increased percentage cover of *M. edulis*, there was a decrease in percentage cover of *S. alveolata.* This is expected as when undersize *M. edulis* lives in the same area as *S. alveolata*, *M. edulis* is likely to overgrow the reef and slowly contribute to its death by smothering it with bio-deposits (Desroy, *et al.*, 2011). These bio-deposits can also contribute to the death of *S. alveolata* by settling in the tubes which restricts feeding especially as both *M. edulis* and *S. alveolata* are in competition for the same food resource.

This report has confirmed that *M. edulis* and *S. alveolata* are in direct competition with one another for space and resources. As depicted in Figure 25, high percentage cover of *M. edulis* coincides with warmer air temperatures found in the summer, which is before the sea surface temperature warms up towards late summer. This may be explained by the spat settling on Heysham Flat in late spring and due to the ambient water temperatures, *M. edulis* is able to grow quickly and efficiently (Seed & Suckanek, 1992). Figure 26 compares the mean percentage coverage of *S. alveolata* and *M. edulis* per season which shows that in spring 2012 and spring 2015 *S. alveolata* displayed a higher mean percentage coverage than undersize *M. edulis*. Despite Figure 26 showing a cyclical three year trend of *S. alveolata*, this conclusion is drawn from estimates of the mean percentage cover of *S. alveolata* and *M. edulis* in spring 2012 and spring 2013 as no surveys were conducted at fixed stations during these seasons.

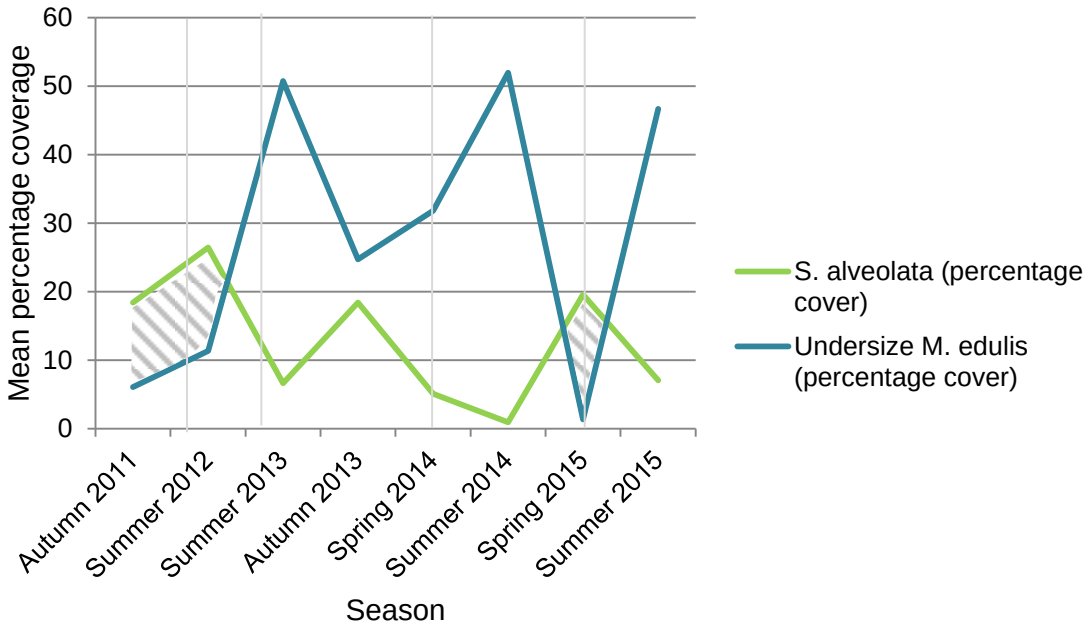


Figure 26 - Line graph comparing the mean percentage cover of *S. alveolata* and *M. edulis* at fixed stations between 2011 and 2015. The faint grey vertical lines represent spring each year. The grey striped polygons represent periods where percentage cover of *S. alveolata* has exceeded *M. edulis*.

6.4. Biodiversity

Previous studies reporting distribution and health of *S. alveolata* in the UK have found that the species out-competes all other littoral species in a homogenous capacity (Cunningham, *et al*., 1984). As is well documented, *M. edulis* will seize the opportunity to settle upon *S. alveolata* as it provides a solid substratum to fix upon specifically upon older areas of *S. alveolata* (Hammond, 2000). Despite not specifically investigating the age of *S. alveolata* in this report, it is possible that the positive correlation between *S. alveolata* percentage cover and species richness is due to other species taking advantage of the older and/or dead areas of *S. alveolata.*

As with previous reports from Foster (2015) and Egerton (2014) there was a slight positive correlation between *S. alveolata* cover and species richness and a weak negative correlation with *M. edulis* and species richness. Similar findings have been widely reported in literature where *S. alveolata* is reported to enhance biodiversity, especially on older reef settlements and when surrounded by sand or mud dominated homogenous habitats (Dubois, *et al*., 2002). The weak correlation in this study may either be an accurate representation of the relationship of the *S. alveolata* and species richness or it could be reasoned that the surveying technique used to calculate this parameter was not strong enough. Although not analysed in this report, the correlation between higher biodiversity and *S. alveolata* percentage may have been stronger if species richness was only compared against *S.*

alveolata which was recorded to be dead or with worn appertures (Dubois, *et al*., 2002). Habitat defragmentation is associated with these degraded conditions of *S. alveolata* which would have a knock on effect of altered hydrodynamics over reef structures thus leading to increased sedimentation and larve establishment (Nowell & Jumars, 1984; Dubois, *et al*., 2002). Any further studies investigating *S. aveolata* and biodiversity could assess if these correlations exist.

Biodiversity was not a focus of this survey and was collected most accurately when there was not a tight time limitation to the survey and when surveyors with expert knowledge were recording data. It is possible that many records of species were not recorded or identified to species level due to lack of knowledge. Although not surveyed in accordance with this study, a variety of birds roost and feed on Heysham Flat. Species include Eurasian oystercatcher (*Haematopus ostralegus*), European herring gull (*Larus argentatus*) and knot (*Calidris canutus*) and could possibly contribute towards the dynamic cycle of the distribution and health of *S. alveolata* on Heysham Flat (Wilson, 1973).

7. Conclusion

The cyclical nature of the distribution and abundance of *S. alveolata* on Heysham Flat between 2011 and 2015 can most likely be attributed to two factors: the life cycle of the species and the competition with annual resettlement of *M. edulis.* This report has reinforced findings from previous years from Egerton (2014) and Foster (2015) which suggested that a cycle of recovery and decline of *S. alveolata* occurs as it competes with *M. edulis* on Heysham Flat. This report has found that currently this cycle resets every three years where the mean percentage coverage of *S. alveolata* exceeds *M. edulis* for a short period of time. It is likely that these significant inter-annual fluctuations will continue as long as the larval distribution of *S. alveolata* and *M. edulis* continues to settle and form in Morecambe Bay.

8. Future research and recommendations

This study has provided five years of data regarding the distribution and health of *S. alveolata* on Heysham Flat. The project has completed the aims and objectives that were set out to achieve in 2011 as part of the Morecambe Bay Management Scheme Action Plan (Morecambe Bay Partnership, 2012). These were as follows:

- Aim to survey: "*the extent and health of the Heysham Flat Sabellaria reefs, as part of mussel stock assessments*"
- Objective of revealing: "*changes in the distribution and quality of honeycomb worm reefs… to inform management of shell fisheries and other activities*" in the area.

The Morecambe Bay Management Scheme Action Plan has since been updated (Morecambe Bay Partnership, 2014). In addition to the aims and objectives detailed above, the updated action plan also states that:

- *"Assessment will be carried out if it is identified there is a pressure on the feature from fishing activities".*

Throughout the past five years the NWIFCA have used this study to help inform the management of the seed mussel fishery on Heysham Flat skear. In 2015 the NWIFCA issued an authorisation to remove undersize mussels from Heysham Flat skear. This authorisation clarified that undersize mussels should not be taken from the exclusion zone which encapsulates the historical area of *S. alveolata* as explained in Byelaw 6 (refer back to Figure 3) (NWIFCA, 2015a). The distribution and health of *S. alveolata* is continuously being protected on Heysham Flat due to the designations of these Byelaws which are enforced by the NWIFCA. In addition, these Byelaws contribute to the protection of the historical area of *S. alveolata* as an EMS.

In terms of future research for this project as it stands there is still not enough data in this report from which to statistically analyse and draw strong conclusions. In this report due to the distribution and quantity of the data, all statistical tests were non-parametric alternatives. Therefore any conclusions drawn from this report must be backed up by further evidence, for example by descriptive surveys. Furthermore, for any further studies mapping the distribution and health of *S. alveolata,* either on Heysham Flat or elsewhere, should consider adding in extra surveys to avoid missing crucial changes in abundance of *S. alveolata* or *M. edulis*. These surveys should be conducted in late winter/ early spring when tides and daylight hours allow a survey to safely be completed.

The productive partnership between the North West Wildlife Trusts and NWFICA in relation to the Cumbria Wildlife Trust and the Wildlife Trust for Lancashire, Manchester and North Merseyside's Marine Training Programme has been successful in researching distribution and health of *S. alveolata* on Heysham Flat. For future studies for this partnership to pursue,

it might be of interest to survey other areas of *S. alveolata* in Cumbria, as briefly surveyed in 2012 (Miles, 2013). It has been agreed between NWIFCA and Natural England's Irish Sea Team that five years' worth of monitoring the *S*. *alveolata* have produced enough evidence that the competition between *M. edulis* and *S. alveolata* is the main cause for the health and distribution changes on Heysham Flat, and that both species are highly ephemeral in the way they exist on the skear. It has also been agreed to suspend the surveys on Heysham Flat and to concentrate resources on gaining a better understanding of *S*. *alveolata* in other parts of the NWIFCA district such as Allonby Bay and Cumbria Coast – both now designated Marine Conservation Zones (MCZs). The Senior Scientist has given an undertaking to monitor the situation by observations while carrying out *M. edulis* fishery inspections and surveys, and should it appear that anything has changed significantly from how the two species are operating then to re-instate the surveys.

As technology advances surveying methodologies using unmanned aerial vehicles (UAVs), commonly known as drones, are becoming increasingly popular in conservation science (Koh & Wich, 2012). In hindsight, if a drone were available to survey *S. alveolata* on this survey it would negate all issues of accidentally trampling and killing the established *S. alveolata* settlements as all analysis would be collected aerially. Using a drone would also enable surveyors to assess areas of Heysham Flat which are difficult or impossible to safely access and survey. Surveys conducted using video transects have successfully and commonly been used in conjunction with surveying methodologies such as underwater visual census and benthic surveys (Tessier, *et al.*, 2005). Therefore it would be possible to develop a new methodology to assess *S. alveolata* distribution and health via video transects and analysed using video software.

9. References

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10. Appendices

10.1. Appendix I - Formation and health classification of *S. alveolata* guide

Formation Type			
Patchy	**Sheet**	**Hummock**	**Reef**
			
Small crusts or mounds which are less than 30 cm^2.	Flat crust which are greater than 30 cm^2.	Raised mound which are greater than 30 cm^2.	Large mounds which are greater than 1 m^2.
Health Categories			
Dead	**Worn Apertures**	**Crisp Apertures**	**Newly Settled**
			
Tubes have merged into a block of sediment. If a piece of reef is detached from the substratum.	There has been no clear new growth/ tube building. The apertures can still be seen. The tubes are still attached to the substratum.	New growth of tubes can be seen, the apertures are crisp and will have a fine wall. Tend to be a lighter sandy colour compared with worn reef.	Very small apertures between 1 mm and 4 mm. Usually found around the larger, older apertures as shown above.

10.2. Appendix II - Raw data from all 2015 surveys regarding *S. alveolata* distribution and health

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
A7	54.056582	-2.918625	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
A8	54.056132	-2.918607	2015	Spring	23/03/2015	5	100	0	0	0	0	100	0	0
A9	54.055682	-2.918589	2015	Spring	23/03/2015	70	0	0	0	100	20	80	0	0
A10	54.055233	-2.918572	2015	Spring	23/03/2015	40	0	10	0	90	50	25	0	25
A11	54.054783	-2.918552	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
AL1	54.058040	-2.914423	2015	Spring	23/03/2015	3	100	0	0	0	0	100	0	0
AL2	54.058401	-2.913926	2015	Spring	23/03/2015	30	40	0	60	0	20	80	0	0
AL4	54.058850	-2.913359	2015	Spring	23/03/2015	60	0	0	0	100	40	60	0	0
AL5	54.059952	-2.910618	2015	Spring	23/03/2015	1	100	0	0	0	0	0	0	100
AL6	54.060015	-2.909834	2015	Spring	23/03/2015	70	0	100	0	0	0	100	0	0
B7	54.056612	-2.917866	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
B8	54.056162	-2.917848	2015	Spring	23/03/2015	75	20	80	0	0	20	80	0	0
B9	54.055713	-2.917830	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
B10	54.055263	-2.917812	2015	Spring	23/03/2015	10	0	0	100	0	80	20	0	0
B11	54.054813	-2.917794	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
C7	54.056643	-2.917106	2015	Spring	23/03/2015	10	0	0	100	0	15	85	0	0
C8	54.056194	-2.917089	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
C9	54.055744	-2.917070	2015	Spring	23/03/2015	50	0	100	0	0	0	20	0	80
C10	54.055293	-2.917053	2015	Spring	23/03/2015	10	0	0	100	0	0	80	0	20
C11	54.054844	-2.917035	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
D6	54.057123	-2.916366	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
D7	54.056673	-2.916348	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
D8	54.056224	-2.916328	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
D9	54.055774	-2.916311	2015	Spring	23/03/2015	3	0	100	0	0	0	0	0	100
D10	54.055325	-2.916292	2015	Spring	23/03/2015	65	0	100	0	0	40	40	0	20
D11	54.054875	-2.916275	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
E5	54.057603	-2.915623	2015	Spring	23/03/2015	1	100	0	0	0	100	0	0	0
E6	54.057153	-2.915606	2015	Spring	23/03/2015	15	100	0	0	0	20	55	0	25
E7	54.056704	-2.915588	2015	Spring	23/03/2015	25	100	0	0	0	45	55	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
E8	54.056255	-2.915570	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
E9	54.055804	-2.915552	2015	Spring	23/03/2015	50	0	0	0	100	0	10	0	90
E10	54.055355	-2.915534	2015	Spring	23/03/2015	75	0	0	0	100	0	90	0	10
E11	54.054905	-2.915515	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
F5	54.057633	-2.914864	2015	Spring	23/03/2015	10	100	0	0	0	0	100	0	0
F6	54.057183	-2.914846	2015	Spring	23/03/2015	60	0	0	0	100	5	95	0	0
F7	54.056734	-2.914828	2015	Spring	23/03/2015	50	0	0	100	0	25	75	0	0
F8	54.056285	-2.914810	2015	Spring	23/03/2015	1	100	0	0	0	100	0	0	0
F9	54.055836	-2.914793	2015	Spring	23/03/2015	75	0	0	0	100	0	50	0	50
F10	54.055386	-2.914774	2015	Spring	23/03/2015	50	0	100	0	0	30	40	0	30
F11	54.054935	-2.914757	2015	Spring	23/03/2015	65	0	100	0	0	10	10	15	65
G3	54.058563	-2.914142	2015	Spring	23/03/2015	75	0	0	0	100	100	0	0	0
G5	54.057664	-2.914106	2015	Spring	23/03/2015	5	100	0	0	0	0	50	0	50
G6	54.057214	-2.914086	2015	Spring	23/03/2015	60	100	0	0	0	5	95	0	0
G7	54.056764	-2.914069	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
G8	54.056315	-2.914051	2015	Spring	23/03/2015	2	100	0	0	0	5	95	0	0
G9	54.055865	-2.914033	2015	Spring	23/03/2015	10	0	0	100	0	0	10	0	90
G10	54.055416	-2.914015	2015	Spring	23/03/2015	35	100	0	0	0	0	50	0	50
G11	54.054967	-2.913996	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
H4	54.058144	-2.913364	2015	Spring	23/03/2015	60	0	0	0	100	55	45	0	0
H5	54.057694	-2.913346	2015	Spring	23/03/2015	2	100	0	0	0	0	0	0	100
H6	54.057245	-2.913327	2015	Spring	23/03/2015	18	10	0	0	90	90	0	0	10
H7	54.056796	-2.913310	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
H8	54.056345	-2.913292	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
H9	54.055896	-2.913273	2015	Spring	23/03/2015	50	0	100	0	0	5	10	0	85
H10	54.055447	-2.913255	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
H11	54.054996	-2.913237	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
I4	54.058175	-2.912604	2015	Spring	23/03/2015	5	100	0	0	0	0	0	0	100
I5	54.057726	-2.912586	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
I6	54.057274	-2.912568	2015	Spring	23/03/2015	25	0	100	0	0	0	90	0	10

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
I7	54.056825	-2.912550	2015	Spring	23/03/2015	25	0	100	0	0	10	90	0	0
I8	54.056376	-2.912533	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
I9	54.055926	-2.912514	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
I10	54.055477	-2.912497	2015	Spring	23/03/2015	50	0	100	0	0	10	60	0	30
J1	54.059554	-2.911899	2015	Spring	23/03/2015	46	100	0	0	0	55	45	0	0
J2	54.059104	-2.911882	2015	Spring	23/03/2015	5	0	0	100	0	0	50	0	50
J3	54.058655	-2.911863	2015	Spring	23/03/2015	21	100	0	0	0	0	50	0	50
J4	54.058206	-2.911845	2015	Spring	23/03/2015	2	100	0	0	0	50	50	0	0
J5	54.057755	-2.911826	2015	Spring	23/03/2015	2	100	0	0	0	0	0	0	100
J6	54.057306	-2.911809	2015	Spring	23/03/2015	50	100	0	0	0	0	80	0	20
J7	54.056857	-2.911791	2015	Spring	23/03/2015	10	100	0	0	0	50	50	0	0
J8	54.056406	-2.911773	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
J9	54.055956	-2.911756	2015	Spring	23/03/2015	20	0	100	0	0	5	85	0	10
J10	54.055507	-2.911737	2015	Spring	23/03/2015	50	100	0	0	0	10	60	0	30
K1	54.059615	-2.910380	2015	Spring	23/03/2015	15	100	0	0	0	50	50	0	0
K2	54.059165	-2.910363	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K3	54.058716	-2.910344	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K4	54.058267	-2.910326	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K5	54.057817	-2.910308	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K6	54.057367	-2.910290	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K7	54.056917	-2.910272	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K8	54.056467	-2.910254	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
K9	54.056018	-2.910236	2015	Spring	23/03/2015	60	0	0	0	100	0	30	0	70
K10	54.055568	-2.910217	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
L1	54.059584	-2.911140	2015	Spring	23/03/2015	1	100	0	0	0	100	0	0	0
L2	54.059136	-2.911122	2015	Spring	23/03/2015	80	0	0	0	100	95	5	0	0
L3	54.058686	-2.911104	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
L4	54.058235	-2.911086	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
L5	54.057786	-2.911068	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
L6	54.057336	-2.911049	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
L7	54.056887	-2.911032	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
L8	54.056437	-2.911013	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	0
L9	54.055988	-2.910995	2015	Spring	23/03/2015	40	0	0	0	100	0	30	0	70
L10	54.055537	-2.910977	2015	Spring	23/03/2015	60	0	100	0	0	0	50	0	50
L11	54.055088	-2.910959	2015	Spring	23/03/2015	85	0	100	0	0	40	20	0	40
MK1	54.055548	-2.913841	2015	Spring	23/03/2015	50	0	0	0	100	20	20	0	60
Q4	54.055826	-2.909468	2015	Spring	23/03/2015	15	100	0	0	0	5	85	0	10
Q5	54.056255	-2.909125	2015	Spring	23/03/2015	40	0	100	0	0	0	40	0	60
Q6	54.056609	-2.909186	2015	Spring	23/03/2015	5	100	0	0	0	0	0	0	100
A7	54.056582	-2.918625	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
A10	54.055233	-2.918572	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
B7	54.056612	-2.917866	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
B8	54.056162	-2.917848	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
B9	54.055713	-2.917830	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
B10	54.055263	-2.917812	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
B11	54.054813	-2.917794	2015	Summer	06/06/2015	20	100	0	0	0	0	100	0	0
C7	54.056643	-2.917106	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
C8	54.056194	-2.917089	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
C9	54.055744	-2.917070	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
C10	54.055293	-2.917053	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
C11	54.054844	-2.917035	2015	Summer	06/06/2015	20	70	30	0	0	0	70	30	0
D6	54.057123	-2.916366	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
D7	54.056673	-2.916348	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
D8	54.056224	-2.916328	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
D9	54.055774	-2.916311	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
D10	54.055325	-2.916292	2015	Summer	06/06/2015	40	100	0	0	0	0	95	5	0
D11	54.054875	-2.916275	2015	Summer	06/06/2015	15	0	100	0	0	0	0	100	0
E5	54.057603	-2.915623	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
E6	54.057153	-2.915606	2015	Summer	06/06/2015	3	100	0	0	0	0	0	90	10
E7	54.056704	-2.915588	2015	Summer	06/06/2015	10	100	0	0	0	5	0	70	25

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
E8	54.056255	-2.915570	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
E9	54.055804	-2.915552	2015	Summer	06/06/2015	60	0	0	100	0	0	95	5	0
E10	54.055355	-2.915534	2015	Summer	06/06/2015	5	0	100	0	0	0	0	100	0
E11	54.054905	-2.915515	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
F5	54.057633	-2.914864	2015	Summer	06/06/2015	15	0	100	0	0	0	0	99	1
F6	54.057183	-2.914846	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
F7	54.056734	-2.914828	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
F8	54.056285	-2.914810	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
F9	54.055836	-2.914793	2015	Summer	06/06/2015	2	0	100	0	0	0	0	100	0
F10	54.055386	-2.914774	2015	Summer	06/06/2015	20	0	100	0	0	0	0	100	0
F11	54.054935	-2.914757	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
G6	54.057214	-2.914086	2015	Summer	06/06/2015	10	100	0	0	0	0	0	100	0
G7	54.056764	-2.914069	2015	Summer	06/06/2015	8	100	0	0	0	0	0	100	0
G8	54.056315	-2.914051	2015	Summer	06/06/2015	15	0	100	0	0	0	95	5	0
G9	54.055865	-2.914033	2015	Summer	06/06/2015	25	100	0	0	0	0	0	100	0
G10	54.055416	-2.914015	2015	Summer	06/06/2015	70	0	0	100	0	10	0	90	0
G11	54.054967	-2.913996	2015	Summer	06/06/2015	10	100	0	0	0	0	100	0	0
H5	54.057694	-2.913346	2015	Summer	06/06/2015	1	100	0	0	0	0	0	100	0
H6	54.057245	-2.913327	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
H7	54.056796	-2.913310	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
H8	54.056345	-2.913292	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
H9	54.055896	-2.913273	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
H10	54.055447	-2.913255	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
I5	54.057726	-2.912586	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
I6	54.057274	-2.912568	2015	Summer	06/06/2015	10	0	100	0	0	0	0	0	100
I7	54.056825	-2.912550	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
I8	54.056376	-2.912533	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
I9	54.055926	-2.912514	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
I10	54.055477	-2.912497	2015	Summer	06/06/2015	60	0	0	100	0	0	75	25	0
J1	54.059554	-2.911899	2015	Summer	06/06/2015	15	0	100	0	0	0	0	0	100

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
J2	54.059104	-2.911882	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
J4	54.058206	-2.911845	2015	Summer	06/06/2015	5	100	0	0	0	0	0	0	100
J5	54.057755	-2.911826	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
J6	54.057306	-2.911809	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
J7	54.056857	-2.911791	2015	Summer	06/06/2015	35	100	0	0	0	40	0	0	60
J8	54.056406	-2.911773	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
J9	54.055956	-2.911756	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
J10	54.055507	-2.911737	2015	Summer	06/06/2015	10	0	100	0	0	0	0	100	0
K1	54.059615	-2.910380	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K2	54.059165	-2.910363	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K3	54.058716	-2.910344	2015	Summer	06/06/2015	7	100	0	0	0	0	0	0	100
K4	54.058267	-2.910326	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K5	54.057817	-2.910308	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K6	54.057367	-2.910290	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K7	54.056917	-2.910272	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K8	54.056467	-2.910254	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K9	54.056018	-2.910236	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
K10	54.055568	-2.910217	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L1	54.059584	-2.911140	2015	Summer	06/06/2015	5	100	0	0	0	0	0	0	100
L2	54.059136	-2.911122	2015	Summer	06/06/2015	15	100	0	0	0	0	0	70	30
L3	54.058686	-2.911104	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L4	54.058235	-2.911086	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L5	54.057786	-2.911068	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L7	54.056887	-2.911032	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L8	54.056437	-2.911013	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L9	54.055988	-2.910995	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
L10	54.055537	-2.910977	2015	Summer	06/06/2015	40	100	0	0	0	0	100	0	0
L11	54.055088	-2.910959	2015	Summer	06/06/2015	20	100	0	0	0	0	100	0	0
Q4	54.055826	-2.909468	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
Q5	54.056255	-2.909125	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	*S. alveolata*	Patchy	Sheet	Hummock	Reef	Crisp	Worn	New	Dead
Q6	54.056609	-2.909186	2015	Summer	06/06/2015	0	0	0	0	0	0	0	0	0
SD31	54.055960	-2.910180	2015	Summer des	03/09/2015	30	100	0	0	0	0	0	0	100
SD32	54.055950	-2.910180	2015	Summer des	03/09/2015	30	100	0	0	0	30	0	0	70
SD33	54.055650	-2.912120	2015	Summer des	03/09/2015	68	0	0	100	0	0	0	0	100
SD34	54.055100	-2.917420	2015	Summer des	03/09/2015	70	0	0	0	100	0	0	0	100
SD35	54.056000	-2.917490	2015	Summer des	03/09/2015	25	0	0	100	0	0	0	0	100
SD36	54.056640	-2.916660	2015	Summer des	03/09/2015	70	0	0	100	0	0	60	0	40
SD37	54.057790	-2.913900	2015	Summer des	03/09/2015	25	100	0	0	0	100	0	0	0
SD38	54.058980	-2.913610	2015	Summer des	03/09/2015	50	20	0	80	0	0	100	0	0
SD39	54.059790	-2.911280	2015	Summer des	03/09/2015	75	0	0	100	0	70	30	0	0
SD40	54.061520	-2.908710	2015	Summer des	03/09/2015	60	0	0	100	0	70	30	0	0
SD41	54.060790	-2.908270	2015	Summer des	03/09/2015	60	100	0	0	0	100	0	0	0

10.3. Appendix III - Raw data from all 2015 surveys regarding *M. edulis* and substrate cover

Quadrat	Latitude	Longitude	Year	Season	Date	Adult *M. edulis*	Undersize *M. edulis*	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
A7	54.056582	-2.918625	2015	Spring	23/03/2015	50	0	0	5	40	0	3	2	0	0
A8	54.056132	-2.918607	2015	Spring	23/03/2015	5	0	0	44	44	0	0	2	0	0
A9	54.055682	-2.918589	2015	Spring	23/03/2015	5	0	0	15	10	0	0	0	0	0
A10	54.055233	-2.918572	2015	Spring	23/03/2015	40	0	0	15	5	0	0	0	0	0
A11	54.054783	-2.918552	2015	Spring	23/03/2015	10	0	0	5	10	0	75	0	0	0
AL1	54.058040	-2.914423	2015	Spring	23/03/2015	2	0	0	80	14	0	0	0	0	1
AL2	54.058401	-2.913926	2015	Spring	23/03/2015	2	0	0	40	28	0	0	0	0	0
AL4	54.058850	-2.913359	2015	Spring	23/03/2015	2	0	0	28	10	0	0	0	0	0
AL5	54.059952	-2.910618	2015	Spring	23/03/2015	1	0	0	37	60	0	0	1	0	0
AL6	54.060015	-2.909834	2015	Spring	23/03/2015	5	5	0	10	10	0	0	0	0	0
B7	54.056612	-2.917866	2015	Spring	23/03/2015	1	1	0	15	33	0	50	0	0	0
B8	54.056162	-2.917848	2015	Spring	23/03/2015	1	0	0	14	9	0	1	0	0	0
B9	54.055713	-2.917830	2015	Spring	23/03/2015	50	0	0	45	5	0	0	0	0	0
B10	54.055263	-2.917812	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	90	0
B11	54.054813	-2.917794	2015	Spring	23/03/2015	0	0	0	1	99	0	0	0	0	0
C7	54.056643	-2.917106	2015	Spring	23/03/2015	5	0	0	42	43	0	0	0	0	0
C8	54.056194	-2.917089	2015	Spring	23/03/2015	28	0	0	60	10	0	0	2	0	0
C9	54.055744	-2.917070	2015	Spring	23/03/2015	5	0	0	10	5	0	30	0	0	0
C10	54.055293	-2.917053	2015	Spring	23/03/2015	12	0	0	10	40	0	25	0	0	3
C11	54.054844	-2.917035	2015	Spring	23/03/2015	0	0	0	0	100	0	0	0	0	0
D6	54.057123	-2.916366	2015	Spring	23/03/2015	1	0	0	5	89	0	5	0	0	0
D7	54.056673	-2.916348	2015	Spring	23/03/2015	2	0	0	49	47	0	0	2	0	0
D8	54.056224	-2.916328	2015	Spring	23/03/2015	2	0	0	60	38	0	0	0	0	0
D9	54.055774	-2.916311	2015	Spring	23/03/2015	0	0	0	85	12	0	0	0	0	0
D10	54.055325	-2.916292	2015	Spring	23/03/2015	0	0	0	10	23	0	2	0	0	0
D11	54.054875	-2.916275	2015	Spring	23/03/2015	0	0	0	0	100	0	0	0	0	0
E5	54.057603	-2.915623	2015	Spring	23/03/2015	1	0	0	25	73	0	0	0	0	0
E6	54.057153	-2.915606	2015	Spring	23/03/2015	2	0	0	45	38	0	0	0	0	0
E7	54.056704	-2.915588	2015	Spring	23/03/2015	2	0	0	45	28	0	0	0	0	0
E8	54.056255	-2.915570	2015	Spring	23/03/2015	2	0	0	30	18	0	50	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	Adult M. edulis	Undersize M. edulis	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
E9	54.055804	-2.915552	2015	Spring	23/03/2015	0	30	0	20	0	0	0	0	0	0
E10	54.055355	-2.915534	2015	Spring	23/03/2015	0	0	0	15	5	0	5	0	0	0
E11	54.054905	-2.915515	2015	Spring	23/03/2015	0	0	0	5	35	0	60	0	0	0
F5	54.057633	-2.914864	2015	Spring	23/03/2015	1	0	0	10	79	0	0	0	0	0
F6	54.057183	-2.914846	2015	Spring	23/03/2015	2	5	0	15	18	0	0	0	0	0
F7	54.056734	-2.914828	2015	Spring	23/03/2015	5	2	0	22	20	0	0	1	0	0
F8	54.056285	-2.914810	2015	Spring	23/03/2015	10	0	0	79	10	0	0	0	0	0
F9	54.055836	-2.914793	2015	Spring	23/03/2015	0	0	0	15	10	0	0	0	0	0
F10	54.055386	-2.914774	2015	Spring	23/03/2015	0	0	0	15	10	0	25	0	0	0
F11	54.054935	-2.914757	2015	Spring	23/03/2015	0	0	0	10	10	0	15	0	0	0
G3	54.058563	-2.914142	2015	Spring	23/03/2015	1	0	0	15	9	0	0	0	0	0
G5	54.057664	-2.914106	2015	Spring	23/03/2015	2	0	0	40	53	0	0	0	0	0
G6	54.057214	-2.914086	2015	Spring	23/03/2015	0	0	0	22	15	0	3	0	0	0
G7	54.056764	-2.914069	2015	Spring	23/03/2015	5	0	0	45	50	0	0	0	0	0
G8	54.056315	-2.914051	2015	Spring	23/03/2015	15	0	0	73	10	0	0	0	0	0
G9	54.055865	-2.914033	2015	Spring	23/03/2015	5	0	0	75	10	0	0	0	0	0
G10	54.055416	-2.914015	2015	Spring	23/03/2015	0	0	0	10	50	0	5	0	0	0
G11	54.054967	-2.913996	2015	Spring	23/03/2015	0	0	0	0	100	0	0	0	0	0
H4	54.058144	-2.913364	2015	Spring	23/03/2015	1	0	0	23	15	0	0	1	0	0
H5	54.057694	-2.913346	2015	Spring	23/03/2015	5	0	0	63	30	0	0	0	0	0
H6	54.057245	-2.913327	2015	Spring	23/03/2015	0	0	0	7	50	0	20	5	0	0
H7	54.056796	-2.913310	2015	Spring	23/03/2015	1	0	0	20	64	0	15	0	0	0
H8	54.056345	-2.913292	2015	Spring	23/03/2015	20	0	0	70	10	0	0	0	0	0
H9	54.055896	-2.913273	2015	Spring	23/03/2015	0	0	0	40	10	0	0	0	0	0
H10	54.055447	-2.913255	2015	Spring	23/03/2015	0	0	0	5	50	0	45	0	0	0
H11	54.054996	-2.913237	2015	Spring	23/03/2015	0	0	0	0	100	0	0	0	0	0
I4	54.058175	-2.912604	2015	Spring	23/03/2015	5	2	0	10	78	0	0	0	0	0
I5	54.057726	-2.912586	2015	Spring	23/03/2015	20	0	0	70	10	0	0	0	0	0
I6	54.057274	-2.912568	2015	Spring	23/03/2015	5	1	0	58	10	0	1	0	0	0
I7	54.056825	-2.912550	2015	Spring	23/03/2015	5	5	0	45	20	0	0	0	0	0
I8	54.056376	-2.912533	2015	Spring	23/03/2015	2	1	0	82	15	0	0	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	Adult M. edulis	Undersize M. edulis	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
I9	54.055926	-2.912514	2015	Spring	23/03/2015	55	0	0	30	15	0	0	0	0	0
I10	54.055477	-2.912497	2015	Spring	23/03/2015	45	0	0	5	0	0	0	0	0	0
J1	54.059554	-2.911899	2015	Spring	23/03/2015	1	0	0	41	12	0	0	0	0	0
J2	54.059104	-2.911882	2015	Spring	23/03/2015	0	0	0	47	48	0	0	0	0	0
J3	54.058655	-2.911863	2015	Spring	23/03/2015	1	0	0	36	39	0	3	0	0	0
J4	54.058206	-2.911845	2015	Spring	23/03/2015	5	0	0	68	25	0	0	0	0	0
J5	54.057755	-2.911826	2015	Spring	23/03/2015	1	1	0	15	20	0	60	1	0	0
J6	54.057306	-2.911809	2015	Spring	23/03/2015	0	5	0	30	15	0	0	0	0	0
J7	54.056857	-2.911791	2015	Spring	23/03/2015	1	0	0	18	70	0	0	1	0	0
J8	54.056406	-2.911773	2015	Spring	23/03/2015	0	1	0	20	59	0	20	0	0	0
J9	54.055956	-2.911756	2015	Spring	23/03/2015	0	0	0	15	65	0	0	0	0	0
J10	54.055507	-2.911737	2015	Spring	23/03/2015	0	0	0	25	25	0	0	0	0	0
K1	54.059615	-2.910380	2015	Spring	23/03/2015	1	0	0	20	63	0	0	1	0	0
K2	54.059165	-2.910363	2015	Spring	23/03/2015	2	0	0	48	49	0	1	0	0	0
K3	54.058716	-2.910344	2015	Spring	23/03/2015	3	0	0	25	72	0	0	0	0	0
K4	54.058267	-2.910326	2015	Spring	23/03/2015	5	0	0	80	15	0	0	0	0	0
K5	54.057817	-2.910308	2015	Spring	23/03/2015	15	0	0	65	10	0	10	0	0	0
K6	54.057367	-2.910290	2015	Spring	23/03/2015	0	0	0	65	25	0	10	0	0	0
K7	54.056917	-2.910272	2015	Spring	23/03/2015	0	0	0	85	15	0	0	0	0	0
K8	54.056467	-2.910254	2015	Spring	23/03/2015	0	3	0	57	15	0	25	0	0	0
K9	54.056018	-2.910236	2015	Spring	23/03/2015	0	0	0	15	25	0	0	0	0	0
K10	54.055568	-2.910217	2015	Spring	23/03/2015	0	0	0	40	60	0	0	0	0	0
L1	54.059584	-2.911140	2015	Spring	23/03/2015	15	0	0	79	5	0	0	0	0	0
L2	54.059136	-2.911122	2015	Spring	23/03/2015	0	0	0	15	5	0	0	0	0	0
L3	54.058686	-2.911104	2015	Spring	23/03/2015	24	0	0	60	15	0	1	0	0	0
L4	54.058235	-2.911086	2015	Spring	23/03/2015	0	0	0	0	0	0	0	0	100	0
L5	54.057786	-2.911068	2015	Spring	23/03/2015	10	0	0	73	15	0	2	0	0	0
L6	54.057336	-2.911049	2015	Spring	23/03/2015	0	0	0	50	40	0	10	0	0	0
L7	54.056887	-2.911032	2015	Spring	23/03/2015	5	0	0	85	10	0	0	0	0	0
L8	54.056437	-2.911013	2015	Spring	23/03/2015	0	0	0	75	25	0	0	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	Adult *M. edulis*	Undersize *M. edulis*	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
L9	54.055988	-2.910995	2015	Spring	23/03/2015	0	35	0	25	0	0	0	0	0	0
L10	54.055537	-2.910977	2015	Spring	23/03/2015	0	0	0	5	35	0	0	0	0	0
L11	54.055088	-2.910959	2015	Spring	23/03/2015	0	0	0	5	10	0	0	0	0	0
MK1	54.055548	-2.913841	2015	Spring	23/03/2015	0	45	0	5	0	0	0	0	0	0
Q4	54.055826	-2.909468	2015	Spring	23/03/2015	0	0	0	35	50	0	0	0	0	0
Q5	54.056255	-2.909125	2015	Spring	23/03/2015	0	20	0	25	15	0	0	0	0	0
Q6	54.056609	-2.909186	2015	Spring	23/03/2015	0	0	0	20	10	0	65	0	0	0
A7	54.056582	-2.918625	2015	Summer	06/06/2015	2	50	0	0	48	0	0	0	0	0
A10	54.055233	-2.918572	2015	Summer	06/06/2015	45	5	0	40	5	0	0	0	0	5
B7	54.056612	-2.917866	2015	Summer	06/06/2015	2	70	0	0	28	0	0	0	0	0
B8	54.056162	-2.917848	2015	Summer	06/06/2015	0	95	0	0	5	0	0	0	0	0
B9	54.055713	-2.917830	2015	Summer	06/06/2015	0	95	0	0	5	0	0	0	0	0
B10	54.055263	-2.917812	2015	Summer	06/06/2015	0	0	0	90	10	0	0	0	0	0
B11	54.054813	-2.917794	2015	Summer	06/06/2015	10	10	0	20	36	0	2	1	0	1
C7	54.056643	-2.917106	2015	Summer	06/06/2015	1	70	0	0	29	0	0	0	0	0
C8	54.056194	-2.917089	2015	Summer	06/06/2015	0	95	0	0	5	0	0	0	0	0
C9	54.055744	-2.917070	2015	Summer	06/06/2015	0	90	0	0	10	0	0	0	0	0
C10	54.055293	-2.917053	2015	Summer	06/06/2015	2	30	0	2	66	0	0	0	0	0
C11	54.054844	-2.917035	2015	Summer	06/06/2015	5	20	0	15	40	0	0	0	0	0
D6	54.057123	-2.916366	2015	Summer	06/06/2015	1	35	0	0	64	0	0	0	0	0
D7	54.056673	-2.916348	2015	Summer	06/06/2015	0	70	0	0	30	0	0	0	0	0
D8	54.056224	-2.916328	2015	Summer	06/06/2015	0	95	0	0	5	0	0	0	0	0
D9	54.055774	-2.916311	2015	Summer	06/06/2015	5	77	0	0	15	0	0	0	0	3
D10	54.055325	-2.916292	2015	Summer	06/06/2015	0	35	0	3	22	0	0	0	0	0
D11	54.054875	-2.916275	2015	Summer	06/06/2015	3	10	0	10	62	0	0	0	0	0
E5	54.057603	-2.915623	2015	Summer	06/06/2015	2	10	0	25	61	0	2	0	0	0
E6	54.057153	-2.915606	2015	Summer	06/06/2015	1	15	0	3	76	0	0	2	0	0
E7	54.056704	-2.915588	2015	Summer	06/06/2015	3	65	0	5	15	0	0	2	0	0
E8	54.056255	-2.915570	2015	Summer	06/06/2015	0	75	0	0	25	0	0	0	0	0
E9	54.055804	-2.915552	2015	Summer	06/06/2015	1	20	0	9	10	0	0	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	Adult *M. edulis*	Undersize *M. edulis*	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
E10	54.055355	-2.915534	2015	Summer	06/06/2015	0	30	0	2	63	0	0	0	0	0
E11	54.054905	-2.915515	2015	Summer	06/06/2015	0	15	0	10	75	0	0	0	0	0
F5	54.057633	-2.914864	2015	Summer	06/06/2015	3	55	0	17	6	0	0	3	0	1
F6	54.057183	-2.914846	2015	Summer	06/06/2015	1	60	0	1	38	0	0	0	0	0
F7	54.056734	-2.914828	2015	Summer	06/06/2015	0	65	0	0	34	0	0	1	0	0
F8	54.056285	-2.914810	2015	Summer	06/06/2015	0	10	0	5	5	0	80	0	0	0
F9	54.055836	-2.914793	2015	Summer	06/06/2015	0	80	0	0	18	0	0	0	0	0
F10	54.055386	-2.914774	2015	Summer	06/06/2015	0	40	0	0	40	0	0	0	0	0
F11	54.054935	-2.914757	2015	Summer	06/06/2015	0	5	0	10	75	0	10	0	0	0
G6	54.057214	-2.914086	2015	Summer	06/06/2015	2	35	0	3	46	0	0	2	0	2
G7	54.056764	-2.914069	2015	Summer	06/06/2015	1	40	0	5	46	0	0	0	0	0
G8	54.056315	-2.914051	2015	Summer	06/06/2015	10	40	0	20	15	0	0	0	0	0
G9	54.055865	-2.914033	2015	Summer	06/06/2015	2	56	0	0	15	0	0	0	0	2
G10	54.055416	-2.914015	2015	Summer	06/06/2015	5	10	0	2	13	0	0	0	0	0
G11	54.054967	-2.913996	2015	Summer	06/06/2015	0	10	0	5	75	0	0	0	0	0
H5	54.057694	-2.913346	2015	Summer	06/06/2015	0	44	0	5	50	0	0	0	0	0
H6	54.057245	-2.913327	2015	Summer	06/06/2015	1	55	0	0	44	0	0	0	0	0
H7	54.056796	-2.913310	2015	Summer	06/06/2015	3	55	0	7	34	0	0	1	0	0
H8	54.056345	-2.913292	2015	Summer	06/06/2015	2	60	0	15	23	0	0	0	0	0
H9	54.055896	-2.913273	2015	Summer	06/06/2015	4	60	0	2	32	0	0	1	0	1
H10	54.055447	-2.913255	2015	Summer	06/06/2015	0	10	0	5	80	0	4	1	0	0
I5	54.057726	-2.912586	2015	Summer	06/06/2015	4	20	0	20	56	0	0	0	0	0
I6	54.057274	-2.912568	2015	Summer	06/06/2015	7	75	0	5	0	0	0	3	0	0
I7	54.056825	-2.912550	2015	Summer	06/06/2015	1	55	0	0	44	0	0	0	0	0
I8	54.056376	-2.912533	2015	Summer	06/06/2015	2	90	0	0	8	0	0	0	0	0
I9	54.055926	-2.912514	2015	Summer	06/06/2015	1	75	0	1	23	0	0	0	0	0
I10	54.055477	-2.912497	2015	Summer	06/06/2015	10	10	0	8	8	0	0	1	0	3
J1	54.059554	-2.911899	2015	Summer	06/06/2015	0	60	0	10	15	0	0	0	0	0
J2	54.059104	-2.911882	2015	Summer	06/06/2015	5	24	0	40	30	0	0	0	0	1
J4	54.058206	-2.911845	2015	Summer	06/06/2015	5	35	0	15	38	0	0	2	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	Adult M. edulis	Undersize M. edulis	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
J5	54.057755	-2.911826	2015	Summer	06/06/2015	1	40	0	0	59	0	0	0	0	0
J6	54.057306	-2.911809	2015	Summer	06/06/2015	0	60	0	1	38	0	0	1	0	0
J7	54.056857	-2.911791	2015	Summer	06/06/2015	2	30	0	2	23	0	0	7	0	1
J8	54.056406	-2.911773	2015	Summer	06/06/2015	0	90	0	0	10	0	0	0	0	0
J9	54.055956	-2.911756	2015	Summer	06/06/2015	3	80	0	5	12	0	0	0	0	0
J10	54.055507	-2.911737	2015	Summer	06/06/2015	10	30	0	15	35	0	0	0	0	0
K1	54.059615	-2.910380	2015	Summer	06/06/2015	0	15	0	40	43	0	0	2	0	0
K2	54.059165	-2.910363	2015	Summer	06/06/2015	0	30	0	5	63	0	0	2	0	0
K3	54.058716	-2.910344	2015	Summer	06/06/2015	2	15	0	10	66	0	0	0	0	0
K4	54.058267	-2.910326	2015	Summer	06/06/2015	10	35	0	0	54	0	0	1	0	0
K5	54.057817	-2.910308	2015	Summer	06/06/2015	5	80	0	2	10	0	1	2	0	0
K6	54.057367	-2.910290	2015	Summer	06/06/2015	0	15	0	1	69	0	0	15	0	0
K7	54.056917	-2.910272	2015	Summer	06/06/2015	3	74	0	1	20	0	1	0	0	1
K8	54.056467	-2.910254	2015	Summer	06/06/2015	1	80	0	0	19	0	0	0	0	0
K9	54.056018	-2.910236	2015	Summer	06/06/2015	1	89	0	2	7	0	0	1	0	0
K10	54.055568	-2.910217	2015	Summer	06/06/2015	1	10	0	74	15	0	0	0	0	0
L1	54.059584	-2.911140	2015	Summer	06/06/2015	2	25	0	35	30	0	0	3	0	0
L2	54.059136	-2.911122	2015	Summer	06/06/2015	0	15	0	20	47	0	0	2	0	1
L3	54.058686	-2.911104	2015	Summer	06/06/2015	20	5	0	35	40	0	0	0	0	0
L4	54.058235	-2.911086	2015	Summer	06/06/2015	3	45	0	2	49	0	0	1	0	0
L5	54.057786	-2.911068	2015	Summer	06/06/2015	3	60	0	2	35	0	0	0	0	0
L7	54.056887	-2.911032	2015	Summer	06/06/2015	5	45	0	3	47	0	0	0	0	0
L8	54.056437	-2.911013	2015	Summer	06/06/2015	5	70	0	0	25	0	0	0	0	0
L9	54.055988	-2.910995	2015	Summer	06/06/2015	5	89	0	0	5	0	0	1	0	0
L10	54.055537	-2.910977	2015	Summer	06/06/2015	0	20	0	10	29	0	0	1	0	0
L11	54.055088	-2.910959	2015	Summer	06/06/2015	0	20	0	5	55	0	0	0	0	0
Q4	54.055826	-2.909468	2015	Summer	06/06/2015	2	60	0	15	23	0	0	0	0	0
Q5	54.056255	-2.909125	2015	Summer	06/06/2015	0	95	0	0	5	0	0	0	0	0
Q6	54.056609	-2.909186	2015	Summer	06/06/2015	1	94	0	0	5	0	0	0	0	0

Quadrat	Latitude	Longitude	Year	Season	Date	Adult *M. edulis*	Undersize *M. edulis*	Mud	Shell	Sand	Rock	Cobble	Algae	Pool	Other
SD31	54.055960	-2.910180	2015	Summer des	03/09/2015	7	7	6	4	25	0	0	1	20	0
SD32	54.055950	-2.910180	2015	Summer des	03/09/2015	0	30	34	3	0	0	0	1	2	0
SD33	54.055650	-2.912120	2015	Summer des	03/09/2015	15	5	0	7	4	0	0	1	0	0
SD34	54.055100	-2.917420	2015	Summer des	03/09/2015	10	7	0	10	2	0	0	1	0	0
SD35	54.056000	-2.917490	2015	Summer des	03/09/2015	62	5	0	3	5	0	0	0	0	0
SD36	54.056640	-2.916660	2015	Summer des	03/09/2015	10	0	0	15	5	0	0	0	0	0
SD37	54.057790	-2.913900	2015	Summer des	03/09/2015	3	0	2	15	50	0	0	5	0	0
SD38	54.058980	-2.913610	2015	Summer des	03/09/2015	0	0	35	10	5	0	0	0	0	0
SD39	54.059790	-2.911280	2015	Summer des	03/09/2015	0	0	2	20	3	0	0	0	0	0
SD40	54.061520	-2.908710	2015	Summer des	03/09/2015	4	0	25	2	3	0	0	3	0	3
SD41	54.060790	-2.908270	2015	Summer des	03/09/2015	0	0	0	4	35	0	0	1	0	0

10.4. Appendix IV - number of records of species recorded during *S. alveolata* distribution and health assessment

Species	Common name	Number of Records
Including but not limited to *Balanus crenatus*	Barnacle species	126
Sea anemone species	Sea anemone	7
Ulva flat spp.	Gutweed	32
Cerastoderma edule	Common cockle	8
Carcinus maenas	Shore crab	9
Lanice conchilega	Sandmason worm	134
Tellina tenuis	Tellin	1
Bryozoa species	Bryozoan	12
Whelk species	Whelk	1
Arenicola marina	Lugworm	18
Hydroid species	Hydroid	19
Isopod species	Isopod	3
Crangon crangon	Common shrimp	3
Gammarus spp.	Gammarus	1
Phyllodoce maculata	Paddleworm	3
Chlamys varia	Scallop (variegated)	9
Pelvetia canaliculata	Channel wrack	5
Fucus vesiculosus	Bladder wrack	3
Fucus spiralis	Spiral wrack	8
Fucus serratus	Serrated wrack	1
Paguroidea spp.	Hermit crab	3
Ctenophora spp.	Comb jelly	3
Littorinidae	Periwinkle species	2