Cyfoeth Naturiol Cymru
Natural Resources Wales

Skomer Marine Conservation Zone Distribution & Abundance of *Zostera marina* in North Haven 2018.

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NRW Evidence Report No 322.

April 2019

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Report series:	NRW Evidence Report
Report number:	322
Publication date:	April 2019
Title:	Skomer Marine Conservation Zone Distribution & Abundance of *Zostera marina* in North Haven 2018
Author(s):	Burton M, Lock K, Griffiths, J, Newman P, Jones, J
Technical Editor:	Newman, P
Peer Reviewer(s)	Brazier, D.P
Restrictions:	None

Distribution List (core)

NRW Library, Bangor	2
National Library of Wales	1
British Library	1
Welsh Government Library	1
Scottish Natural Heritage Library	1
Natural England Library (Electronic Only)	1

Distribution List (others)

Via NRW website

Recommended citation for this volume:

Burton, M., Lock, K., Griffiths, J., Newman, P., & Jones, J. 2019. Skomer Marine Conservation Zone Distribution & Abundance of *Zostera marina* in North Haven 2018. NRW Evidence Report No 322.

Synopsis

The seagrass bed (*Zostera marina*) within North Haven, Skomer MCZ was surveyed by a group of volunteer divers over 3 weekends in June and July 2018. This survey repeated the methods of previous surveys to estimate the area of extent and shoot density of the seagrass bed.

The 2018 results show a slight increase in area of extent, 8567.6 m^2 compared to 8224.6 m^2 in 2014 and a very encouraging increase in shoot density, 33.0 shoots/m^2 compared with 18.8 shoots/m^2 in 2014. Shoot density had been on a downward trend since 2002 but the 2018 results are the highest ever recorded.

NRW Fisheries Assessment Team conducted repeat surveys using a Biosonics DT-X split beam echo sounder in between 2013 - 2018. The diver survey results compare well against the Biosonics acoustic surveys. The remote acoustic method provides an efficient alternative to the diver survey for getting annual results for area of extent.

The 2018 results are very encouraging but other studies (Jones et al. 2018) show evidence that the health of the seagrass at Skomer may be limiting growth. Seagrass health and ecosystem services are discussed with examples of existing evidence from the Skomer seagrass bed.

Crynodeb

Cynhaliwyd arolwg o wely morwellt (*Zostera marina*) o fewn North Haven, Parth Cadwraeth Morol Sgomer, gan grŵp o blymwyr gwirfoddol dros gyfnod o dri phenwythnos ym mis Mehefin a Gorffennaf 2018. Cafodd dulliau arolygon blaenorol eu hailadrodd yn yr arolwg hwn i wneud brasamcan o arwynebedd y gwely morwellt a dwyster ei gyffion.

Yn ôl canlyniadau 2018, bu cynnydd bach ym maint yr arwynebedd (8,567.6 m^2 o'i gymharu ag 8,224.6 m^2 yn 2014) a chynnydd calonogol iawn yn nwyster y cyffion (33.0 cyffyn/m^2 o'i gymharu â 18.8 cyffyn/m^2 yn 2014). Mae dwyster y cyffion wedi bod ar i lawr ers 2002 ond canlyniadau 2018 yw'r uchaf a gofnodwyd erioed.

Cynhaliodd Tîm Asesu Pysgodfeydd Cyfoeth Naturiol Cymru arolygon ailadrodd gan ddefnyddio atseinydd dau baladr BioSonics DT-X rhwng 2013 a 2018. Mae cymhariaeth dda rhwng canlyniadau arolwg y plymwyr â chanlyniadau acwstig BioSonics. Mae'r dull acwstig o bellter yn darparu opsiwn amgen effeithlon i arolwg y plymwyr ar gyfer cael canlyniadau blynyddol ar gyfer maint yr arwynebedd.

Mae canlyniadau 2018 yn galonogol iawn ond mae astudiaethau eraill (Jones ac eraill, 2018) yn dangos tystiolaeth fod iechyd y morwellt yn ardal Sgomer yn cyfyngu ar ei dwf. Caiff iechyd y morwellt a gwasanaethau ecosystemau eu trafod gydag enghreifftiau o dystiolaeth bresennol o wely morwellt Sgomer.

Contents

1 Introduction

1.1 Seagrass beds

Zostera marina Linnaeus, (1758) is the only flowering plant within the British Isles that grows and produces seed entirely submerged by seawater. *Z. marina* populations are highly productive habitats and they provide an important stabilising function for the mobile marine sediments (Bertelli & Unsworth 2013). The maintenance of *Z. marina* populations directly influences the associated algal and invertebrate communities that are supported by them. These communities are an important source of food for other marine animals and birds. The optimal growth conditions for *Z. marina* are in relatively shallow, sheltered and stable environments.

Z. marina, is one of two seagrass species which are listed as nationally scarce. In 1994, the UK government published the UK Biodiversity Action Plan(BAP), for species and habitats that were identified as being threatened. Intertidal and subtidal seagrasses were both included as threatened habitats. BAP was superseded by the NERC Act (2008) and further by the Environment (Wales) Act, 2016, where seagrass beds are listed as a Section 7 habitat due to the declines and level of threat to this habitat. Section 7 states that 'all reasonable steps to maintain and enhance the living organisms and types of habitat included in any list published under this section and encourage others to take such steps.'

Seagrass beds have been recognised by the European Union as a 'sub-feature' within Special Areas of Conservation (SACs) under the EU Habitats Directive 1992 (Council Directive 92/43/EEC). The Habitats Directive states that habitats, e.g. estuaries, shallow inlets and bays, must be maintained in their present state, or where possible, to restore to a more favourable condition.

Zostera beds are also on the OSPAR list of Threatened and/or Declining Species and Habitats (declining in Region II – North Sea and Region III – Celtic sea, and threatened in Region V- wider Atlantic)

1.2 Ecosystems Services provided by seagrass

Seagrass beds provide many ecosystem services including; stabilisation of sediments, nursery areas for commercially important species (Nordlund et al. 2018; Unsworth et al. 2018 a & b) and are responsible for 20% of the marine and estuarine carbon sequestration (Crooks et al. 2011; Duarte et al. 2013).

Seagrass habitats influence the physical, chemical and biological environments in shallow coastal waters, acting as important ecological engineers and providing numerous important ecosystems services to the marine environment (Orth et al. 2006). When present in large areas and in good condition, seagrass meadows form vast filters for the coastal environment (both landward and seaward), recycling nutrients and reducing pathogens (Flindt et al. 1999; Lamb et al. 2017).

Seagrass meadows support a high biodiversity of species, including nursery grounds of commercially and recreationally important fish and crustaceans, (Davidson & Hughes 1998). The plant's dense and complex root structure encourages sedimentation and helps to stabilise the underlying substratum. This allows seagrass beds to act as natural coastal defence systems and assist in the reduction of coastal erosion (Boyes et al. 2008).

The carbon sequestration importance of seagrass is due to its ability to encourage sedimentation. 'Blue Carbon' is the term given to organic carbon held in the marine system, this is held in the sediments and thus stored in the seagrass bed. If there are few stresses on the seagrass bed and sediments, then organic carbon can be stored and preserved for decades or millennial time scales (Hemminga and Duarte 2000).

1.3 Threats to seagrass beds

Seagrasses are important but also threatened on a global scale with an estimated decline rate of 7% per year globally (Waycott et al. 2009). Human influences affecting the abundance *of Zostera marina* include:

- Land reclamation,
- Nutrient and sediment run-off,
- Physical disturbance (e.g. dredging, bait digging, construction, moorings and anchoring),
- Invasive species e.g. *Sargassum muticum*,
- Pollution

(Davidson & Hughes 1998, Nordlund et al, 2017; Unsworth, 2018.

Nutrient input e.g. effluent and fertiliser run-off is one of the largest threats (Jones et al. 2018). Increased nutrients create more favourable conditions for more opportunistic and faster growing macroalgae and epiphytic algae which can out compete or smother seagrass meadows (Jones 2014). Increases in epiphytic algae and increased water turbidity can also reduce the light absorbed by the seagrass leading to degradation of the seagrass and in turn reduce the resilience of the meadow (Jones 2014).

The population of *Zostera spp.* across the whole of the North Atlantic seaboard was decimated by a wasting disease in the 1930s resulting in the loss of over 90% of seagrass beds by 1932 (see Muehlstein, 1989 for a comprehensive review). Butcher (1934 and 1941) reported 2 distinct periods of deterioration in the UK, one in the early 1920s and the other in the early 1930s. The initial destruction was not noticed until investigations into massive declines in wildfowl populations (Brent geese) in the US. The loss of the seagrass beds had effects across the whole coastal ecosystem, not just on wildfowl. Cottam (1934) reported declines in; clams, lobster, scallops, crab, cod and flounder. The loss of seagrass as an effective breakwater and sediment stabiliser resulted in coastal erosion, an increase in water turbidity and pollution (Cottam and Munro 1954). The cause of this wasting disease was a marine slime mould of the *Labyrinthula* genus (Muehlstein 1989) with possible links to pollution and eutrophication (Hughes et al. 2018). Interestingly the seagrass beds in brackish, low salinity environments were less susceptible to the disease. This event highlighted just how important seagrass beds are to the coastal ecosystem, a lesson that seems to have been forgotten in recent times.

1.4 Review of *Zostera marina* Mapping Studies in North Haven, Skomer, 1946 - 2018

The occurrence of *Z. marina* in North Haven, Skomer was first recorded by Bassindale (1946 and 1950) and subsequently by Hunnam (1976). The extent and density of the *Z. marina* bed in North Haven was unknown. The first mapping studies were completed in 1979, 1980 (Jones and Hodgson 1980) and 1981 (Jones et al. 1983), however the surveys were less intensive than subsequent surveys and so comparison between years is difficult. In 1982 a more detailed method was devised based on a fixed grid area and used a defined abundance scale (Jones et al. 1983), this method formed the basis of the Skomer Marine Nature Reserve (MNR) survey completed in 1997 (Lock 1998).

The method used in 1997 to map the distribution and abundance of *Z. marina* closely followed that used in 1982, which allowed for a comparison to be made. The main change in method was that actual counts of *Z. marina* shoots in a quadrat were made instead of using an abundance scale. This avoided discrepancies between recorders and had the advantage of providing numbers for comparison in future surveys (Lock 1998). The 1997 survey also established fixed corner markers for the survey plot. This method was successfully repeated in 2002. The method was then expanded in 2006 (Lock et al. 2006) and repeated in 2010, 2014 and 2018.

In 1997 a basic map of the *Z. marina* bed boundary was produced using shore-based surveyors taking bearings on the divers' surface marker buoys using digital hand-held compasses. In 2000 a GPS (Geographic Positioning System) unit was used to electronically record the position of the divers and the boundary of the *Z. marina* bed. This has been repeated from 2002 onwards. In 2013 a Biosonics DT-X echo sounder was used to acoustically estimate the coverage of *Z. marina* in North Haven. This method was repeated in 2014 and 2018 and ground-truthed against the diver survey data. In 2018 the *in situ* diver survey was repeated alongside a Biosonics acoustic survey.

1.5 Current Management of *Zostera marina* bed in North Haven, Skomer

***Zostera marina* population**

Z. marina population, due to its conservation importance was selected in 1990 as a management plan feature of the Skomer MNR (now Skomer Marine Conservation Zone (MCZ)). As such it is ascribed "specified limits", which contribute to "performance indicators" used to assess its conservation status (Alexander 2003).

The 1997 mapping results were used to establish "limits of acceptable change" (now referred to as upper and lower specified limits) for the *Z. marina* population at North Haven. These are defined in the Skomer MNR Management Plan 2000 and are as follows:

The extent of the *Z. marina* bed:

Upper Specified limit: No limit set

Lower Specified limit: 5500 m^2 (from 1982 level)

The mean density of the *Z. marina* bed:

Upper Specified limit: No limits set

Lower Specified limit: mean density $^{>}/_{=}$ 36 shoots/ m^2 (from 1997 level as calculated from comparable survey stations see Figure 3.4)

North Haven
North Haven is marked as an anchorage on Admiralty Charts and is the access to the Skomer Island landing. Many boats use the area especially during the summer months; these include yachts, motorboats, dive boats and fishing vessels.

From 1992 onwards "No anchoring" marker buoys, clearly defining the northern edge of the *Z. marina* bed, have been installed as part of management measures designed to protect the bed from damage from anchoring. A number of visitor moorings were established at the same time to the north side of the *Z. marina* bed and their use is encouraged. All vessels are requested to refrain from anchoring southwards of the marker buoys. This information is included in the Skomer MCZ User Regulation leaflet that is distributed by the Marine Conservation Officers during on-water patrol and is available on the NRW website https://www.naturalresources.wales/skomer?lang=en

1.6 Study Objectives

The key objectives of this survey are:

- To determine distribution and abundance of *Z. marina*.
- To map the boundaries of the *Z. marina* bed with *in situ* diver survey and acoustic sonar methods.
- To compare the results with previous surveys.
- To determine if the *Z. marina* bed is within specified limits for conservation assessment.
- Ground-truth acoustic survey methods against *in situ* diver surveys.

2 Methods

2.1 Establishment of Survey Plot

The survey plot used from 2006 onwards was re-established (see Figure 2.1). The fixed locations of the two "No Anchoring" marker buoy moorings, a ring-bolt secured to the Loaf rock and a metal sinker with a sub-surface buoy were relocated. Divers laid seven lead lines for the duration of the survey, two parallel between the markers in the west-east direction forming the south and north lines and one to mark the centre of the plot as shown in Figure 2.2. An east and a west line were laid to form a complete square around the main bed and 2 additional lines were laid parallel to the east and west lines 20 m out (see Figures 2.2 & 2.5). These lines aid navigation and ensure the east and west transects are laid on the correct bearings. The lead lines were marked every 5 m with fluorescent tape and tags marked with the distance along the rope. On completion of the survey, divers retrieved the lead lines and secured the four corner markers as permanent markers for future surveys.

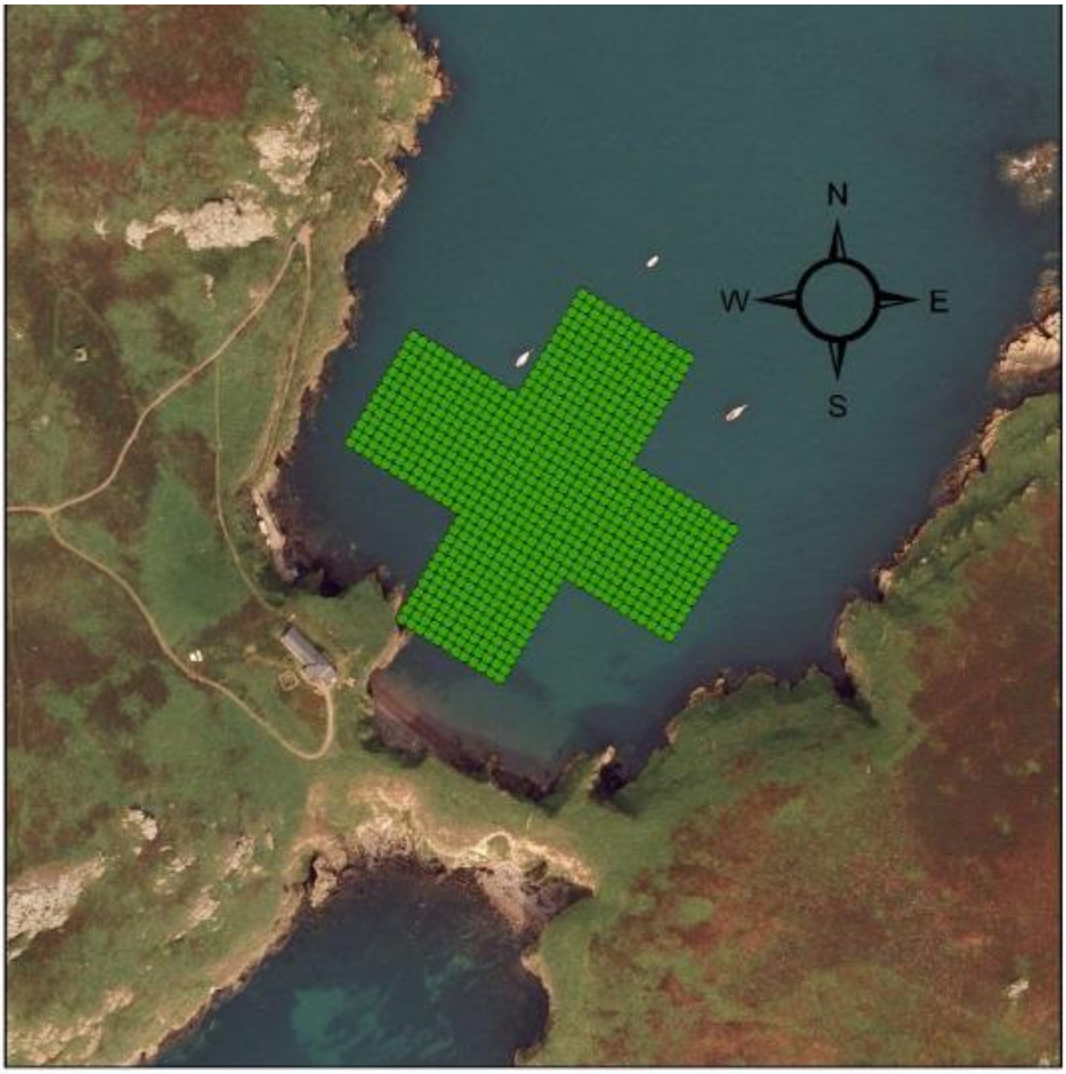


Figure 2.1 Location of North Haven survey grid.

Each green dot is 5 metres apart and represents a sampling station surveyed in 2018.

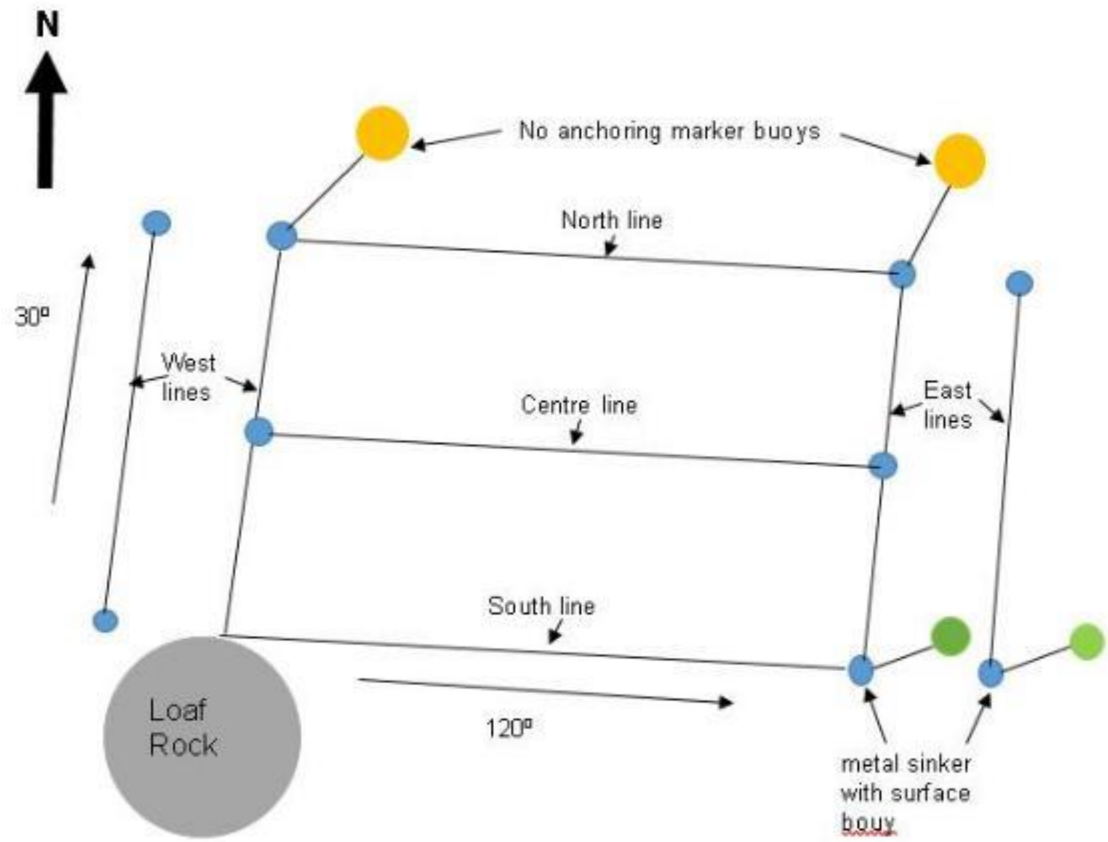


Figure 2.2 Fixed markers and lines marking the *Z. marina* plot, North Haven, Skomer.

2.2 Distribution and Abundance of *Zostera marina* Method

The survey method followed that used in 2006. The recording procedure was as follows:

Example for the 0 m transect line

1. Diver pair secures the end of a 30 m tape measure using a diving weight to the south line 0 m mark. Divers lay the 30 m tape from the south line to the centre line 0 m mark where the end is secured. This is repeated using a second 30 m tape from the centre line 0 m mark to the north line 0 m mark. The tapes thus represent the 0 m transect line of 60 m length as shown in Figure 2.4.

2. Divers swim back along the tapes checking that they have been laid and secured correctly.

3. Diver pair work either side of the tape commencing from the south line at '0 m' on the transect tape (called station 0). Each diver lays a 0.25 m x 0.25 m quadrat 'randomly' next to the station, then counts and records the total number of *Z. marina* shoots within the quadrat. Repeat so that each diver completes 3 quadrats (total of 6 quadrats completed by the diving pair) as shown in Figure 2.4.

Figure 2.3 Divers completing survey

4. On completion, divers move along the transect tape to ‘5 m’, Station 5, and complete quadrat counts. Divers repeat the process at 5 m intervals between each station, Station 10, 15, 20, finishing at Station 60 on the north line.

5. On completion of the transect, divers retrieve the transect tapes and re-lay for the subsequent transect starting at the 5 m mark on the south line for the ‘5 m transect line’.

6. The method is repeated for each transect, working at 5 m intervals along the south line and finishing with the ‘65 m transect’ completing the survey plot.

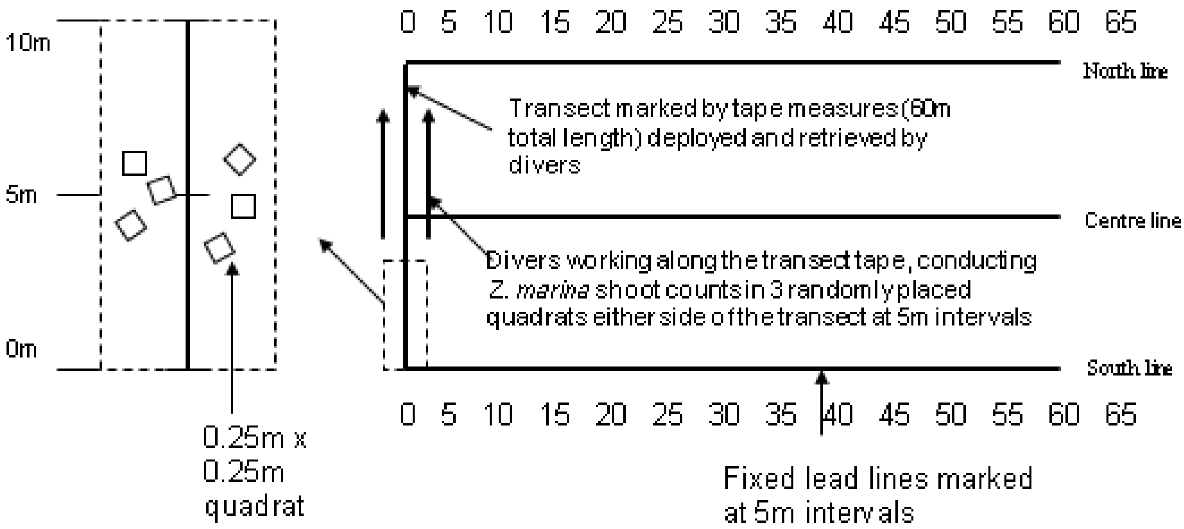


Figure 2.4 Survey methods measuring the abundance of *Z. marina* in the fixed plot area.

On completion of the survey within the central plot area, the distribution and abundance of *Z. marina* outside the plot area was recorded:

7. Two 30 m tapes on reels are laid by divers in place of the ‘0 m transect’ forming the west line and two 30 m tapes laid in place of the ‘65 m transect’ forming the east line, thus completing the sides of the study plot, see Figure 2.5.

8. Divers attach the end of a 30 m tape to the 0 m mark at the corner of the south/west lines, lay the tape out on a bearing of 300° westwards. They will cross the outside line and check that the tape crosses at the correct distance for transect (see Figure 2.5). In 2014 and 2018 the full 60 m East and West was surveyed for each transect (or until unsuitable habitat was encountered).

9. Divers work either side of the tape completing quadrat counts every 5 m along the tape as described in 3 and 4 above until 60 m is reached.

10. On completion, divers retrieve the tape, re-lay and repeat the method at 5 m intervals (*see note below) until all transects from the west line are complete.

11. Divers repeat the method from 7-9 for each direction out from the study plot; the north line working 30° northwards, the east line 120° eastwards and the south line working 210° southwards, as shown in Figure 2.5.

*Note: In 1997 and 2002 tapes were laid at 10 m intervals this was reduced to 5 m intervals from 2006 onwards.

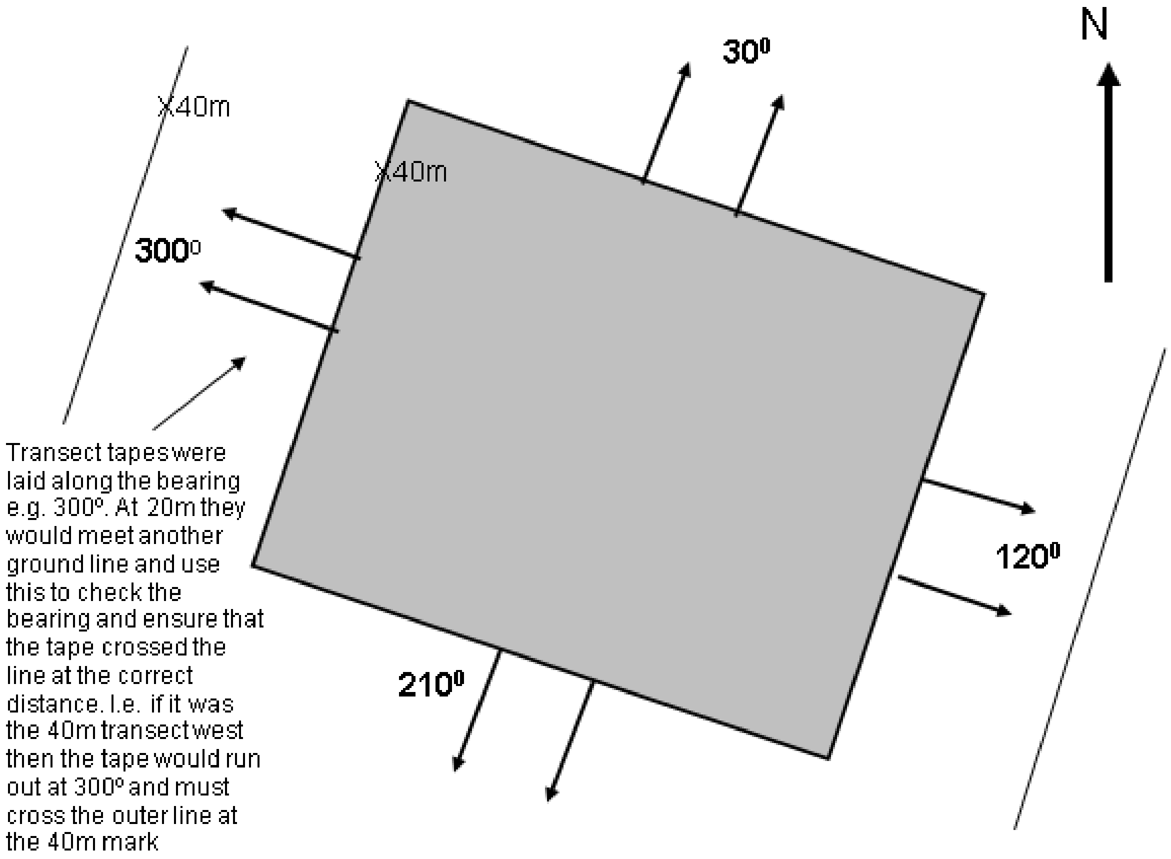


Figure 2.5 Establishing the distribution and abundance of *Z. marina* outside the central plot area.

No outer lines were laid in the north and south directions as transect distances were typically less than 20 m.

3 Results

All transects were completed by a team of volunteer divers over 3 weekends in June and July 2018.

3.1 *Zostera marina* Shoot Density Results, *In situ* Diver Survey

	Mainbed	South	North	East	West	Overall
Mean	69.16	19.75	0.84	52.44	16.00	33.0
std Dev	33.8	43.5	7.3	38.1	26.9	41.5
variance	1140.3	1892.1	53.2	1453.5	722.6	1718.3
Count	182	156	158	156	144	796
STD error 95%	4.91	6.83	1.14	5.98	4.39	2.88
Min	0.0	0.0	0.0	0.0	0.0	0.0
Max	162.0	232.7	74.0	148.0	101.3	232.7

Figure 3.1 2018 Density (shoots / m^2) results.

	Mainbed	South	North	East	West	Overall
Mean	41.09	8.39	2.98	28.08	8.59	18.8
std Dev	18.6	19.7	12.1	26.9	14.0	24.1
variance	344.5	386.2	147.1	721.9	194.8	579.4
Count	182	144	162	156	144	788
STD error 95%	2.70	3.21	1.87	4.22	2.28	1.68
Min	0.0	0.0	0.0	0.0	0.0	0.0
Max	86.7	85.3	82.0	104.7	57.3	104.7

Figure 3.2 2014 Density (shoots / m^2) for comparison.

Compared with 2014, increases in shoot density were recorded at the main bed, the southern section and the eastern and western sections. Decreases (compared with 2014) were recorded in the northern section. Overall the shoot density in 2018 was nearly double that recorded in 2014.

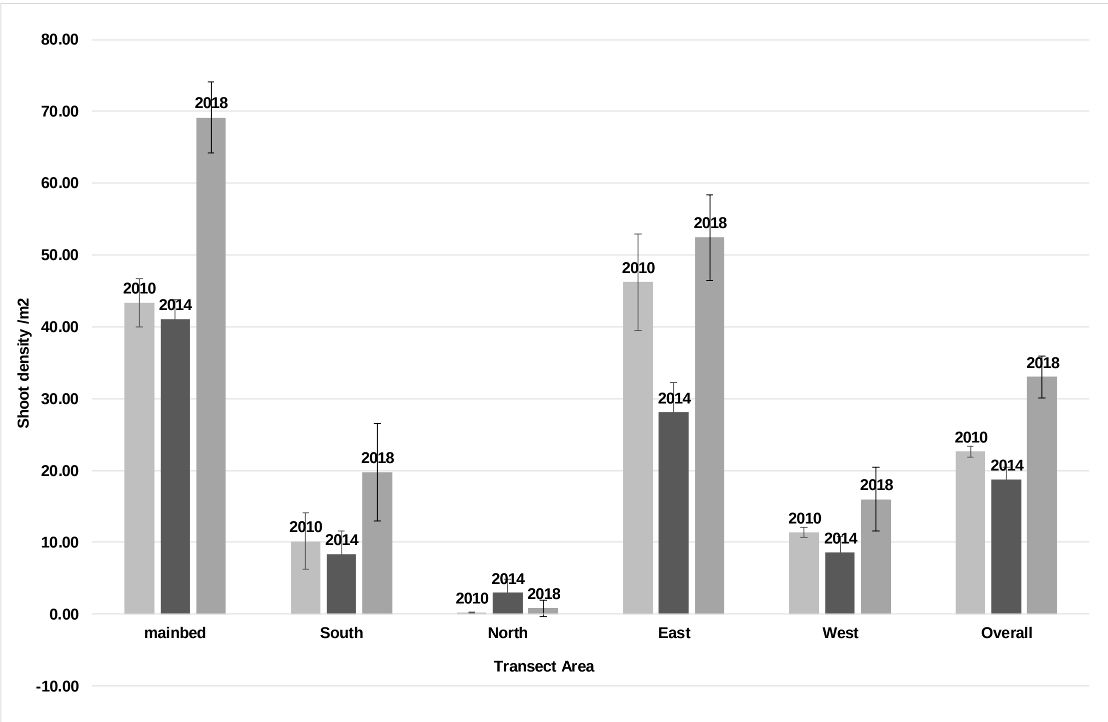


Figure 3.3 Graph comparing 2010, 2014 and 2018 shoot density results (95% S.E. bars).

From Figure 3.3 it can be seen that the main increase in density in 2018 came from the main bed and the east section. The other areas (although lower in 2014) are very similar to densities seen in 2010.

	1997	2002	2006	2010	2014	2018
Mean	**36.2**	**53.6**	**48.0**	**41.1**	**35.1**	**59.2**
Std Dev	27.3	38.5	31.4	30.6	23.3	38.7
Variance	746.0	1478.4	987.8	933.6	544.4	1498.7
95%Std error	3.1	4.4	3.6	3.5	2.7	4.5
n	289	288	289	289	289	289
min	0	0	0	0	0	0
max	104.0	156.0	128.7	182.7	104.7	162.0

Figure 3.4 Comparison of overall shoot density (per m^2) for all years 1997 - 2018
(Only using data from sample stations with replicates in every sampling year)

By selecting sample stations used in 1997 it is possible to make direct comparisons between all the results since 1997. 2018 has the highest shoot density recorded to date. These values are to be used when making the condition assessment for the sea grass feature – Shoot Density.

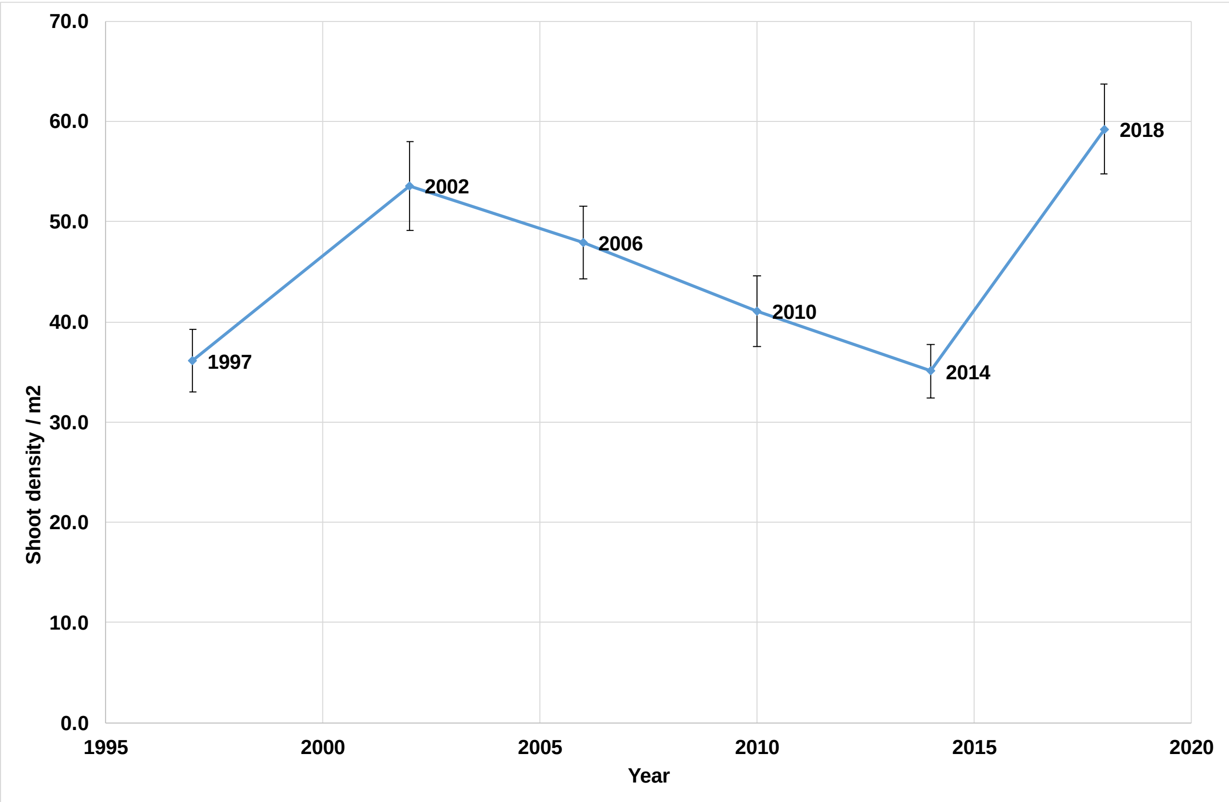


Figure 3.5 Graph of overall shoot density (per m^2) for 1997 – 2018
(Using comparable data from Figure 3.4 - Shown with 95% S.E of mean error bars).

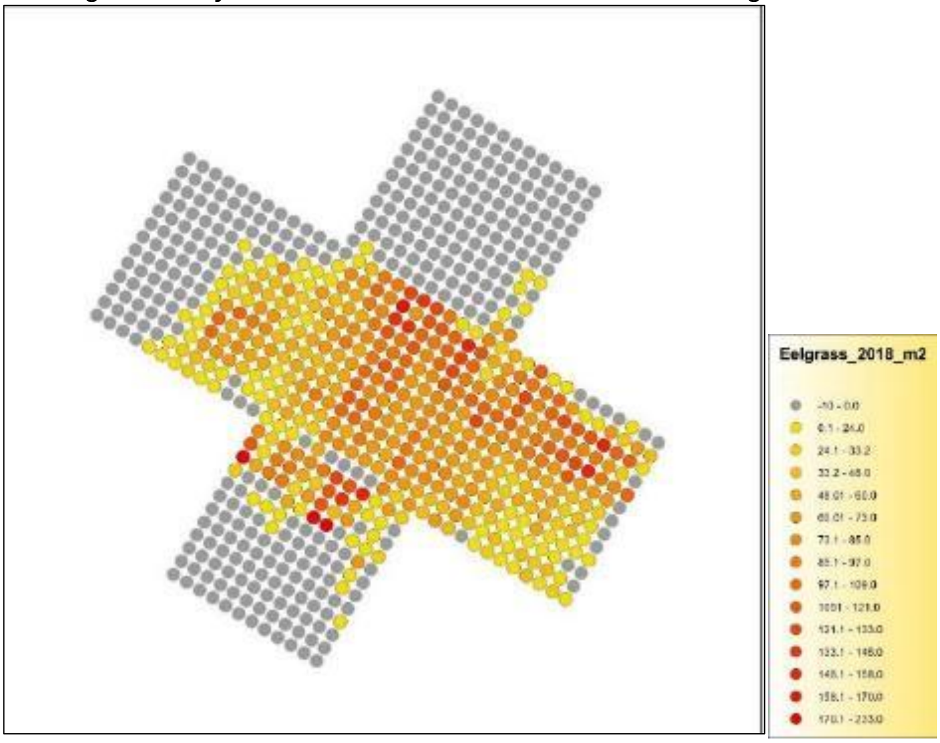
Figure 3.5 highlights the decline in overall shoot density from 2002 - 2014 with a significant increase in 2018.

A one-way ANOVA test between years on (logx+1) transformed data showed a significant difference in shoot density between years P<0.01% with 2018 being significantly higher than 1997, 2010 and 2014.

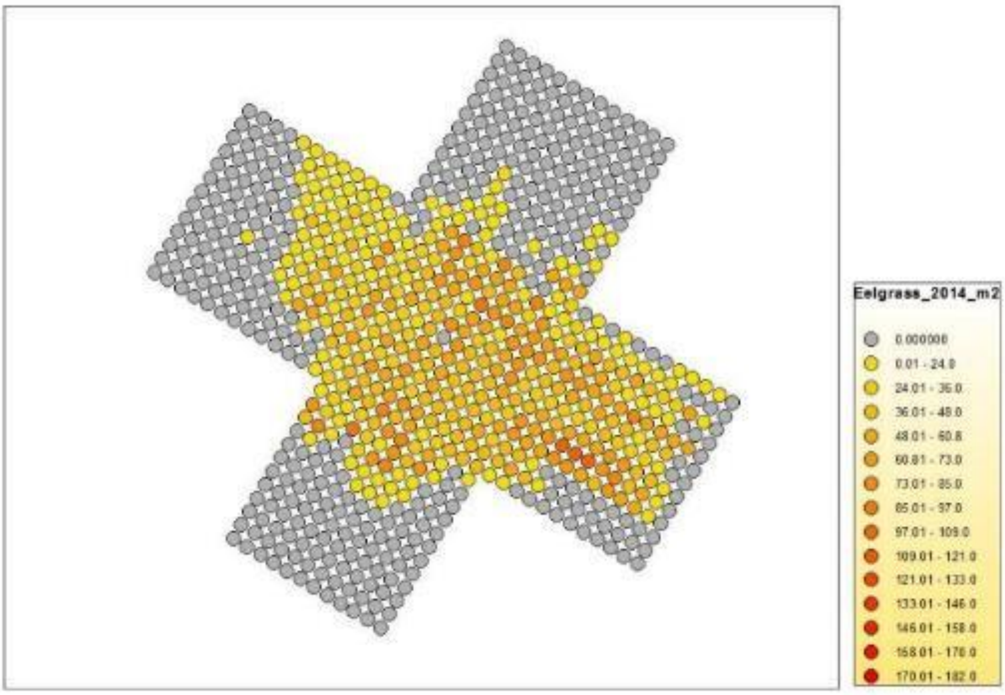
3.2 Spatial Analysis of Shoot Density Using GIS

Position data and mean shoot density from all the sampling stations from every survey year were entered into ArcMap (v10.2.2). Thematic maps were then produced showing the variation in shoot density across the whole seagrass bed for each year.

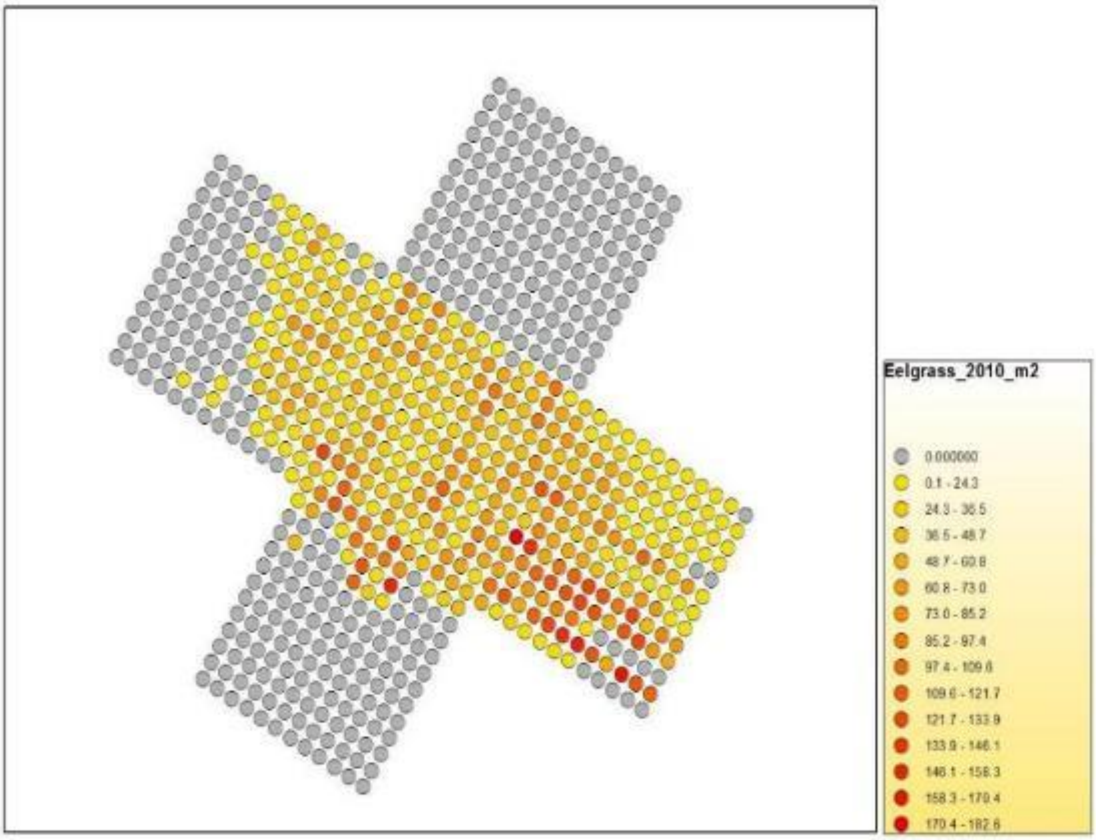
Figure 3.6 Thematic shoot density maps 1997 –2018
See legend: Grey = No shoots. The darker the colour the greater the shoot density.



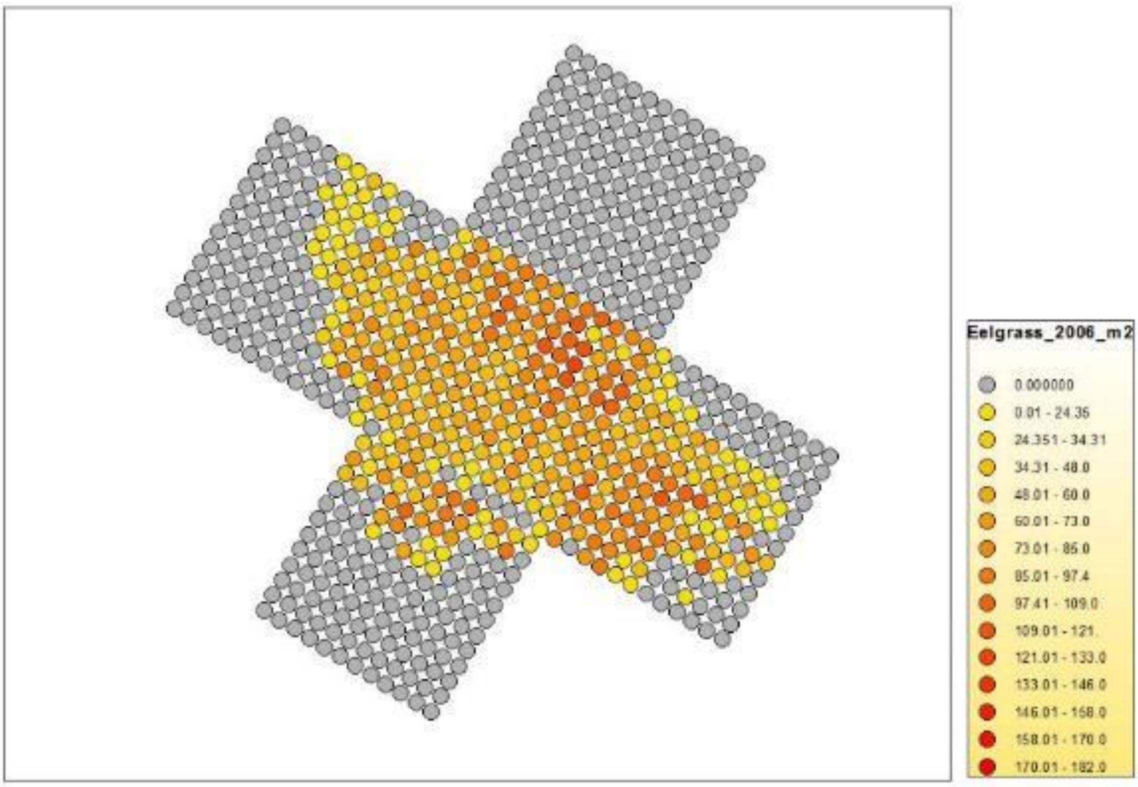
a) 2018 shoot density map (shoots / m^2).



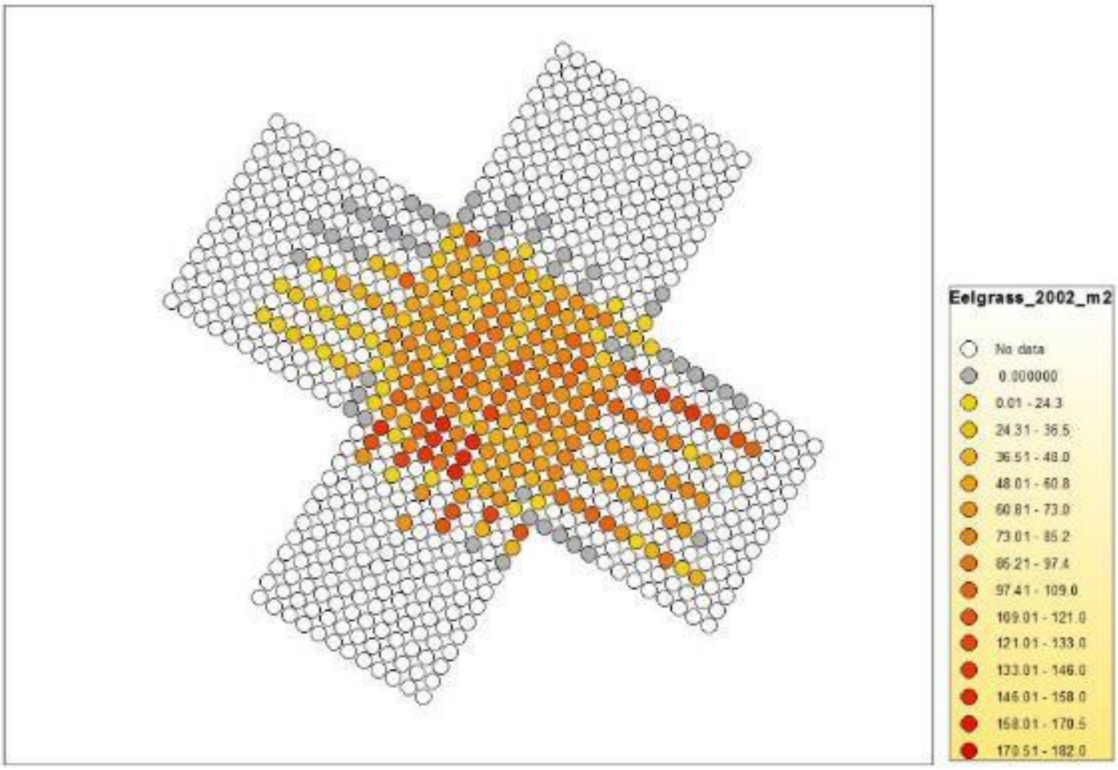
b) 2014 shoot density map (shoots / m^2).



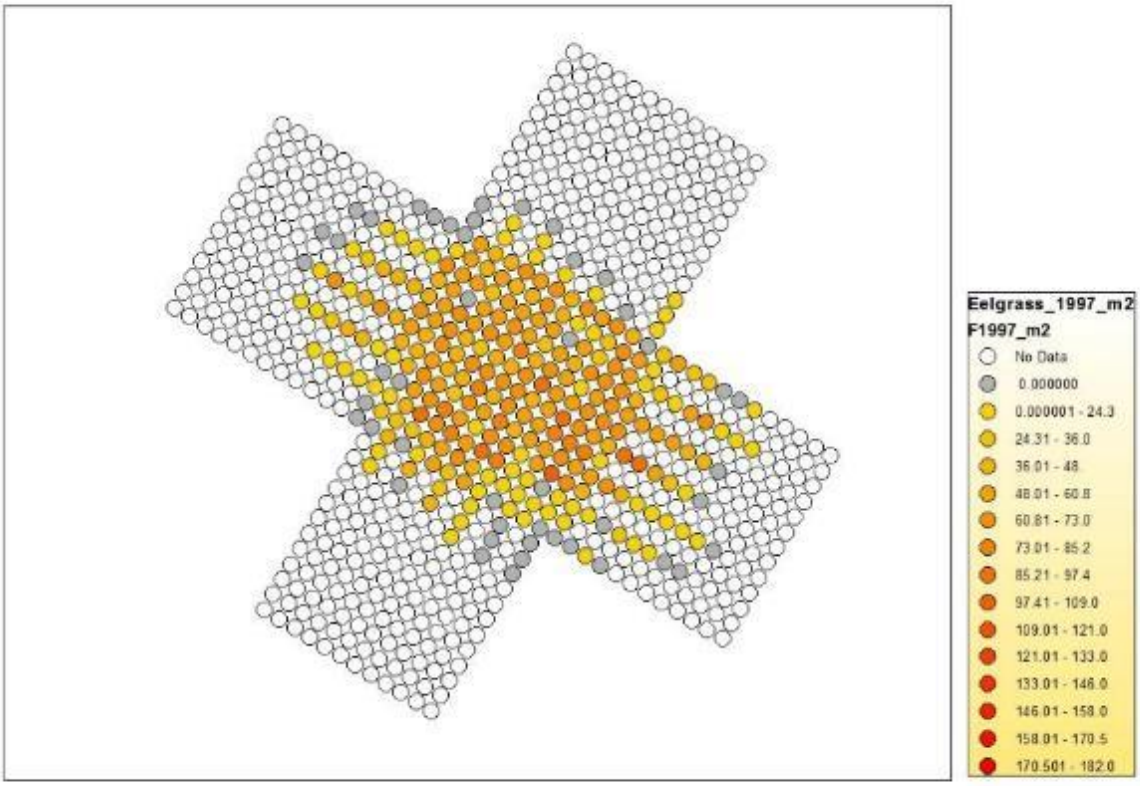
c) 2010 shoot density map (shoots / m^2).



d) 2006 shoot density map (shoots / m^2).



e) 2002 shoot density map (shoots / m^2).
See Legend: white = Not surveyed that year i.e. no data



f) 1997 shoot density map (shoots / m^2).
See Legend: white = Not surveyed that year i.e. no data

Differences between the last 2 surveys (2014 and 2018) can be mapped by plotting a function of; diff = 2018 density – 2014 density. A negative value means a decrease in density in 2018 compared to 2014 see Figure 3.7.

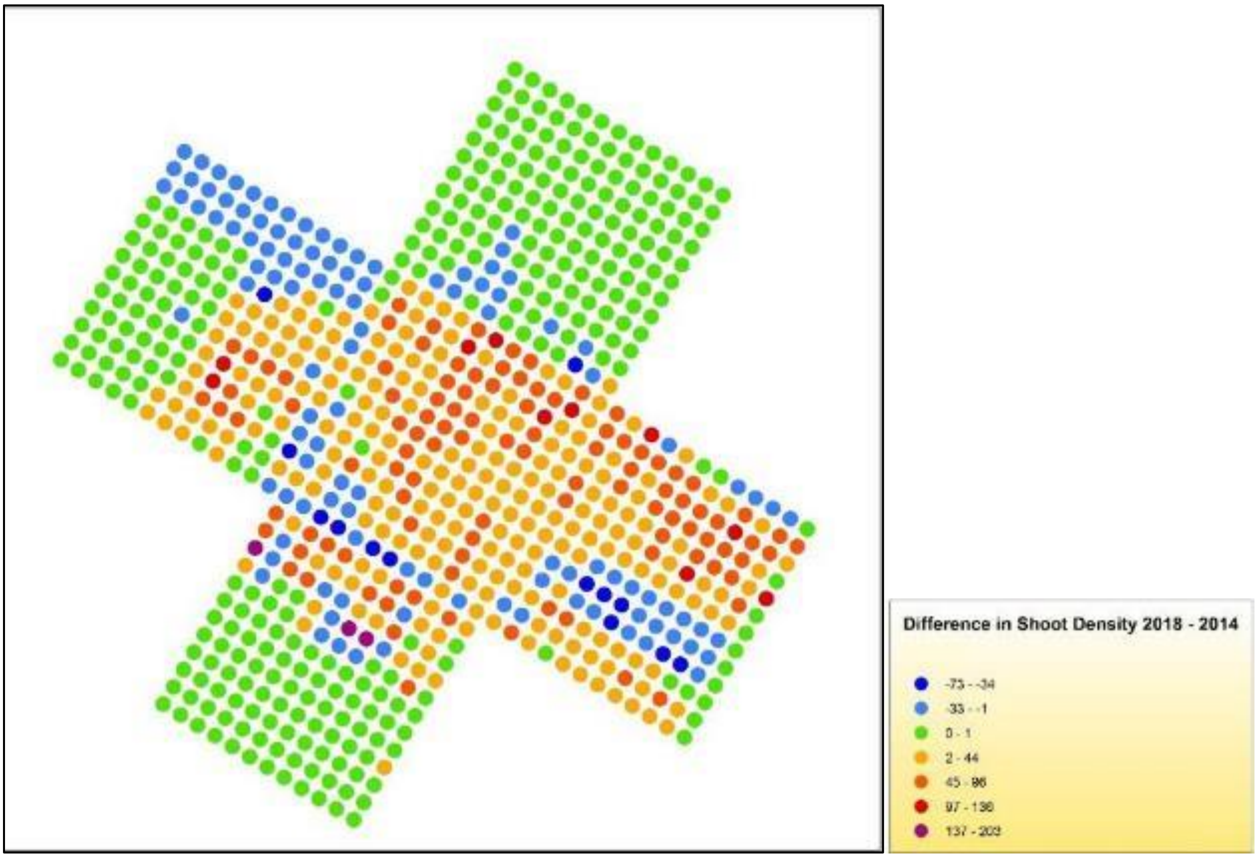


Figure 3.7 Comparison between 2018 and 2014 shoot density data (/m^2).
Blue areas show a decrease in density in 2018, compared with 2014. Red areas show an increase in density in 2018 and green highlights areas of little or no change.

The majority of the main bed has increased in density since 2014. There are 2 main areas of loss in density; the NW corner and a block in the eastern bed. The northern areas of the eastern section and the main bed seemed to have had the greatest increases in density.

3.3 Area of Extent of the *Z. marina* Bed, *In situ* Diver Survey

Since 1997 there have been 3 methods used to estimate the area of extent of the North Haven *Z. marina* bed using the diver survey:

- Diver swims of the boundary, giving a series of GPS waypoints around the edge of the bed. (these were completed in 2000, 2002 and 2004 (see Figure 3.10).
- Polygons drawn in GIS software using the survey grid data. “MapInfo” was used with positions recorded using the WGS84 projection from 1997 to 2010. In 2014 the software was changed to “ArcMap 10.2” and British National Grid was used as the coordinate system. This was used to complete the 2014 map (see Figure 3.8) and used to create the 1997 – 2010 maps for comparison (see Figure 3.9).
- The Biosonics acoustic survey produces an estimate of area covered based on various values of Percent Area Inhabited (PAI). These were conducted in 2015 and 2018.

The area estimates using each method are compared in Figures 3.10 and 3.11.

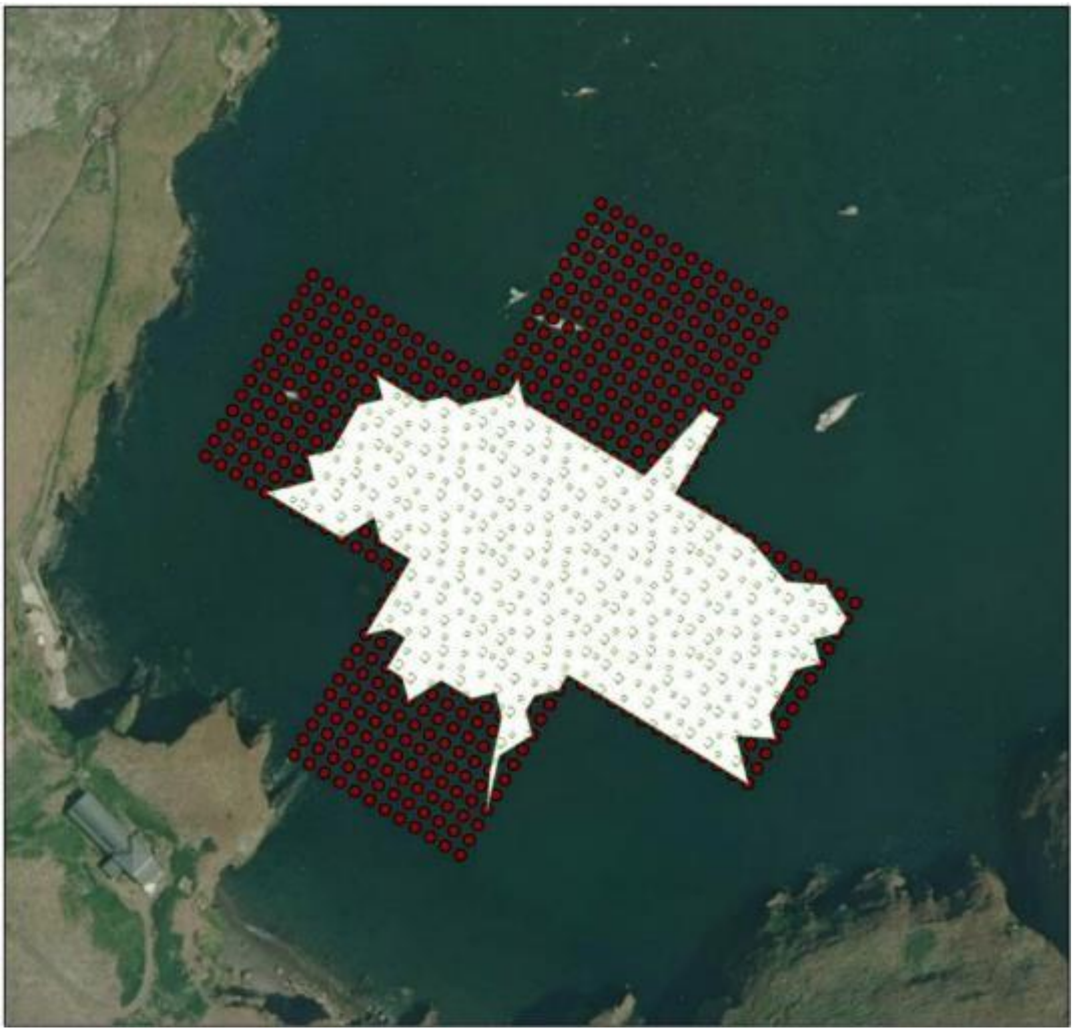


Figure 3.8 2018 area of extent, drawn from 5 m survey grid using ArcMap (v10.2.2).

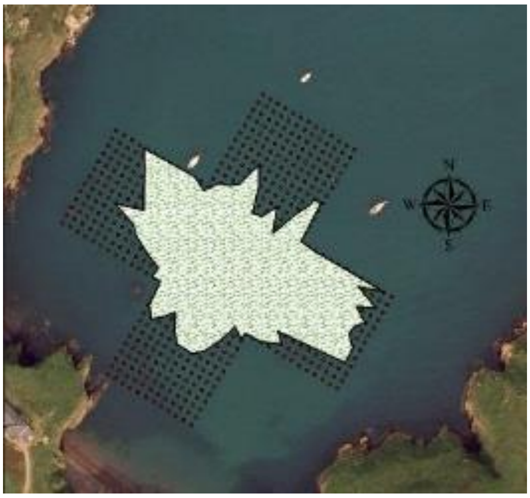
The estimated area, from the 5 m Grid, of the whole *Z. marina* bed in 2018 is **8567.6 m^2** compared to **8224.6m^2** in 2014.

Area of extent 1997

Area of extent 2002

Area of extent 2006

Area of extent 2010



Area of extent 2014

Area of extent 2018

Figure 3.9 Area of extent for 1997 – 2018 from the 5 m grid survey.

Year	Area Estimate m² (from survey grid) MapInfo	Area Estimate m² (from survey grid) ArcGIS	Area Estimate m² (from swim)	Area Estimate (Biosonics acoustic survey 60-70 PAI)
1982	3788			
1997	6333.4	6484.2		
2000	No survey		7007.8	
2002	6569.5	6439.6	7683.20	
2004	No survey		6817.5	
2006	7336.6	7587.2		
2010	7980.6	8044.0		
2013				8290
2014		8224.6		8621
2015				6133
2018		8567.6		8244

Figure 3.10 Estimated area of extent (m^2) 1982 – 2018 all survey methods.

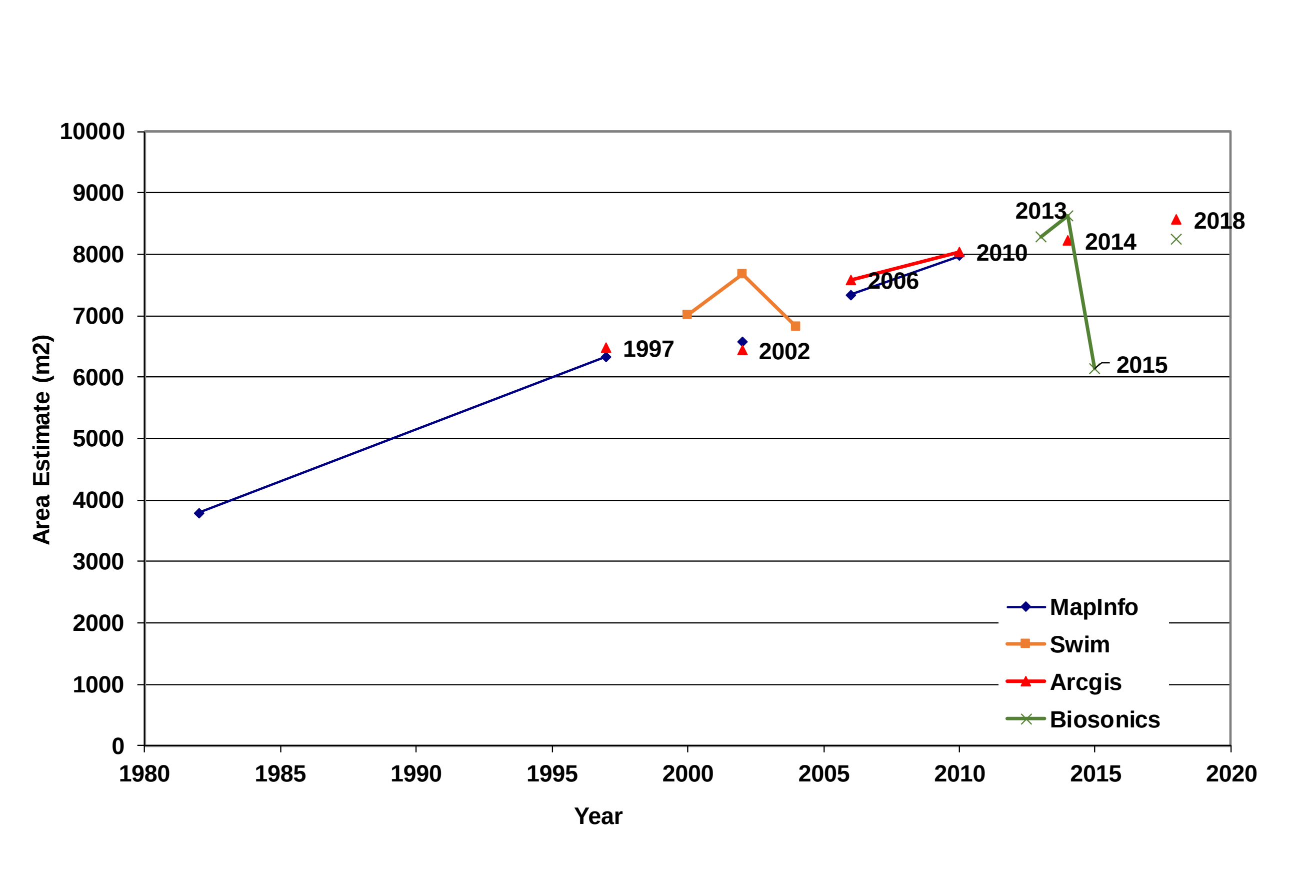


Figure 3.11 Graph of area estimates (m^2).

The two different GIS methods (MapInfo and ArcMap) using two different projections (WGS 84 & British National Grid) give similar results.
The area of extent appears to be increasing and in 2018 the area estimate of 8567.6 m^2 is well above the lower specified limit of 5500 m^2.

To directly compare the boundary of the *Z. marina* bed between surveys, the boundary outline for each survey has been overlaid. Figure 3.12 shows a comparison for surveys from 1997 to 2018, and Figure 3.13 shows the changes between 2014 and 2018.

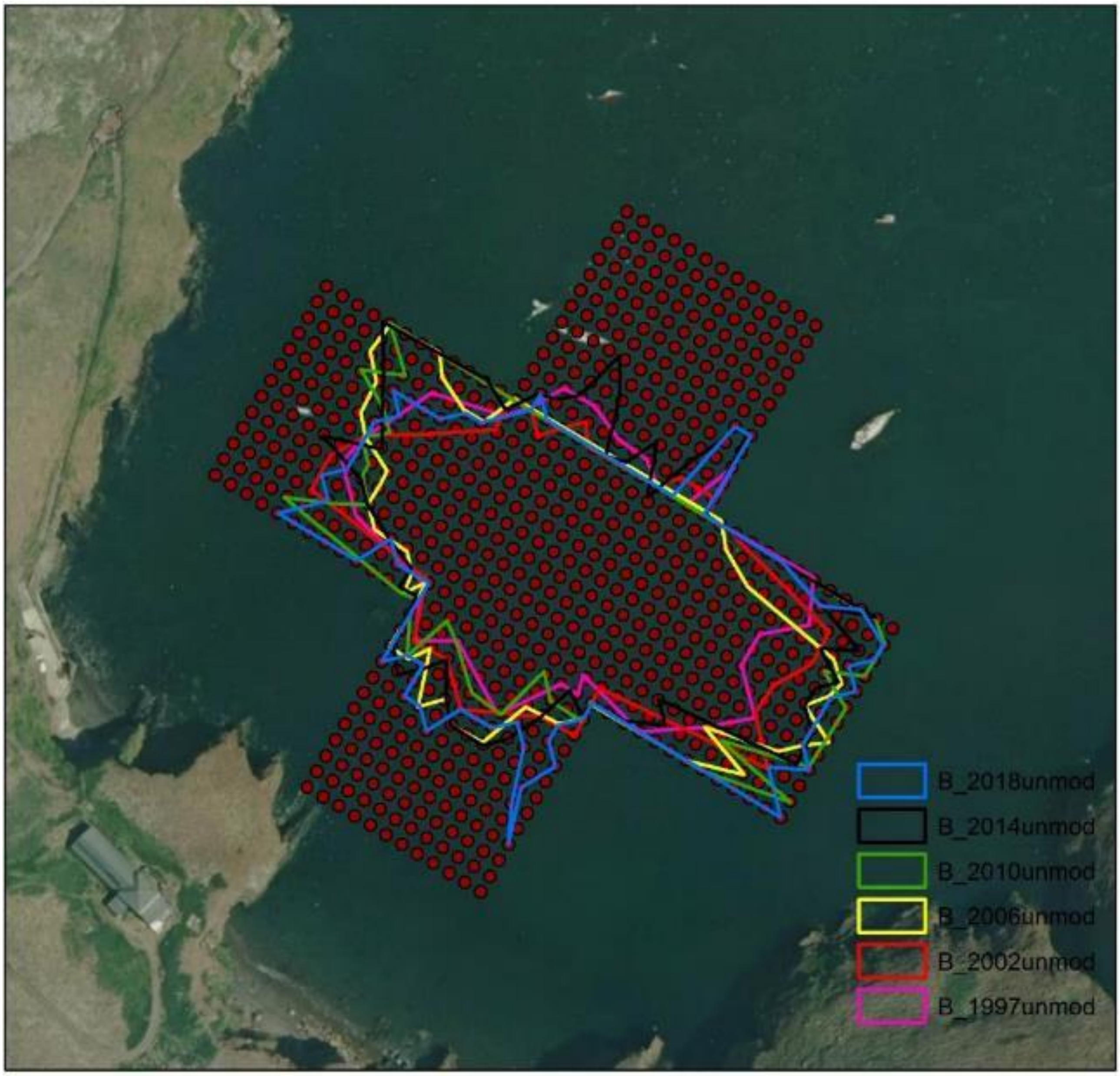


Figure 3.12 Area of extent polygons 1997 – 2018.

The expansion into the eastern area is notably from 2010 onwards otherwise the bed extends over a similar area and it has probably reached the physical limits of available habitat.

Figure 3.13 Area of extent polygon for 2014 and 2018.

Increases in the south eastern areas can be seen in 2018 but there are corresponding losses in the north western area.

3.4 Acoustic Survey Results

The NRW Fisheries assessment team surveyed the North Haven *Z. marina* bed in 2013, 2014, 2015 and 2018 using the same Biosonics DT-X sonar equipment. See Clabburn et al. (2014) for details of methods.

3.4.1 Area of extent

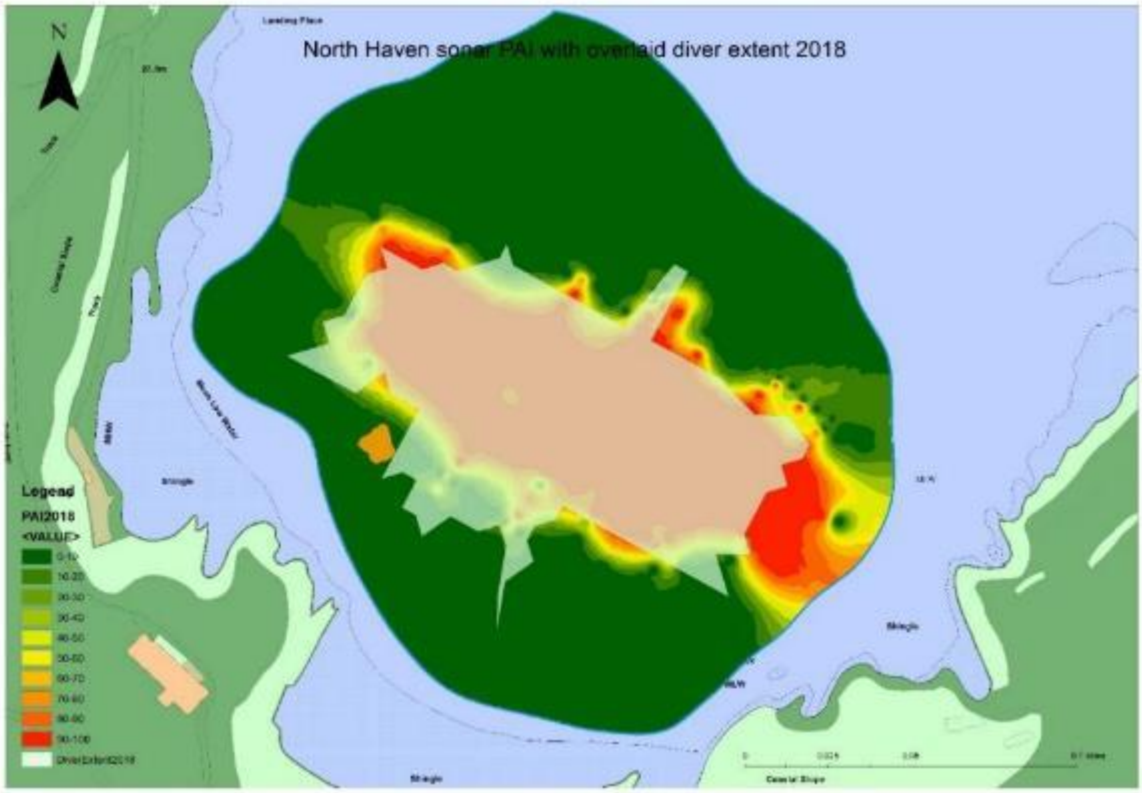


Figure 3.15 2018 Interpolated plot of percentage area inhabited (PAI 0-100%) overlaid with the diver survey estimate.

% Area Inhabited Contour	2013 Area Estimate (m^2)	2014 Area Estimate (m^2)	2015 Area Estimate (m^2)	2018 Area Estimate (m^2)
90	6140.2	6282.1	3833	6086
80	7126.0	7329.4	4910	7004
70	7742.1	8041.8	5572	7589
60	8290.1	8621.1	6133	8244

Figure 3.16 Estimated area of extent from acoustic survey data 2013-2018.

Different cut off (contour) values can be used to set the edge of the *Z. marina* bed, the 60% contour appears to match up best with the *in situ* diver area estimate. In 2015 the area estimate was very low (see Figure 3.17), no *in situ* data was available to confirm this. 2018 survey matches closely to the diver survey with the exception being the south east corner which shows as dense seagrass in the acoustic survey but not in the diver survey.

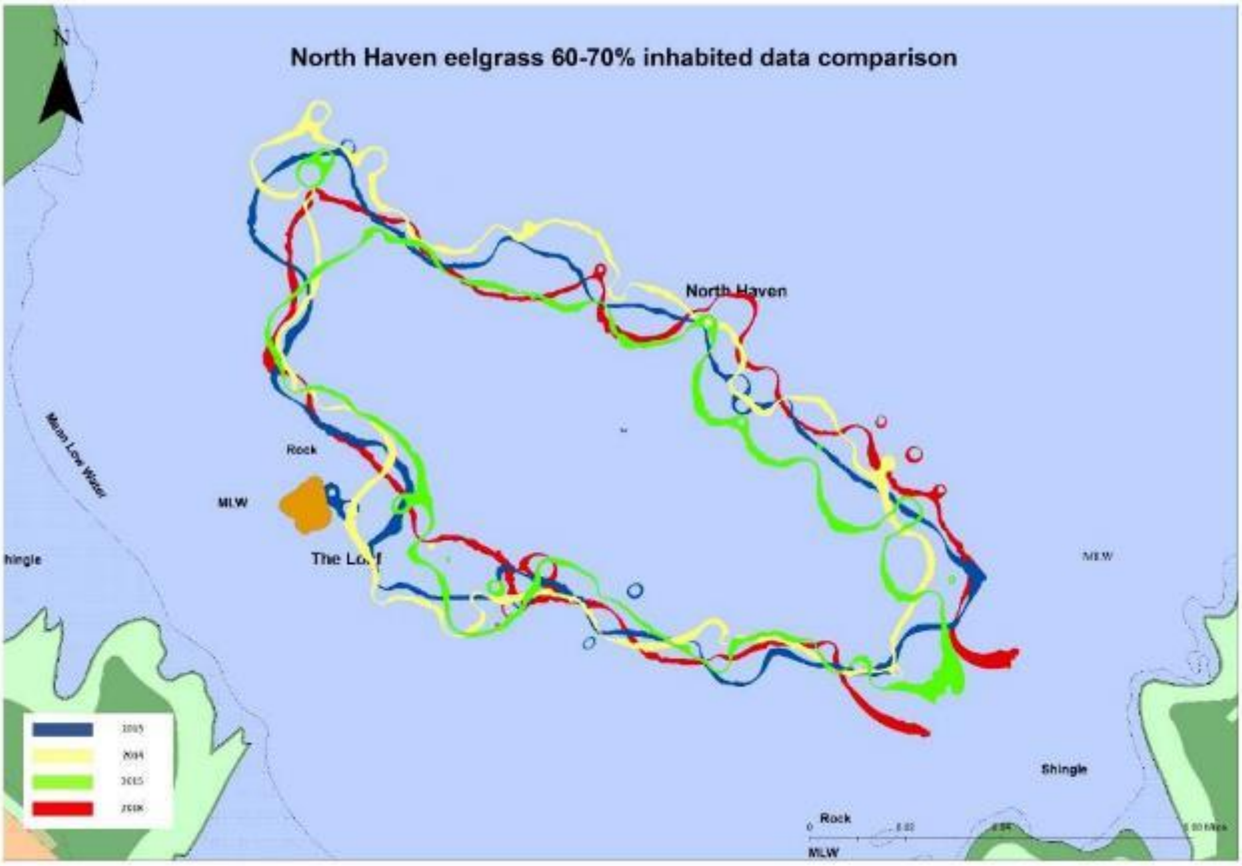


Figure 3.17 Area of extent estimated from Biosonics acoustic survey 2013 – 2018 (using 60-70% area inhabited contour from GIS interpolation).

Apart from being a wonderful piece of modern art, this plot shows the area of extent of *Z. marina* bed detected by the Biosonics acoustic survey based on the 60-70 percent area inhabited contours. This is based on interpolated data and relies on the Sonar 5 Pro software output which can be used to detect where *Z. marina* is based on the acoustic return signal. It gives a consistent picture over the years and it matches up well to the diver survey results, providing confidence in the methodology.

3.4.2 Stand Height of *Z. marina* 2018

The Sonar 5 Pro software also allows the user to estimate “bio-height” from the acoustic data. This measures the height of the *Z. marina* acoustic signal above the seabed which provides an estimate of stand height of the *Z. marina* blades. (See Figure 2.3 for an image of what the seagrass blades look like underwater).

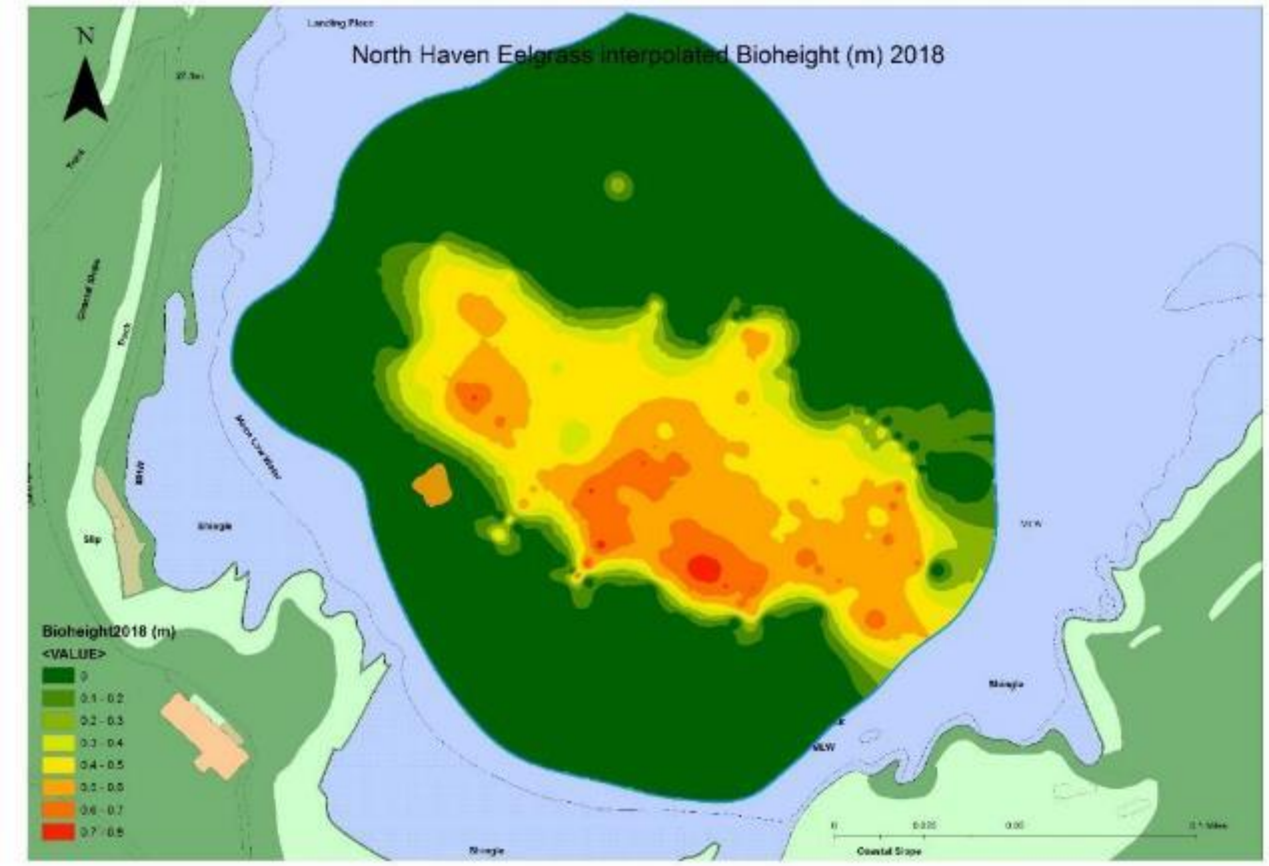


Figure 3.18 Bio- Height (m) of *Z. marina*, 2018.

The values of 70 - 80cm need ground truthing as no physical measurements of stand height were taken during the diver survey. From these results it appears that the seagrass is taller in the shallower (southern) areas.

4 Discussion

4.1 Shoot Density

Shoot density was low in 2014 (18.8 shoots/m^2) but has increased significantly in 2018 (33.0 shoots/m^2). The declining trend has abated, and the bed now has the highest density of shoots ever recorded. The survey conditions were excellent and the general weather patterns of the spring and summer were very calm, hot and sunny alongside good underwater visibility. This may well have given the seagrass some good growing conditions prior to the survey.

Factors affecting shoot density:

- Light availability – high turbidity in the water column above the bed will reduce photosynthetic activity and growth (Olesen et al. 1993 and Unsworth et al. 2014). Turbidity records are regularly taken within the Skomer MCZ (see Figure 4.1). This data shows that the period from 1997 to 2002 was relatively clear. Since then water turbidity has been very variable with poor turbidity in 2004 to 2009, 2012 and 2014. This may account for the declining trend from 2002 - 2014. In 2018 visibility was above average, especially in the period leading up to the survey.

- Photosynthetic Active Radiation (PAR) levels at the seagrass bed. Since 2015 a PAR sensor has been used on a weekly basis to record light levels through the water column over the seagrass bed. The results so far show the attenuation of light through the water column is reasonably constant with; 15% of available light reaching 5m depth (shallow areas of the bed) and only 7% of the available light getting down to 8m depth. Cloudy days with a high tide in the middle of the day will mean very little light is available to the seagrass for photosynthesis.

- Net Radiation and Sunshine Hours. The amount of available light can be estimated from a local weather station 1 km away. The data is consistent back to 2006 and does not show much inter-annual variation (see Figure 4.2). Only having shoot density records every 4 years makes it difficult to correlate to these types of environmental factors.

- Physical damage. This would tend to produce a localised effect. There have been very few instances of anchoring recorded within the bed. The “no anchoring” buoys and the visitor moorings appear to be working.

- Water quality and health of the seagrass. Jones et al. (2018) suggest that high nitrogen and phosphorus loading in the Skomer seagrass could be limiting growth. Burkholder et al. (1992) demonstrated that high nitrogen loads caused a decline in seagrass health, especially in spring. To date, only one set of tissue samples have been taken to look at C:N:P ratios. Jones (2018) suggests using ^{15}N to separate out nitrogen from human and agricultural origins.

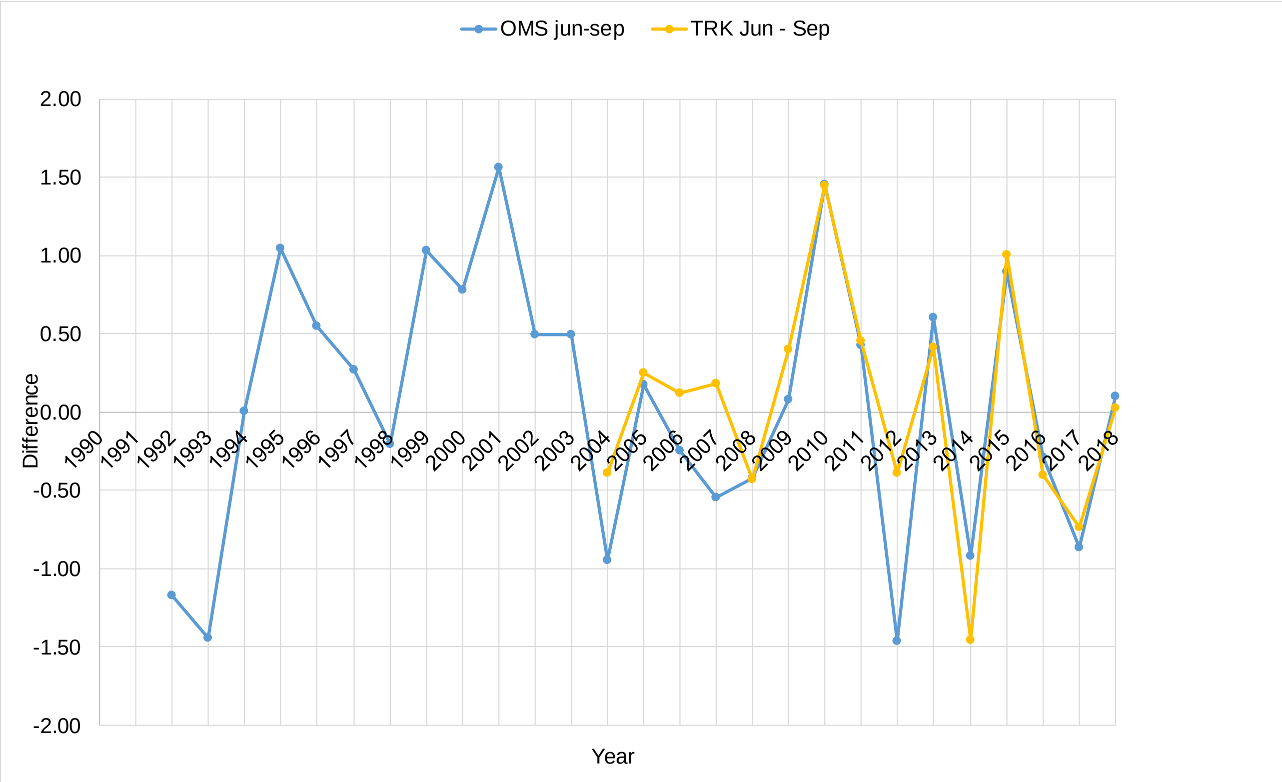


Figure 4.1 Secchi disk data (turbidity) for Skomer MCZ From 2 sites (OMS on the north side of Skomer and TRK on the south side)
Annual Difference from Grand Overall Mean (negative results = cloudy water).

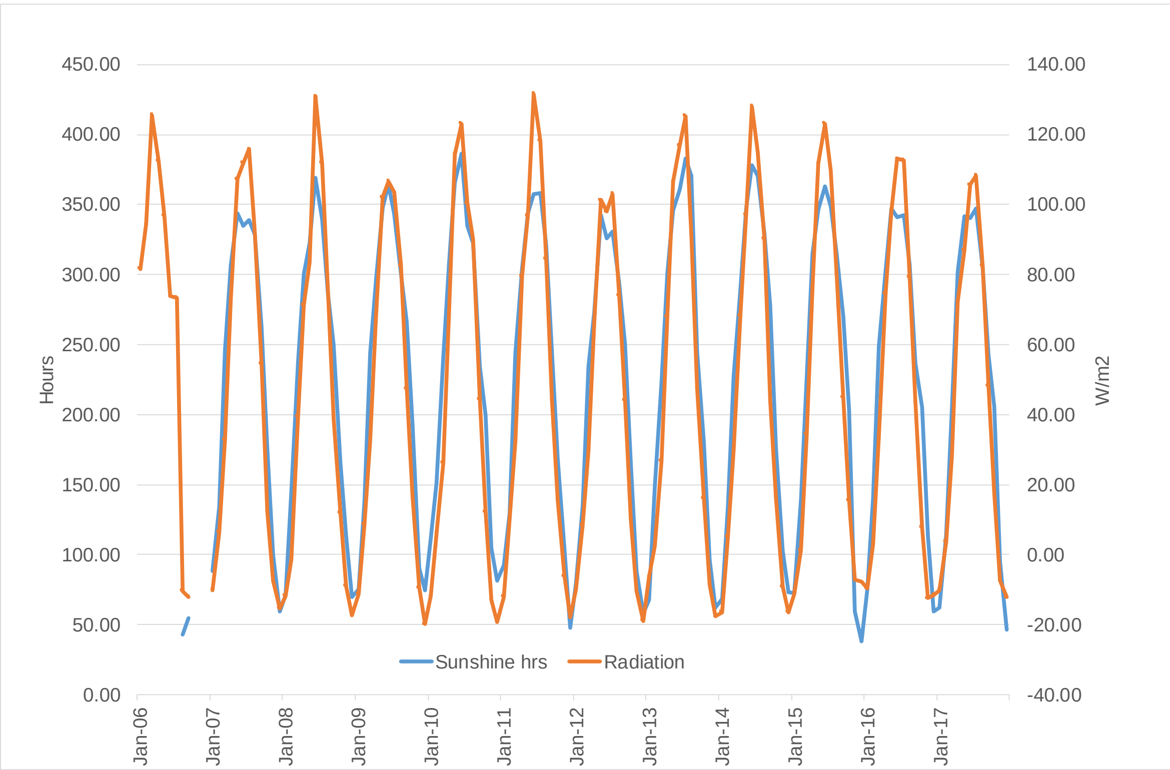


Figure 4.2 Sunshine hours (hrs) and net radiation (watts/m^2) – Wooltack Point weather station.

4.2 Area of Extent

The 2018 estimate of area of extent is the highest of all the survey years. The edges of the bed seem to be dynamic but within the limits of physical space to the south, east and west and the increasing depth (therefore lack of available light) to the north. We can therefore assume the seagrass now occupies most of the suitable habitat (under current environmental conditions) within North Haven.

The Biosonics acoustic method of surveying the estimated area of extent has worked very well and matches very closely to the *in situ* diver survey results. This method is very quick and provides a practical way to get an annual estimate of area of extent. It can also pick up areas outside of the normal survey grid (e.g. to the northeast and northwest) which would not normally be surveyed.

The only area which is consistently different from the diver survey is the south east corner. More diver survey time is needed to confirm if this is an artefact of the interpolation method (could be a change in substrate type of algal cover which mimics the acoustic signal of seagrass) or an area of seagrass that has been consistently missed by the diver survey.

4.3 Acoustic Estimate of Bio Height

The stand height of the seagrass could be a useful output from the Biosonics acoustic survey but there is, as yet, no diver data to test against. The height of the seagrass may vary seasonally and between years, so it would require a diver survey very close to the time of the acoustic survey to ground truth the output. The results suggest that the shallower areas of the seagrass bed have taller blades. This would make sense in that shallow water would attenuate less light, increasing light availability for growth.

4.4 Further Work and Ecosystem Services

4.4.1 Health of the seagrass bed

The current survey methods are fit for purpose in assessing area of extent and shoot density. What is not covered is an assessment of the "health" of the seagrass and what underlying causes may reduce that health. The subject of seagrass health is a little subjective but recent work looking at nitrogen, phosphorus and carbon ratios (Jones et al. 2018) suggests a tested way to assess environmental status and condition. This method involves collecting shoots from the seagrass bed, measuring the shoots' biometrics and analysing for C:N:P content and ratio (it also takes into account shoot density). Jones et al. (2018) suggests looking at the stable isotope ^{15}N as an indicator of where the nitrogen enrichment is coming from. The real power of this study comes from comparing each seagrass bed with results from other beds around the UK and then comparing to the rest of the world.

Results from 2014 samples taken from North Haven, Skomer suggest some reasons for concern (Jones and Unsworth 2018);

- Shoot length, width and biomass were lower than a lot of the sites in the UK, suggesting that growth is limited at Skomer.
- Seagrass at Skomer had some of the highest nitrogen concentrations in the UK.
- Seagrass at Skomer had some of the highest phosphorus concentrations in the UK.

- The C:N ratio at Skomer suggested limited growth, this may be due to light limitation but high nitrogen concentration in *Zostera* can cause carbon to be shunted away from cellulose production into amino acid production (Hughes et al. 2018) which will limit growth.
- Coupled with this is the observation that these UK seagrass beds, in general, have higher nutrient concentrations than those seen in other parts of the world (see Figure 4.3 – "study averages"), which puts the Skomer results in an even poorer light.

location	%C	%N	%P	C:N	N:P	C:P
North Carolina, USA	32.84	1.84	0.22	20.81	18.49	384.94
North Carolina, USA	33.67	1.53	0.25	25.66	13.53	347.31
Virginia, USA	37.50	2.20	0.22	19.88	22.11	439.57
Denmark	38.40	1.92		23.32		
California, USA	38.40	2.37	0.34	18.90	15.41	291.25
South Korea	35.28	2.73		15.09		
Denmark	30.78	1.94		19.44		
Oregon, USA	34.00	2.70	0.40	14.69	14.93	219.20
Oregon, USA	35.00	1.30	0.20	31.40	14.37	451.29
Oregon, USA	29.00	1.40	0.10	24.16	30.96	747.85
various	36.00[a]	2.50[b]	0.39[c]	16.79	14.18	238.04
global average	34.62	2.04	0.27	20.92	18.00	389.93
study averages	47.73	3.58	0.21	16.54	38.9	654.53

[a] Forty-six measurements.
[b] Forty-five measurements.
[c] Thirty-six measurements.

Figure 4.3 *Zostera marina* leaf carbon, nitrogen and phosphorus content (from Jones *et al*. 2018)

Skomer results (from samples taken in 2014) in comparison were: %N - 5.3, %P – 0.36 (Jones *et al.* 2018)

The ^{15}N isotope ratio analysis (Jones et al. 2018) showed that although nitrogen concentrations at Skomer are relatively high the ^{15}N ratio was low. This suggests that the nitrogen inputs into the Skomer seagrass are not from urban sewage or agricultural effluent.

An MSc project (Sleight 2019) on nitrogen and phosphorous content in the soils of Skomer Island showed that the nitrogen levels were up to 4 times higher in Skomer soils compared to the mainland and phosphorous levels were over 10 times higher. The land around North Haven has some of the highest densities of Manx shearwater burrows (see Figure 4.4) so high levels of nitrogen and phosphorous runoff would be expected. The study also investigated the ^{15}N ratio of the soils and found that the Skomer soils had a high (9-16%) ^{15}N ratio which corresponded well to the bird species feathers and prey species. This contradicts the findings of Jones et al. (2018) which found the ^{15}N ratio of the seagrass tissue to be low (~6%). So, it is unclear where the nitrogen enrichment is coming from. Further investigation is needed, currently there is only 1 set of nutrient results for the seagrass at Skomer. Seasonal and annual studies may show trends in the nutrient enrichment.

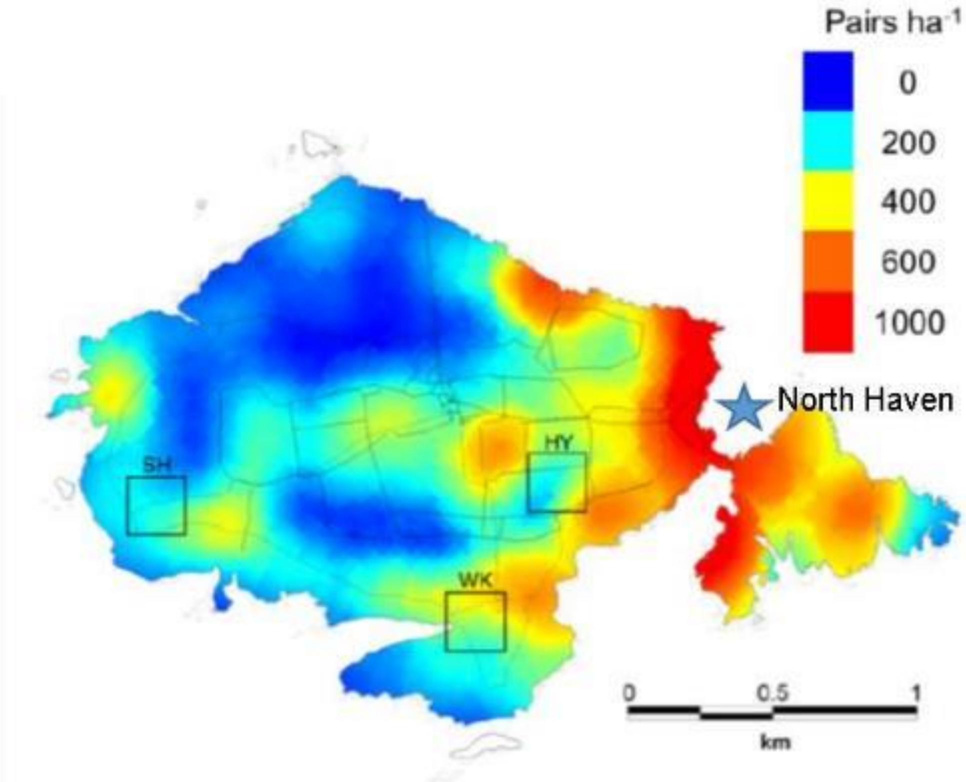


Figure 4.4 Density of Manx shearwater (*Puffinus puffinus*) burrows on Skomer Island. From Sleight (2019).

The comprehensive monitoring programme of the Skomer MCZ means that a lot of other potential underlying causes of reduced seagrass health (e.g. turbidity, available PAR, physical disturbance and wave action) are recorded and could be analysed if needed in the future.

4.4.2 Ecosystem Services Provision

There have been some studies into the biodiversity provided by the seagrass bed in North Haven. Edwards et al. (2003) looked at the epifloral growth on the seagrass at four Welsh seagrass beds. At North Haven, 33 epiphytic algae species using the seagrass were recorded, the highest for the four sites.

Student projects have looked at fish presence using baited, remote underwater camera. Furness (2017) showed that seagrass habitats were important for commercially important fish species such as cod, pollack and flat fish.

The North Haven *Z. marina* survey methods do not measure associated biodiversity directly, but anecdotal evidence from the survey divers shows the seagrass bed is being used by lots of species. Conditions were excellent for the 2018 survey so there was an opportunity to take underwater photographs, a selection of which are shown here to highlight the diversity of species using the seagrass bed (see Figure 4.4).

Other ecosystem services such as carbon sequestration, nutrient recycling, sediment stabilization and pathogen reduction are not currently monitored.

Figure 4.5 Examples of biodiversity from the 2018 survey

1. Juvenile Gadoid (Cod), HC

2. Razor clam, *Ensis sp*. in sediment, HC

3. Snake pipefish, *Entelurus aequreous*, HC

4. Sea Slug, *Polycera quadrilineata,* HC

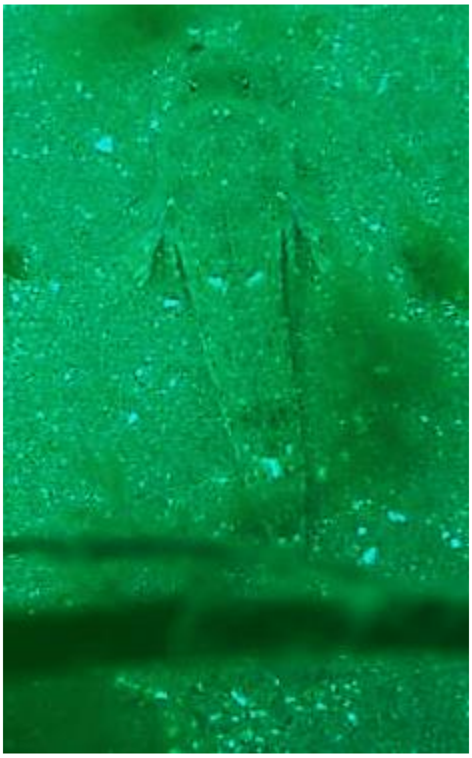
5. Juvenile Flat fish, HC

6. Hermit Crab, *Pagurus bernhardus*, KLe

7. Spider crab, *Maja brachydactyla*, VH

8. Sea hare, *Aplysia punctata*, KLe

9. Tub gurnard, *Chelidonichthys lucernus*, AL



10. Dragonet, *Callionymus lyra*, HF

4.5 Current Management of *Zostera marina* bed in North Haven, Skomer

The Skomer MCZ management plan objectives for the population of *Z. marina* in North Haven as outlined in Section 1.5 is to maintain it in favourable condition where:

The extent of the *Z. marina* bed:

Upper Specified limit: No limit set

Lower Specified limit: 5500 m^2 (from 1982 level)

In 2018 the extent is **8567.6 m^2** and is therefore in favourable condition.

The mean density of the *Z. marina* bed:

Upper Specified limit: No limits set

Lower Specified limit: comparable mean density $^{>}/_{=}$ 36 shoots/ m^2 (from 1997 level)

In 2018 the comparable mean density is **59.2 shots /m^2** and is therefore in favourable condition.

5. Conclusion

The Skomer MCZ management plan targets for the population of *Z. marina* in North Haven for both extent and shoot density have been met and the feature is in favourable condition.

The four-yearly *Z. marina* distribution and abundance survey using volunteer divers has provided valuable and cost-effective data for the Skomer MCZ.

NRW Fisheries Assessment Team conducted repeat surveys using a Biosonics DT-X split beam echo sounder in between 2013 - 2018. The diver survey results compare well against the Biosonics acoustic surveys. The remote acoustic method provides an efficient alternative to the diver survey for getting annual results for area of extent.

The 2018 results are very encouraging but other studies (Jones et al. 2018) show evidence that the health of the seagrass at Skomer may be limiting growth. Further work is therefore needed to investigate the impacts and causes of nutrient inputs on the Skomer seagrass.

The Skomer MCZ is within the Pembrokeshire Marine Special Area of Conservation (SAC) and data collected here is used to help assess the condition of features of the SAC. The North Haven *Zostera marina* bed data is applicable to some of the attributes of Favourable Conservation Status of the Large Shallow Inlet and Bay's feature.
Examples are shown in the table below:

Favourable Conservation Status Statement	**Attibute**	**Measure**	**Target**
RANGE: Distribution and extent of Large Shallow Inlets and Bays within the site is stable or increasing	**Distribution** of encompassed features	Conservation status of distribution attributes of encompassed habitats and habitat features within the LSI&B feature (i.e. the distribution attributes of features within LSI& B need to be met for this attribute to be favourable)	Favourable

Distribution and extent as above	**Extent** of encompassed features	Conservation status of extent attributes of encompassed habitats and habitat features within the LSI&B feature (i.e. the distribution attributes of features within LSI& B need to be met for this attribute to be favourable)	Favourable. i.e. the encompassed features need to be in favourable condition for the LSI&B feature to be favourable
FUNCTION: Nutrients in the water column and sediments to be: - at or below existing statutory guideline concentrations, - within range that are not potentially detrimental to the long term maintenance of Large Shallow Inlets and Bays species populations, their abundance and range	Community composition (from biological monitoring)	Evidence of community composition indicative of elevated levels of Dissolved Available Inorganic Nitrogen (DAIN) &/or Dissolved Available Inorganic Phosphorus (DAIP) (*i.e.* hypertrophic / eutrophic); indicated by univariate and multivariate analytical techniques.	No evidence that community composition indicates elevated levels of nutrients.
TYPICAL SPECIES: The physiological health, reproductive capacity and recruitment of typical species of Large Shallow Inlets and Bays are determined by natural biotic and abiotic factors that are not degraded	Detrimental physiological stress	For seagrass: - epibiota burden - shoot density	*No target – surveillance (pending development of suitable monitoring targets)*

There are also measures for water clarity and light that have previously had ‘depth of brown algae’, from NRW monitoring, as measures. Depth of seagrass would be a useful measure to include in assessments in the future.

The targets relating to range have been met for seagrass in the Skomer MCZ. The ‘Function and Typical species targets’ (relating to evidence of community composition indicating high nutrient levels and to detrimental physiological stress) need further investigation.

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6. Recommendations

- Continue the 4 yearly *in situ* volunteer diver survey and maintain the continuity of data.

- The current monitoring target for the lower specified limit is set from the 1997 survey. The methods have changed since 2006 and the survey now has a more comprehensive coverage of the whole area of suitable habitat. In order to get a value for the current shoot density a subset of survey points are used which match to the 1997 survey (see Fig 3.4). These survey points are mainly in the densest part of the seagrass bed and therefore give artificially high shoot density results when compared with density values that encompass the whole area of suitable habitat. Therefore:

  Amend the lower specified limit for *Z. marina* mean density in the Skomer MCZ management plan. New limits to be set based on the survey data points used since 2006 and the lower limit set from results in the 2014 survey (lowest density since 2006). These would be as follows:

    The mean density of the *Z. marina* bed:
    Upper Specified limit: No limits set
    Lower Specified limit: comparable mean density $^{>}/_{=}$ 35.1 shoots/ m^2 (from 2014 level)

- Continue with an annual acoustic survey of the eelgrass bed for area of extent and Check the boundary areas of the bed with a drop down video to confirm acoustic results.

- Ground-truth the bio-height results from the acoustic survey with *in situ* records.

- Develop a project to monitor shoot density, plant health and surveillance of environmental factors to allow some conclusions to be drawn about changes in shoot density. Ideally this would be an annual survey.

- Link in with other research and monitoring projects for eelgrass around Wales and the UK (see Unsworth et al. 2014).

- Start monitoring C: N, ^{15}N and C:P ratios along with measurements of leaf biometrics.

7. Acknowledgements

Peter Clabburn and the NRW Fisheries Assessment Team.

Brian Dilly and Tim Smith-Gosling at SOAS dive boat charter.

Photo contributors: Hayden Close (HC), Vicki Howe (VH), Kerry Lewis (KLe), Chiara Bertelli (CB), Howard Fortescue (HF) and Annette Lister (AL).

Volunteer divers: Kerry Lewis, Lucy Philips, Steve Bounds, Stephanie Eccles, Hayden Close, Rob Gibbs, Mark Barnard, Howard Fortescue, Chiara Bertelli, Max Robinson, Louise Bebb, Erin Smyth-Evans, Annette Lister, Mick Baross, Matt Walters, Matt Green, Sam Rees, Hayley Glanville, Paula Young, Vicki Howe, Katheryn Last, Stuart Last, Rich Grice, Paul Gray, David Wharf, Huw Roberts, Martin Saunders, Francis Milton.

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Published by:
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Cambria House
29 Newport Road
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