Cyfoeth Naturiol Cymru
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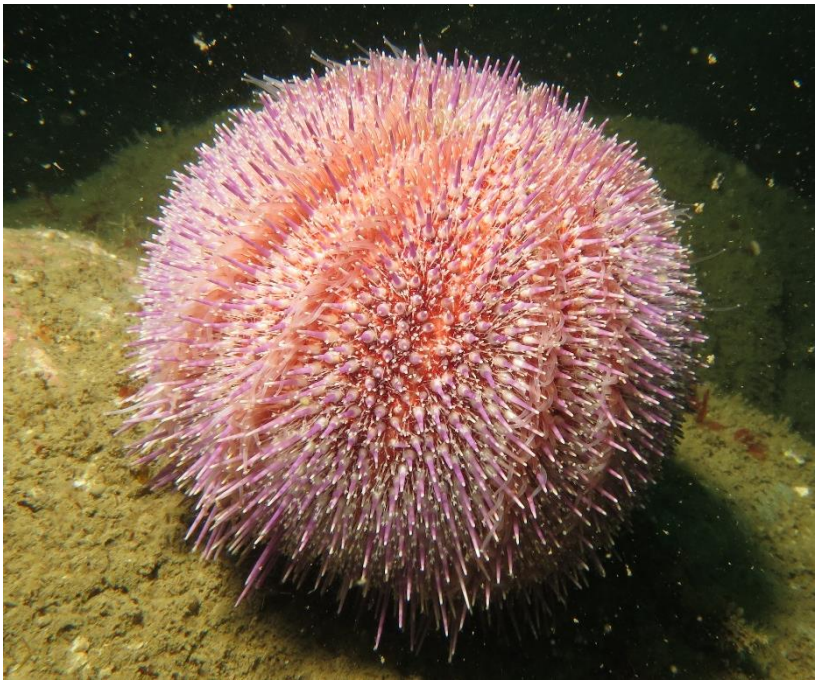
Skomer Marine Conservation Zone Distribution and abundance of *Echinus esculentus* and selected starfish species 2015

M. Burton, K. Lock, J. Jones
& P. Newman

NRW Evidence Report No.158



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Report Distribution

Skomer Marine Conservation Zone Distribution and Abundance of *Echinus esculentus* and selected starfish species 2015
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Synopsis

Echinus esculentus plays a key role in the structure of subtidal communities. Large numbers were removed from Skomer MCZ during the 1970s when divers targeted the population for the curio trade. Population surveys were completed in 1979 and 1982, but no repeat surveys were completed until 2003, when data was collected to establish the status of both the *E. esculentus* population and conspicuous starfish species. In 2007 fixed surveys sites were established for use in future surveys and to allow data to be directly comparable. These sites were resurveyed in 2011 and on this survey in 2015.

The survey was completed over 4 days by a team of 29 volunteer divers. *E. esculentus* were counted along 30m transects at different depth zones and the diameter of each *E. esculentus* measured. *Marthasterias glacialis*, *Crossaster papposus* and *Luidia ciliaris* were also counted along these transects. The study sites were selected from the north and south coasts of the island and the north coast of the mainland. The mean densities of *E. esculentus* and *M. glacialis* were 9.7 and 2.2 per $100m^2$ respectively for the whole MCZ, but density varied between sites. A normal size frequency distribution for *E. esculentus* was found and the mean size of *E. esculentus* was found to be smaller in the 5m depth zone.

Plankton samples collected from March to November identified Echinoderm ophiopluteus larvae in samples, with abundance peaking in August. Identification could not be made to species level, therefore presence of *E. esculentus* larvae could not be confirmed.

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Crynodeb

Mae *Echinus esculentus* yn rhan hollbwysig o strwythur cymunedau islanwol. Symudwyd nifer fawr ohonynt o Barth Cadwraeth Morol Sgomer yn ystod y 1970au pan aeth deifars ati i dargedu'r boblogaeth ar gyfer y fasnach creiriau. Cynhaliwyd arolygon ar y boblogaeth yn 1979 ac 1982, ond ni chynhaliwyd arolygon wedyn tan 2003, pan gasglwyd data ar gyfer pennu statws y boblogaeth *E. esculentus* a'r rhywogaethau sêr môr amlwg. Yn 2007 pennwyd safleoedd arolygu sefydlog ar gyfer eu defnyddio mewn arolygon yn y dyfodol, a hefyd er mwyn gallu cymharu'r data'n uniongyrchol. Ailarolygwyd y safleoedd hyn yn 2011 ac yn ystod yr arolwg hwn yn 2015.

Cwblhawyd yr arolwg dros gyfnod o bedwar diwrnod gan dîm o 29 o ddeifars gwirfoddol. Cafodd *E. esculentus* eu cyfrif ar hyd trawsluniau mewn parthau o wahanol ddyfnder a mesurwyd diamedr pob *E. esculentus*. Ymhellach, cafodd *Marthasterias glacialis*, *Crossaster papposus* a *Luidia ciliaris* eu cyfrif ar hyd y trawsluniau hyn. Cafodd safleoedd yr astudiaeth eu dewis ar arfordir gogleddol a deheuol yr ynys ac ar arfordir gogleddol y tir mawr. Dwysedd cymedrig *E. esculentus* ac *M. glacialis* oedd 9.7 a 2.2 fesul 100m^2 ar gyfer y Parth Cadwraeth Morol i gyd, ond roedd y dwysedd yn amrywio o safle i safle. Daethpwyd o hyd i ddosbarthiad amlder maint arferol ar gyfer *E. esculentus* a gwelwyd bod maint cymedrig *E. esculentus* yn llai yn y parth dyfnder 5m.

Yn y samplau o blancton a gasglwyd rhwng Mawrth a Thachwedd gwelwyd larfâu *Echinoderm ophiopluteus* yn y samplau, gyda'r niferoedd yn cyrraedd eu huchaf yn ystod mis Awst. Ni ellid adnabod yr union rywogaeth, felly ni ellid cadarnhau presenoldeb *E. esculentus*.

1 Introduction

1.1 *Echinus esculentus* Surveys in the Skomer Marine Conservation Zone (MCZ)

Echinus esculentus Linnaeus (1758) is an omnivorous grazer and a key biological structuring factor in subtidal communities. The grazing clears space making it available for colonisation by other species. In low numbers this grazing effect is beneficial; in high numbers it can be highly destructive even destroying whole kelp forests (Hagan, 1983).

During the 1970s divers targeted the Skomer population for the curio trade and large numbers were removed. The Underwater Conservation Programme carried out the first survey of the *Echinus esculentus* population in Skomer waters in 1978 (Nichols, 1979). The results of the 1978 survey prompted a similar survey in 1981 by the Underwater Conservation Society (Bishop, 1982). Bishop (1982) reported that mean densities of *E. esculentus* of 5.5 per 100m^2 for Skomer in 1981 were not significantly different from densities in a commercially exploited population in Lamorna Cove, Devon. Densities were also significantly lower than those of other non-exploited localities around the UK.

In 2003 the first *E. esculentus* survey since the designation in 1990 of the Skomer Marine Nature Reserve (now Skomer MCZ) was completed. The aim was to establish the current status of the population, including distribution, abundance, density and size frequency. Visual census conducted using standard SCUBA equipment and belt transects was selected as the most appropriate method. The method was designed for use with volunteer divers and is fully described in Luddington *et al* (2004). Study sites were selected from general areas along the north and south coasts of the island and the north coast of the mainland. The range of sites allowed all habitats and depths where *E. esculentus* are found in the Reserve to be surveyed.

In 2007 the survey was completed following the 2003 methods and established fixed survey sites using Geographic Positioning System (GPS) that can be used in future surveys. The 2003 method was reviewed and changes to allow improved size measuring techniques, habitat recording of sites and comparison between surveys. The survey method is fully described in Lock *et al* (2008) and was used again in 2011.

The recording of ‘bald’ *E. esculentus* also began in 2007and continued in 2011. *E. esculentus* with ‘bald’ patches where spines are absent from the upper surface of the animal are occasionally been observed within Reserve and other sites within St Brides Bay. The cause of spine loss is thought to be a bacterial infection (see Section 4.3).

1.2 Starfish Survey in Skomer MCZ

During the 2003, 2007 & 2011 *E. esculentus* surveys selected starfish species were also recorded. The survey method suited the additional counting of easily identifiable species. Three starfish species were chosen: *Marthasterias glacialis* (spiny starfish), *Luidia ciliaris* (seven-armed starfish) and *Crossaster papposus* (common sun-star). *M. glacialis* is regularly found in the Skomer MCZ, however *L. ciliaris* and *C. papposus* are less frequently found despite both having a wide distribution around the UK.

The aim was to establish the distribution and abundance of these starfish species within Skomer MCZ. However the survey for these species are limited as the sites were selected for habitats suiting *E. esculentus* rather than habitats where the different starfish could be expected to occur. *M. glacialis* is found in the same rocky reef habitats as *E. esculentus*, but C*. papposus* is found at sheltered sites with current swept sediment and *L. ciliaris* prefer sandy or sand scoured rock, gravel and mixed sediments (Picton, 1993).

1.3 Survey Objectives

The survey aims to establish the current status of the *Echinus esculentus* population in Skomer MCZ and record selected starfish species. The objectives are:

1. To determine the distribution and abundance of *E. esculentus* and describe their key habitats;

2. To determine the size frequency distribution of *E. esculentus*;

3. To record sun-star, *C. papposus*, spiny starfish, *M. glacialis,* and seven-armed starfish, *L. ciliaris*;

4. To allow a time series of comparable data to develop with the 2003, 2007 & 2011 survey results;

5. To record 'bald' *E. esculentus*.

6. To identify Echinoid larvae in plankton samples.

2 Method

2.1 Site Selection

During the 2007 survey GPS positions for 6 permanent sites were established. These sites were selected to allow for coverage on the north and south coasts of the island and the north coast of the Marloes peninsula. Site habitat descriptions recorded in the 2007 survey showed that 5 of these sites had suitable rock and boulder habitat for *E. esculentus,* and these sites were used again for the 2011 & 2015 surveys. The 2007 survey results showed that the Castle Bay site had unsuitable (pebble) habitat, therefore a new position, following reconnaissance dives to assess suitability, was established in 2011 and this was again used in 2015. Each site is marked with buoyed sinkers for the duration of the survey. The sites are: North Wall (NWA), Thorn Rock (TRK), Castle Bay (CBY), Martins Haven point (MHV), Rye Rocks (RRK) and High/Low Point (HLP), site positions are shown in Figure 2.1.

Figure 2.1. *Echinus esculentus* survey sites Skomer MCZ 2015

2.2 Diving Field Method

2.2.1 Training

Time constraints limited pre-survey training. Teams of volunteers were therefore selected allowing for at least one experienced diver per diver pair. Experience was based on previous involvement of volunteer diving surveys. Each group of divers was briefed on the aims and methods of the survey prior to each dive session.

2.2.2 Field equipment

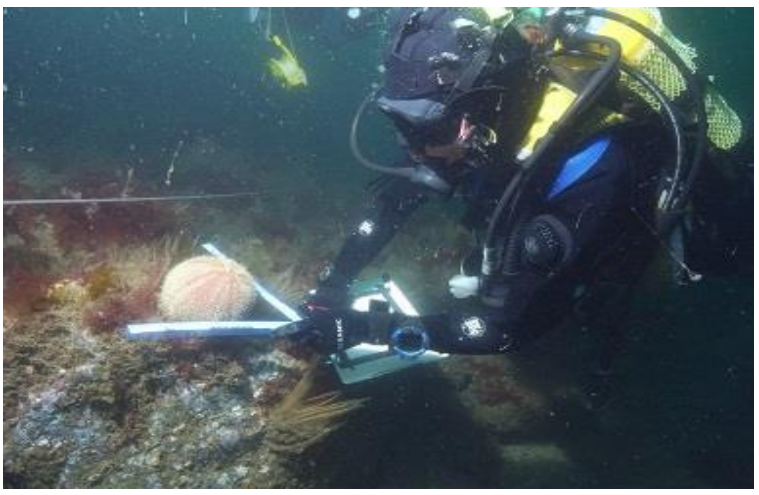
1 underwater writing slate, 1 *Gibbs urchin divider*, 1 transect tape (30m tape measure) and 1 weight (large shackle) attached to end of tape per diver pair.

2.2.3 Field method

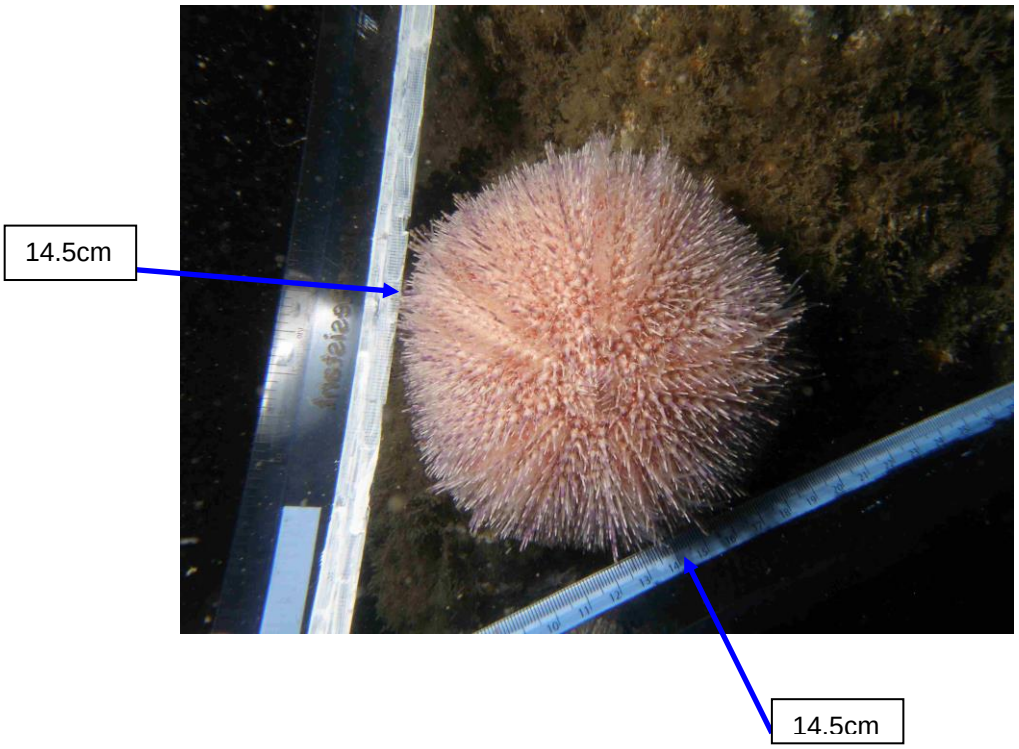
Transects
30m transects were completed at depths of 20m, 15m, 10m and 5m below chart datum (bcd) for each marked site. Site markers were positioned at 15m bcd and this was used as a reference for completing the transects at the different depths as follows: 15m bcd weight secured to site marker, 20m bcd weight secured (in a crevice or around a boulder) 5m deeper than the marker, 10m bcd weight secured 5m shallower than the marker and 5m bcd weight secured 10m shallower than the marker. Each dive pair was allocated which transects to complete before the dive with the aim to complete 2 transects per dive. The divers completed the method as follows:

1. Dive pair secure weight at the allocated transect depth and swims together on a depth contour laying out the 30m tape.

2. Dive pair swims back along the tape counting and measuring *E. esculentus* and counting starfish in a 2m corridor, 1m either side of the tape.



Within the 2m corridor record the distance each urchin is found along the tape and measure each *E. esculentus* using the *Gibbs urchin divider* where the ruler touches the urchin as shown below:



3. Record any 'bald' *E. esculentus*

4. Within the 2m corridor, record the total number of each of the following types of starfish:
Spiny starfish (*Marthasterias glacialis*), common sun-star (*Crossaster papposus*) and seven-armed starfish (*Luidia ciliaris)*

5. On completion of the 30m transect rewind the tape.

6. Repeat the survey at shallower depth.

7. On the surface combine data from each member of the dive pair to obtain a complementary record of sightings for each transect.

Habitat description

Full habitat descriptions were completed, following Seasearch survey methods, at each of the sites established in 2007 and 2011. In 2015 the survey was completed at the 6 established sites and no obvious changes in habitat type were observed, therefore new habitat descriptions were not necessary.

Plankton sampling

Zooplankton sampling is completed following methods used by Plymouth Marine Laboratory (PML). 200µm mesh plankton net is pulled on a vertical haul from 35- 40m depth at 0.2m / sec (3.5 minute haul). The sample is collected in the 'cod-end' bottle and this is preserved in 4% formalin. Two samples are taken at each sampling event, these are taken weekly from the north side of Skomer from beginning of May to the end of October. Sample species analysis is completed by the Sir Alistar Hardy Foundation for Ocean Science.

3. Results

The 2015 survey was carried out by a team of 29 volunteer divers with 18 diving on each of the two survey weekends (20/21st June & 4th/5th July 2015).

A total of 151 transects were completed covering an area of 9060 m^2 and a total of 879 *E. esculentus* were recorded and measured, of these 10 were 'bald urchins'. In addition the following starfish were recorded: 168 *M. glacialis*, two juvenile *L. ciliaris* and no *C. papposus*.

3.1 Survey Site Habitats

A summary of the seabed substrate, habitats and species for all sites are described in Lock *et al* 2007 & 2012. It was not necessary to resurvey in 2015.

3.2 *Echinus esculentus*

3.2.1 Density

2015 density results from each site the total for all sites are shown in Figure 3.1.
The density per transect has been converted to density per 100m^2 to allow for comparison with other years where survey area may have differed.

Figure 3.1 Summary of density results for *Echinus esculentus* 2015.

	Transects	Area	Total	Mean density	95%CI	Mean Density	95%CI
Site	completed	covered	No of urchin	per Transect	(mean / Tx)	Per 100m2	Mean/ 100m2
RRK	28	1680	236	8.43	2.45	14.05	4.09
CBY	20	1200	279	13.95	2.89	23.25	4.82
HLP	26	1560	77	2.96	1.07	4.94	1.78
MHV	29	1740	120	4.14	0.96	6.90	1.59
NWA	26	1560	160	6.15	1.63	10.26	2.72
TRK	22	1320	7	0.32	0.24	0.53	0.40
ALL	151	9060	879	5.82	0.95	9.70	1.58

Thorn Rock (TRK), North Wall (NWA), Rye Rocks (RRK), Martins Haven Point (MHV), High/Low Point (HLP) and Castle Bay area (CBY).

The mean density for the Skomer MCZ is 9.70/100m^2. Mean density varied significantly between the sites **p<0.1%** (Oneway ANOVA F= 25.15, f crit 2.28). Castle Bay (CBY) had a significantly higher density (23.25 *E. esculentus* / 100m^2) to all the other sites. Thorn Rock (TRK) had the lowest density (0.53 *E. esculentus* / 100m^2) and this was significantly lower than all the other sites.
Figure 3.2 compares the mean *E. esculentus* densities (per 100m^2) for all the sites surveyed in 2015 with their corresponding 95% confidence intervals. Figure 3.3 gives a visual representation of how *E. esculentus* density varies spatially across the Skomer MCZ.

Figure 3.2 Mean *E. esculentus* density (per 100m^2) at each site 2015.

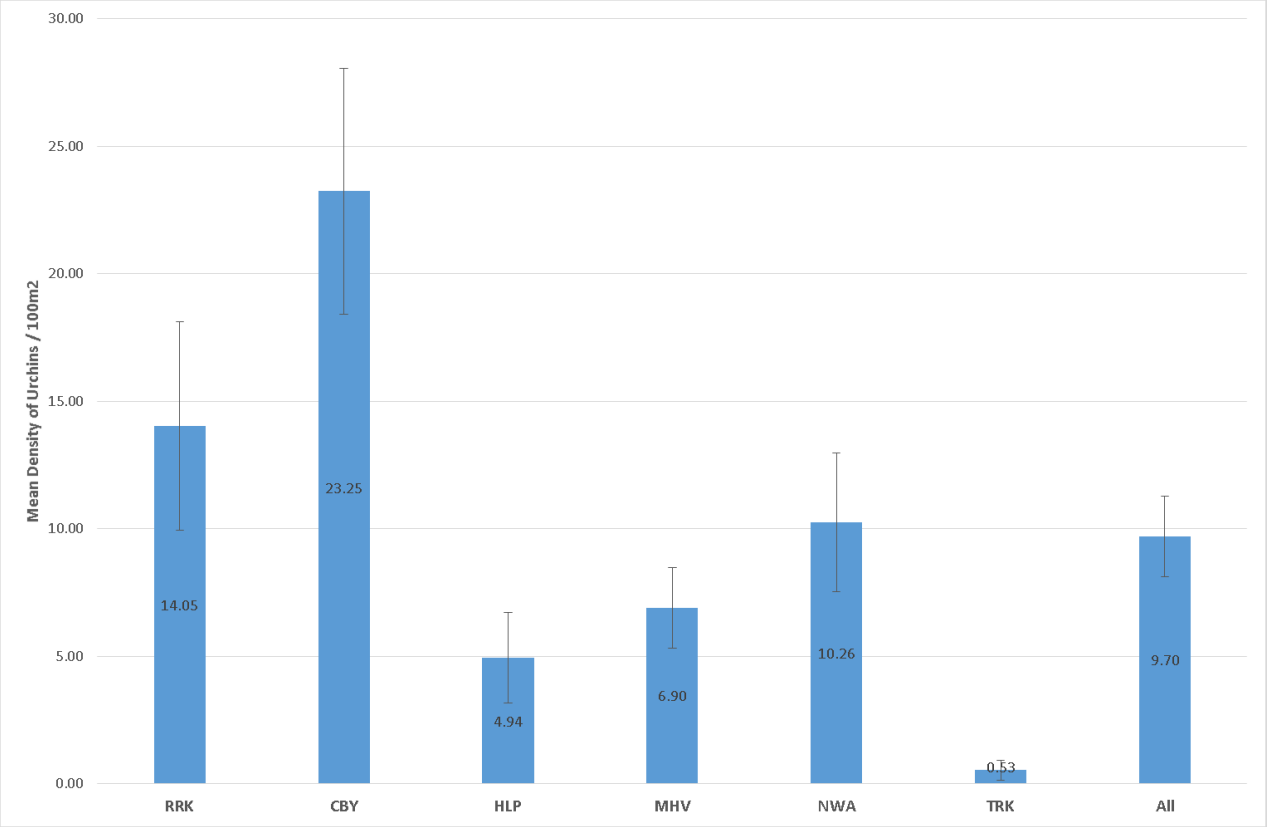
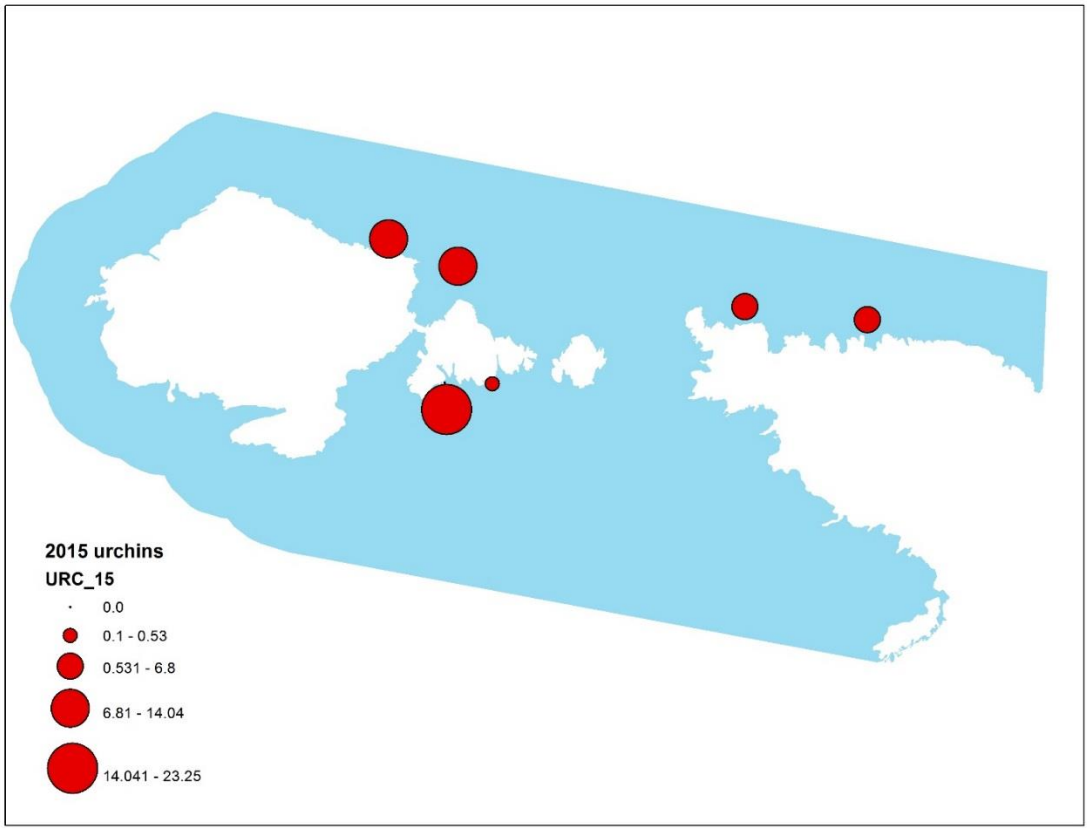
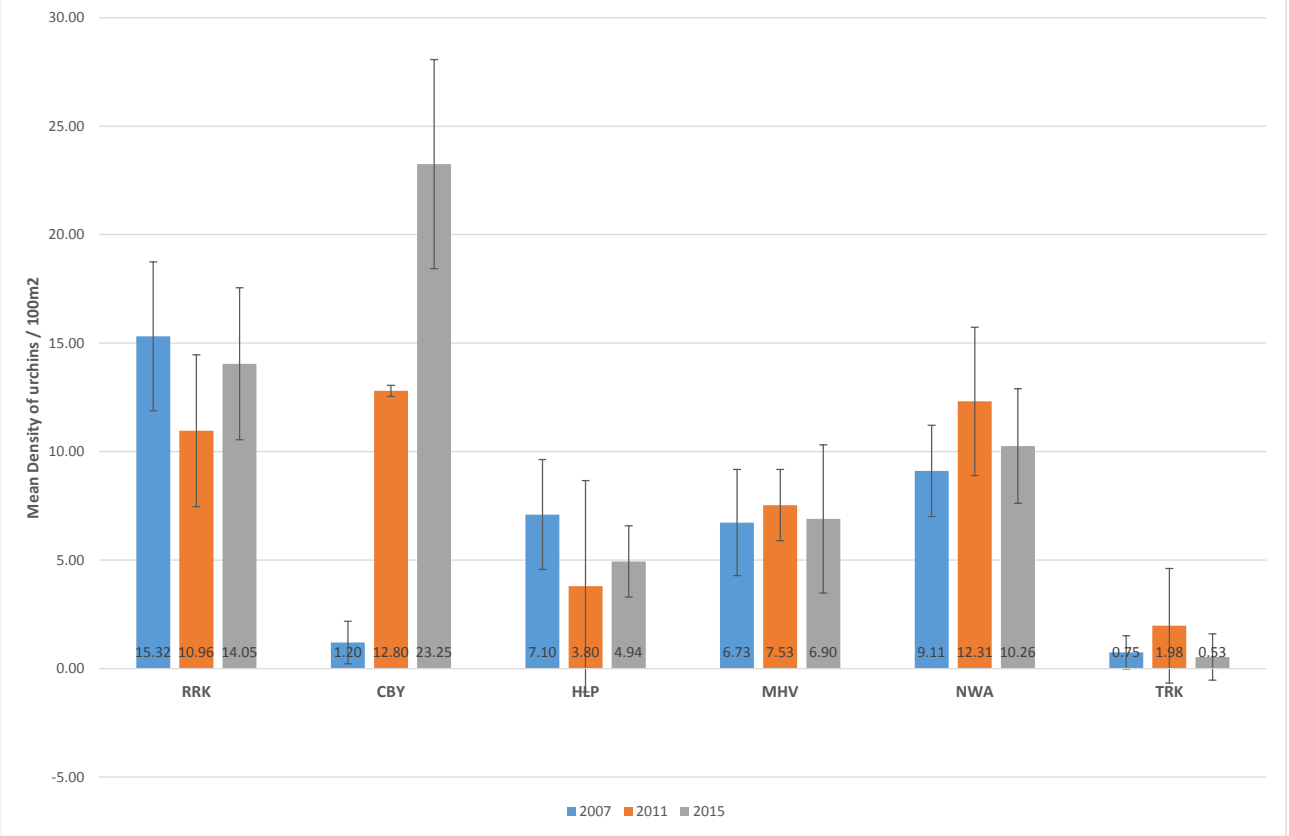


Figure 3.3 Graduated bubble map of *E. esculentus* density in Skomer MCZ 2015.



These results can be compared to the 2007 & 2011 surveys, see figure 3.4 & 3.5

Figure 3.4 Mean *E. esculentus* density (per 100m²) at each site for 2007, 2011 & 2015.



The pattern of variation in density between the sites has not varied much between the years. It is only the Castle Bay site which has shown any significant change (**p<0.1%).** In 2007 an unsuitable location was used in Castle Bay before relocating it in 2011, this accounts for the comparatively low density recorded in 2007. The 2015 Castle Bay records have shown a significant increase in density (**p<0.1%)** compared to 2011. All the other sites show no significant change in density between the years.

Figure 3.5 Summary table of *E. esculentus* density results 2007 - 2015

	Mean Urchins / 100m2			Confidence Intervals		
Year	**2007**	**2011**	**2015**	**07_95%CI**	**11_95% CI**	**15_95%CI**
RRK	15.32	10.96	14.05	3.43	3.50	3.50
CBY	1.20	12.80	23.25	0.98	0.26	4.82
HLP	7.10	3.80	4.94	2.54	4.87	1.65
MHV	6.73	7.53	6.90	2.45	1.65	3.42
NWA	9.11	12.31	10.26	2.11	3.42	2.64
TRK	0.75	1.98	0.53	0.77	2.64	1.07

Density variation with depth

At each of the survey sites transects were completed at 5m, 10m, 15m and 20m depths below chart datum (bcd). The highest number of the transects were conducted at 10m bcd and 15m bcd.
An oneway ANOVA test showed that there was **no** significant difference between the densities of *E. esculentus* found at each depth zone (F = 1.15 f critc 2.67 **not sig @ p 5%)**. This is consistent with results from 2007 & 2011 (Lock *et al* 2008 & 2012).

Figure 3.6 Summary table of *E. esculentus* density with depth.

	Transects	Area	Total	Mean density	95%CI	Mean Density	95%CI
Depths	**completed**	**covered**	**No of urchins**	**per Transect**	**(mean / Tx)**	**Per 100m2**	**Mean/ 100m2**
5 M bcd	11	660	73	6.64	2.85	11.06	4.75
10 M bcd	62	3720	413	6.66	1.62	11.10	2.70
15 M bcd	67	4020	331	4.87	2.00	8.11	2.15
20 M bcd	10	600	62	6.20	2.35	10.33	3.92

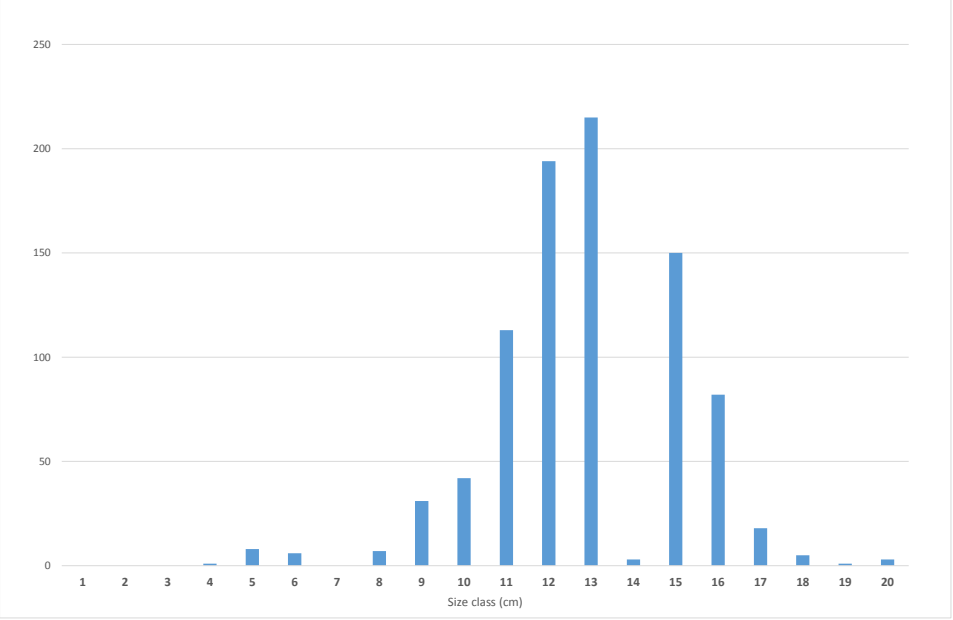
3.2.2 Size of *Echinus esculentus*.

The measurements taken with the “Gibbs urchin divider” were converted into diameters (cm) using the method described in appendix 1.

Mean size of Echinus esculentus for Skomer MCZ

The data for all the *E. esculentus* measured has been collated to give results for the Skomer MCZ population. The size frequency graph, figure 3.7, shows a roughly normal distribution. The low results for 14mm are due to an artefact of the conversion from “gibbs divider” to mm and the way the frequency class are constructed. The mean, maximum and minimum diameters were 13.34 cm, 20 cm and 4 cm respectively.

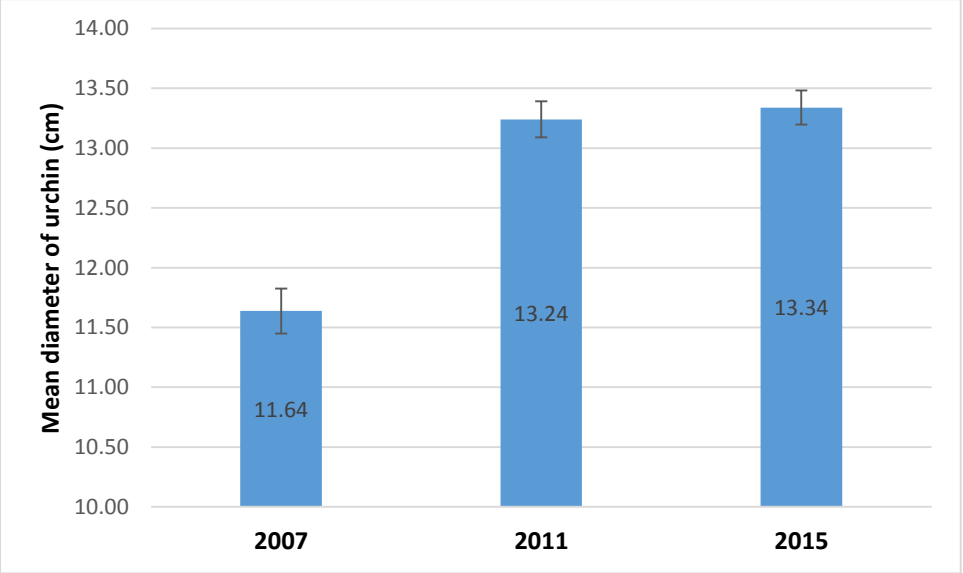
Figure 3.7 Size frequency distribution for whole MCZ population 2015.



The mean diameter of *E. esculetus* measured in the 2007, 2011 and 2015 surveys is compared in figure 3.8.

Figure 3.8 Summary table and graph of mean size of *Echinus esculentus* 2007 - 2015

Year	2007	2011	2015
Mean diameter (cm)	11.64	13.24	13.34
95% CI	0.19	0.15	0.14



One way ANOVA test between years shows that there is a significant difference **p<0.1%** between the mean diameter in 2007 and the following years (F = 125.5 f critc 2.99). In 2007 the mean size of urchin was about 1.5cm smaller.

Differences between sites 2007 - 2015

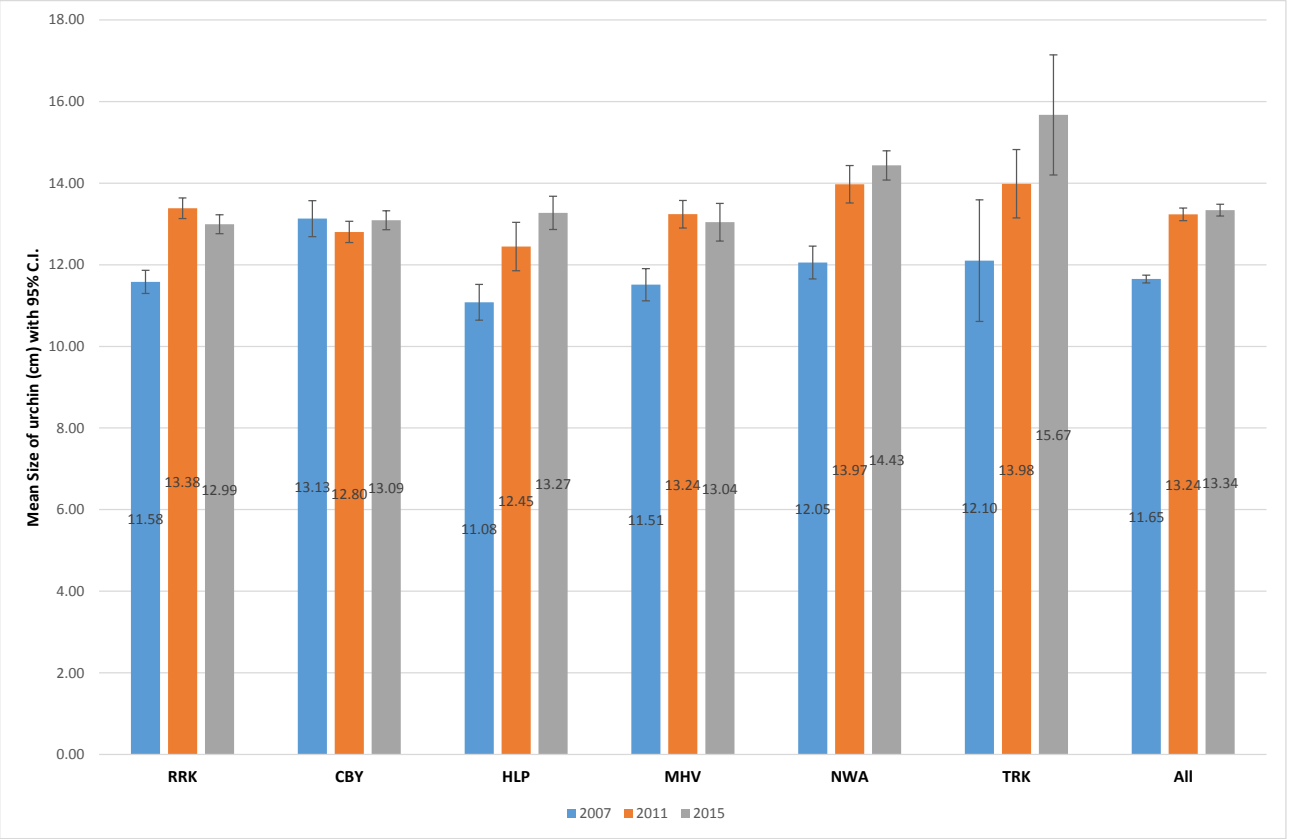
The *E. esculentus* mean diameter found at the 6 sites is compared for 2007, 2011 and 2015 results in Figure 3.9 and 3.10.

Figure 3.9 Summary table of size differences between sites 2007 - 2015

Sizes (cm)	Mean	Mean	Mean	95% CI	95% CI	95% CI
Year	2007	2011	2015	2007	2011	2015
RRK	11.58	13.38	12.99	0.28	0.25	0.23
CBY	13.13	12.80	13.09	0.44	0.26	0.23
HLP	11.08	12.45	13.27	0.44	0.59	0.41
MHV	11.51	13.24	13.04	0.40	0.34	0.46
NWA	12.05	13.97	14.43	0.40	0.46	0.36
TRK	12.10	13.98	15.67	1.49	0.84	1.47
All	11.65	13.24	13.34	0.10	0.15	0.14

Note: the 2007 Castle Bay (CBY) site was at a different location when comparing to 2011 & 2015

Figure 3.10 Graph of mean size (cm) across sites for 2007, 2011 & 2015.



The general trend if for *E. esculentus* to be significantly smaller in 2007 except at Thorn Rock (TRK), however at this site very low numbers were found giving a very small sample size.
2011 and 2015 show no significant differences in size between any of the sites.

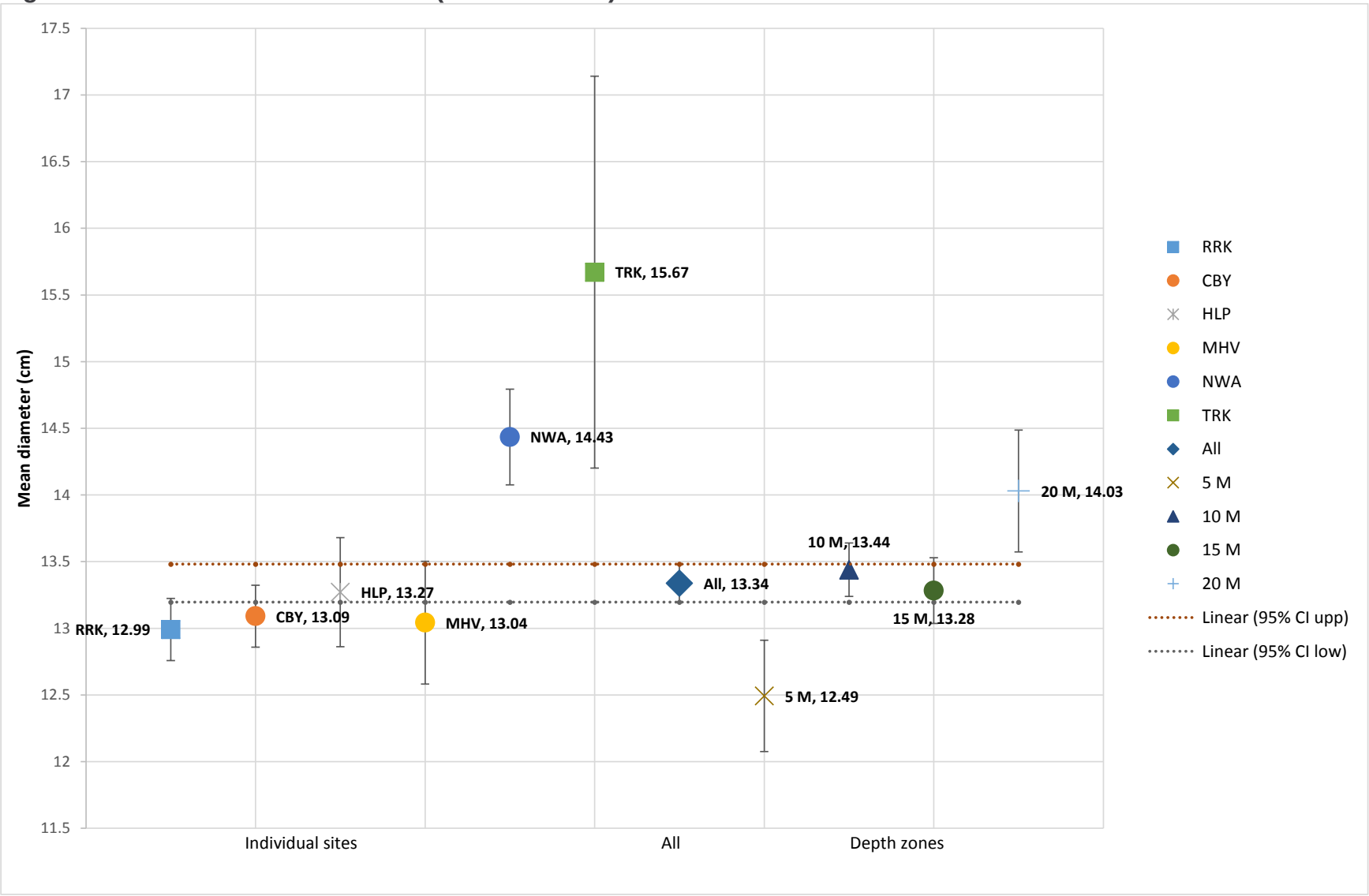
2015 size results between sites & depth zones

A detailed look at the 2015 results allows a comparison between sites and depth zones, see figures 3.11 and 3.12.

Figure 3.11 Summary of mean size (cm) at different depth zones 2015

Depths	Mean size	95% CI
5 M bcd	12.43	0.45
10 M bcd	13.44	0.20
15 M bcd	13.28	0.25
20 M bcd	14.03	0.46

Figure 3.12 2015 Urchin size results (mean size cm).



One way ANOVA test between sites shows a significant difference **p<0.1%** (F = 13.21 f crit 2.22) between the sizes of *E. esculentus* found at different sites in 2015. The *E. esculentus* found at Thorn Rock (TRK) and Northwall (NWA) are bigger than those from other sites surveyed in 2015.
Analysis of *E. esculentus* found at different depth zones also showed a difference in mean size. One way ANOVA between depth zones showed a significant difference in size **p<0.1%** (F = 6.94 f crit 2.61). The *E. esculentus* found at 5m bcd were smaller than those from other depth zones and the *E. esculentus* found at 20m bcd were larger than the rest. However the actual size differences are only in the order of 1cm, possibly not ecologically significant.

3.2.3 Occurrence of "Bald" *Echinus esculentus*

2015 has seen the highest occurrence of 'bald' *E. esculentus* since 2003. All records come from the Castle Bay site from transects at 10m bcd and 15m bcd. The numbers found are still very low, accounting for only 1.15% of the total.

Figure 3.13 Numbers of "bald" *Echinus esculentus* 2003 - 2015

	2003	**2007**	**2011**	**2015**
Total *E. esculentus*	505	609	755	869
Total "bald" *E. esculentus*	0	2	1	10

3.3 Starfish Species

In 2015 a density of 2.17 per 100m^2 *Marthasterias glacialis* was recorded and two individual *Luidia ciliaris* were recorded; both at North Wall. There were no records of *Crossaster papposus* in 2015 and there have been none recorded since 2003.

Figure 3.14 Starfish records for Skomer MCZ 2003 – 2015

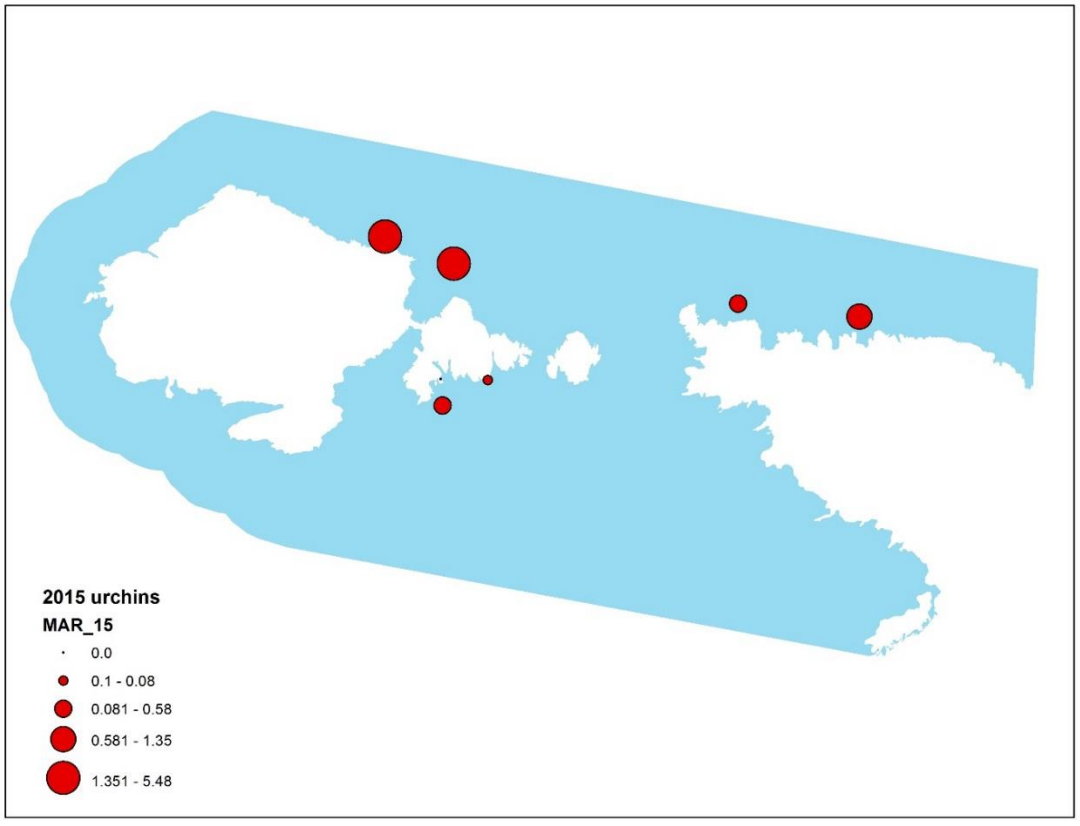
Year	2003	2007	2011	2015
C. papposus - counts	21	0	0	0
M. glacialis – density / 100m^2	4.98	3.47	4.0	2.17
L. ciliaris - counts	0	2	10	2

Marthasterias glacialis was the most abundant starfish recorded in 2015, although less were seen in 2015 compared to previous years across all sites.

Figure 3.15 Density of *M. glacialis* / 100m^2 2003 - 2015

Site	2003	2007	2011	2015
Whole MCZ	4.98	3.47	4	2.17
HLP		2.9	2.1	1.35
MHV		2.37	6	0.57
TRK		1.4	0.6	0.08
RRK		6.3	6.8	5.48
NWA		5.3	7.25	4.23
CBY 2007		1.1		
CBY 2011			1.7	0.58

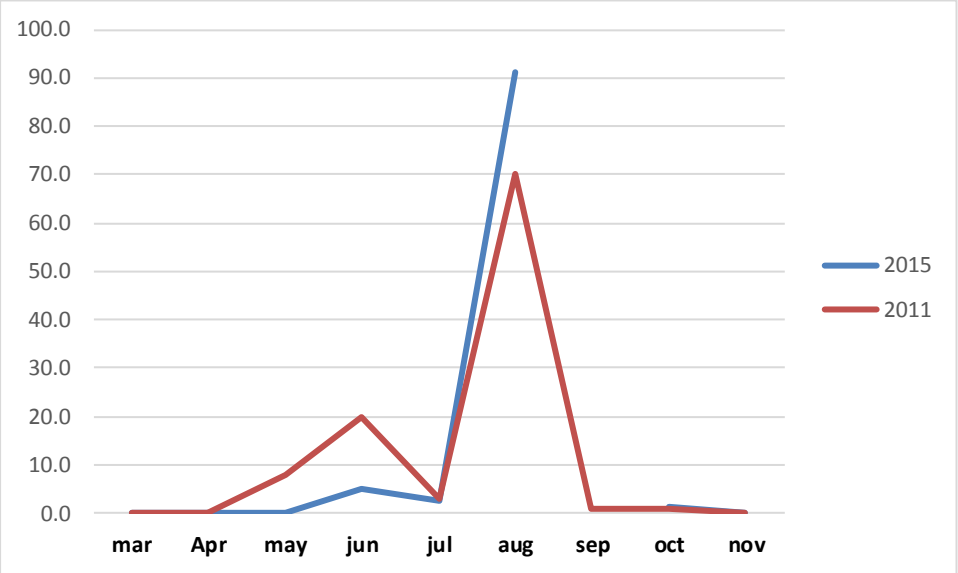
3.16 Graduated bubble map of *M. glacialis* density / 100m^2 Skomer MCZ 2015



3.4 Plankton

Plankton Echinoderm ophiopluteus larvae are seen regularly in the plankton samples taken within Skomer MCZ. It is not possible to identify these down to species so these may include starfish species as well as urchins. Both 2011 and 2015 show August as the peak month for the occurrence of echinoderm larvae.

Figure 3.18 Percentage abundance of Echinoderm larvae in plankton samples within Skomer MCZ 2001 & 2015



4 Discussion

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4.1 *Echinus esculentus* density

The average density of *E. esculentus* in Skomer MCZ in 2015 was compared with densities recorded for Skomer and other locations in the UK (Figure 4.1). Luddington et al (2004) summarised that the densities recorded in the 1981 and 2003 Skomer surveys were similar despite different methods and sample sizes being used and that these densities were much lower than those recorded from other UK sites. In 2007 mean density was again similar to those previously recorded in the MCZ despite method changes and Lock et al (2012) reported that in 2011 the mean density was slightly higher but not to any significant level. In 2015 the mean density was almost the same as that recorded in 2011.

Further comparisons with other UK sites have not been possible as *E. esculentus* density surveys at other locations have not been completed since 1984.

Figure 4.1 Comparison of mean densities of *E. esculentus* per 100m^2 from previous surveys

Location	Mean density per 100m^2	Site variation	Source
Plymouth 1984	20		Nichols (1984)
Millport 1984	160	140 - 304	Nichols (1984)
Skomer 1982	5.5		Bishop (1982)
Skomer 2004	6	0.8 - 14	Luddington *et al* (2004)
Skomer 2007	7.3	0.8 - 15	Lock *et al* (2008)
Skomer 2011	9.1	1.9 - 17	Lock *et al* (2012)
Skomer 2015	9.7	0.5 - 23	Burton et al (2016)

Survey site variations in densities were observed in each of the surveys from 2003 to 2015 and reflect differences in site exposure to wave action and prevailing currents. The prevailing swell and wind direction is from the southwest therefore sites facing this direction are exposed to the greatest wave action.

In 2015 the highest *E. esculentus* density was recorded at Castle Bay as in 2011. The mean density in 2015 of 23.3 per 100m^2 was a significant increase from the mean density of 17.67 per 100m^2 recorded in 2011. This site is a rocky reef area made up of steep rock pinnacles and wide gullies; a habitat that is suitable for *E. esculentus* with lots of areas to shelter from wave action. The habitat supports rich communities of hydroid, bryozoan and algal turf, the preferred food source for *E. esculentus* (Bishop & Earl, 1984).

High densities were also recorded at sites along the north side of Skomer with 14.04 per 100m^2 at Rye Rocks and 10.26 per 100m^2 at North Wall. Both these sites are exposed to moderate tidal current and sheltered from the prevailing south westerly swell and wave action. All surveys at these sites were completed on bedrock reef and boulder slopes providing the preferred substrate for *E. esculentus'* favoured habitat. Sites along the north Marloes Peninsula had lower densities of 6.90 per 100 m^2 at Martins Haven and 4.95 per 100 m^2 at High Low Point. These sites are rocky reef and boulders sheltered from the prevailing south westerly swell and wave action, but these sites are exposed to slightly

lower tidal currents compared to the north coast of Skomer. The deeper transects at these sites also found mixed sediments of muddy shell gravel, a habitat not suited to *E. esculentus*. The lowest *E. esculentus* density was 0.53 per 100 m^2 at Thorn Rock. The low numbers are a reflection of this site being exposed to the prevailing swell and wave action from the south west. Thorn Rock is a silt covered bedrock reef, dominated by sponge species, not the preferred food source of *E. esculentus* (Bishop & Earl, 1984).

At Skomer, Bishop (1982) noted that the highest density of *E. esculentus* was obtained from a bedrock habitat sheltered from wave action, but exposed to fast tidal streams. Luddington *et al* (2004) and Lock *et al* (2007 & 2012) both confirmed these observations and the findings of the 2015 survey were again consistent with the previous studies at Skomer.

Studies have shown variable trends of *E.esculentus* density with depth. The 2015 showed that there was no significant difference in density with depth and this reflected the results found in the 2011 survey. These results also mirrored the findings of Nichols (1985) who showed no significant different difference in density between shallow (8-10m) and deep (20-22m) sites. However other studies have showed varied responses of *E. esculentus* to water depth. Bishop (1982) reported highest densities at 7m and this was also shown by Lock *et a*l (2008) from the 2007 survey. In contrast Luddington *et al* (2004) reported that twice the density of *E. esculentus* was recorded in deeper water (21-25m) compared with shallow water (6-10m), but also noted that the results may be biased as a far greater number of surveys were carried out in the shallow than deep water.

4.2 *Echinus esculentus* size

The mean diameter of *E. esculentus* at Skomer in 2015 was compared with the mean diameters recorded for Skomer and other locations in the UK.

Figure 4.2 Comparison of mean diameter of *E. esculentus* from previous surveys

Location	Mean diameter (cm)	Source
Isle of Skye, Scotland	7-10	Nichols (1979)
Lamorna Cove, Cornwall	11 - 12	Nichols (1979)
Skomer 1982	11.5	Bishop (1982)
St Abbs, Scotland	7.9	Bishop & Earl (1984)
Skomer 1984	11.5	Bishop & Earl (1984)
Skomer 2003	12.5	Luddington *et al* (2004)
Skomer 2007	12.2	Lock *et al* (2008)
Skomer 2011	13.24	Lock *et al* (2012)
Skomer 2015	13.34	Burton et al (2016)

Bishop & Earl (1984) observed a striking contrast between mean diameters of the St Abbs and Skomer populations. Comparing with other locations the Scottish sites, St Abbs and Isle of Skye, closely match as do the southwest Britain sites, Skomer and Lamorna Cove, which suggests that *E. esculentus* growth could be influenced by water temperature.

Nichols et al (1985) suggested that growth in populations of grazing animals such as *E. esculentus* depends on a complex of factors, including sea-water quality and temperature, and food availability. Nichols *et a*l (1985) conducted growth studies on *E. esculentus* on populations in Plymouth and Cumbrae (Scotland) 800 miles apart. The results showed that growth curves from each location were similar; individuals aged 7 years were 10cm in Plymouth and 9cm in Cumbrae. However the results found that the upper levels of the growth curves were higher for Plymouth where individuals >14cm diameter were collected compared to no individuals > 12cm diameter in Cumbrae. This supports that the mean size of *E. esculentus* from Scottish waters is generally below that from southwestern Britain. Ludding ton *et al* (2004) and Lock *et al* (2007 & 2011) reported individuals up to 20cm diameter and this was again the maximum size recorded in the 2015 survey. This suggests that the growth patterns of the Skomer population matches more closely to the southwest Britain populations where sea water temperatures are similar compared to those in Scotland.

Bishop & Earll (1984) suggested that in 1982 Skomer had a sparse and aging population that had not had a successful recruitment of juveniles during the previous 10 years, whilst St Abbs had a dense self-recruiting population. Each of the surveys between 2003 to 2015 all had a high mean diameter of 12-13 cm which could suggest an aging population. However these surveys also show a good spread of diameters with size range of 4 to 20 cm and the repeated surveys every four years have all shown normal size frequency population graphs.

Larsson (1968) suggested that divers were less efficient at observing urchins smaller than 5 cm diameter. Luddington *et al* (2004) recommended intense searches in small areas ($0.25m^2$ quadrats) should be completed to provide evidence that the true age structure of the *E. esculentus* population is recorded. Searches in quadrats were not introduced but in the 2007, 2011 and 2015 surveys the divers were briefed to search carefully for small urchins whilst completing transects. This resulted in smaller *E. esculentus* individuals being found in 2015 compared to the 2003 survey.

The 2015 survey showed that the mean size of *E. esculentus* was the same at the 10m and 15m depths but they were significantly smaller at 5m and significantly bigger at 20m. It is possible that the smaller *E. esculentus* prefer the shallower depth in the kelp forest habitat and an increase in effort to survey the 5m depth area is needed on future surveys.

It is possible that the larval settlement at Skomer is different to the Scottish sites. Bishop (1983) suggested that the moderate and high currents around Skomer may be completely inhospitable to larval settlement and to juveniles, whose preferred habitat maybe in much deeper water (>50m) offshore. Rostron (2000) reported that deep sites offshore Skomer in St Brides bay were primarily sandy habitats and no *E. esculentus* were found. Deep sites > 35m with rock, boulder and cobble habitats close to Skomer have not been explored. Plankton sampling in the Skomer MCZ from 2007 to 2015 has identified Echinoplutei with peak numbers in July and August. Identification of the Echinoplutei to species level has not been possible as larvae in late stages of development have not been found, it is therefore not know which Echinoid species are present (Lock *et al* 2012).

4.3 'Bald' *Echinus esculentus*

Bald urchin disease is a bacterial disease known to affect several species of sea urchin. Janoux (1987) showed that two pathogens were responsible for the disease. Infection generally occurs at the site of an existing physical injury, the affected area changes colour and the spines are lost. Janoux (1987) found that if the lesion remains shallow and covers less than 30% of the animal's surface, the animal tends to survive and eventually regenerates any lost tissue. However if the damage is more extensive or the urchin test is perforated, the disease is fatal. Only 10 'bald' *E. esculentus* were recorded in 2015 accounting for only 1.15% of the total, with all the records coming from the Castle Bay site where the highest numbers of *E. esculentus* were recorded. Although the numbers were very low they were higher than those recorded on previous surveys, so it will be important to continue recording on future surveys.

4.4 Starfish

Marthasterias glacialis was found throughout the MCZ in 2015 showing a similar distribution to those in 2011, 2007 and 2003. This reflects the wide range of habitats in which *M. glacialis* commonly occurs (Picton, 1993) and also that *M. glacialis* is found in similar habitats to *E. esculentus*. The mean density was however slightly lower in 2015 across all sites compared to the previous surveys.

Crossaster papposus was not recorded in 2015. It has not been recorded at Skomer since the 2003 survey when 21 individuals were found at Thorn Rock. Records on the JNCC NBN Gateway show that they have been recorded at a number of sites in Skomer MCZ and in Pembrokeshire but in very low numbers. *C. papposus* is often found with its preferred food, brittle stars. In 2015 Seasearch divers recorded two *C. papposus* close to small patches of brittle stars at Stack Rocks, St Brides Bay, (Lock *pers. comm.*), although they have been rarely recorded on Seasearch dives at Pembrokeshire sites.

Very low numbers of *Luidia ciliaris* were recorded with just two individuals at North Wall. These low numbers are comparable to previous records with 10 recorded in 2011, two in 2007 and none in 2003. Of these records all have been small or juvenile individuals. Luddington *et al* (2004) suggested that this could be due to low densities in the Skomer MCZ or that the habitat surveyed was unsuitable. Typical habitat for *L. ciliaris* is described by Picton (1993) as sandy or sand covered rock, gravel and mixed sediments, where it feeds on other echinoderms. Previous records of *L. ciliaris* can be found on the JNCC NBN Gateway showing that they have been recorded at a number of sites in the Skomer MCZ, but in very low numbers.

The current distribution and abundance of *C. papposus* and *L. ciliaris* are unknown in the Skomer MCZ, it is recommended that records are maintained during all routine Skomer MCZ diving operations and searches are completed at previously known sites.

5. Recommendations

1. The survey of *E. esculentus* and starfish populations should be repeated every four years.

2. Survey methods should follow those developed in the 2007 survey to allow comparisons between surveys.

3. The Castle Bay site position established in 2011 and repeated in 2015 should continue to be used.

4. An increased effort to survey the 5m depth area to record small *E. esculentus*.

5. Sites in the Skomer MCZ where *C.papposus* and *L.ciliaris* have been recorded in the past should be targeted. In addition sightings of these species should be recorded during routine dives.

6. Plankton studies should be continued to investigate the presence of echinoderm larvae in the Skomer MCZ.

7. 'Bald' *E.esculentus* recording should be continued.

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Appendix 1

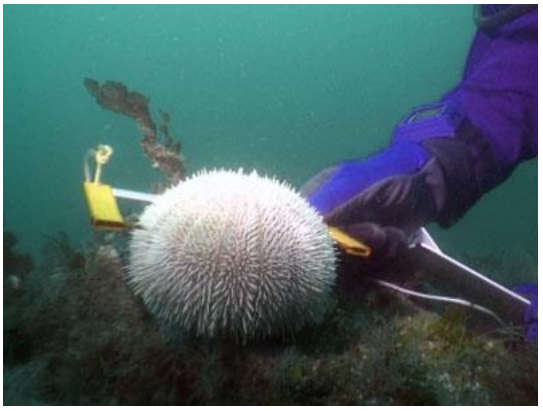
‘Gibbs urchin divider’ data

To improve size measuring of *E. esculentus* a new set of dividers were developed, constructed from two plastic rulers, which are more robust and operationally simpler than a set of callipers. The dividers are fixed at an angle of 60º with the apex of the triangle at the 4 cm mark on the rulers.

FIGURE 4.1 E. esculentus measuring techniques (a) Dividers (b) Callipers

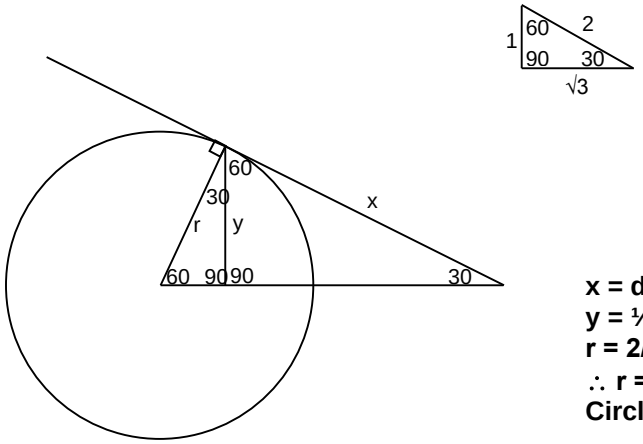
(a)

(b)



The value recorded on the dividers is the tangential meeting point of the rulers with the urchin. The trigonometry required to determine the diameter of the urchin from the value measured off the dividers (which should be equal on both rulers) is illustrated in Figure 4.2

FIGURE 4.2 Trigonometric representation of the method by which the Urchin diameter can be derived from the divider reading (measured in centimetres).



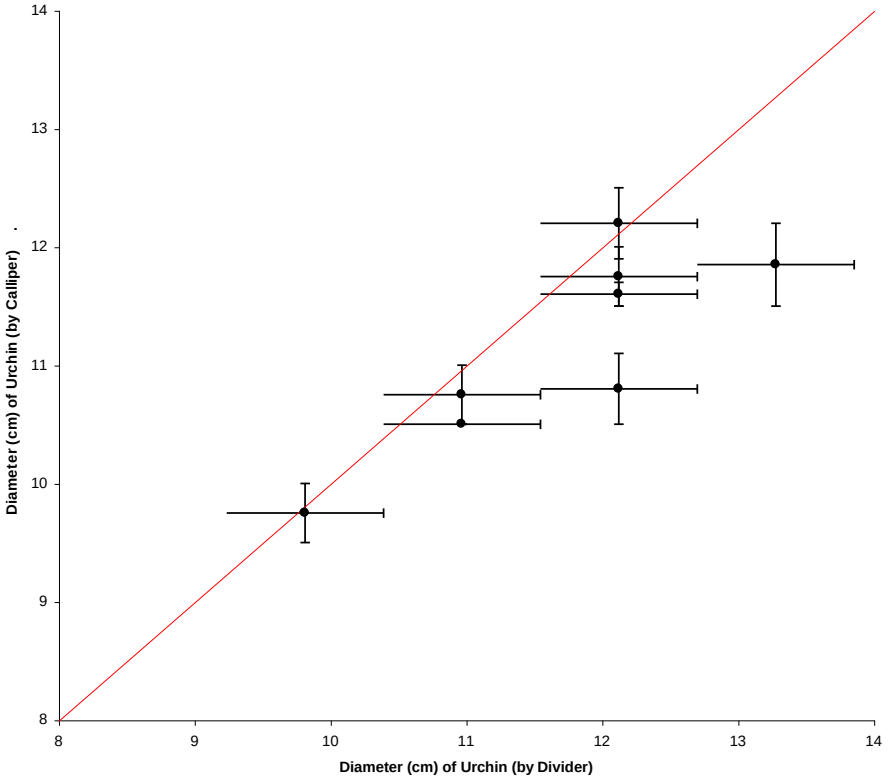
x = divider reading – 4
y = ½ · x
r = 2/(√3) · y
∴ r = x / (√3)
Circle diameter = 2r

As a result, from a divider reading *d* the urchin diameter *D* may be calculated by:

$$D = \frac{2}{\sqrt{3}} \times (d - 4)$$

During one dive eight *E. esculentus* were measured using both the divider and a set of callipers. The correlation between the two different methods, with error bars, is presented in Figure 4.3. Six of the eight urchins are within errors of being equally measured by both methods. Two are over-measured slightly by the divider compared to the callipers. There is a general trend for the divider measurements to result in slightly larger diameters than the callipers. As the data is collated into centimetre size classes this is unlikely to cause difficulty. However, in future surveys better care should be taken in use of the dividers, and the dividers should be rechecked (and adjusted) to ensure the apex angle is exactly 60º.

FIGURE 4.3 Correlation of the diameter of urchins as measured by callipers and dividers, with errors. The red unity line represents direct correlation. Six out of eight urchins are within errors of direct correlation.



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