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Skomer Marine Conservation Zone Distribution and abundance of *Echinus esculentus* and selected starfish species 2019

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

NRW Evidence Report No. 400

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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 survey sites were established for use in future surveys and to allow data to be directly comparable. These sites were resurveyed in 2011, 2015 and on this survey in 2019.

The survey was completed over 4 days by a team of 37 volunteer divers. *E. esculentus* were counted along 30m transects at different depth zones (5m, 10, 15m and 20m below chart data 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 11.11 and 2.3 per $100m^2$ respectively for the whole MCZ, but density varied between sites. A normal size frequency distribution for *E. esculentus* was found.

Echinoderm echinopluteus larvae were identified in plankton samples taken between mid-May to mid-September with abundance peaking in July.

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Crynodeb

Mae *Echinus esculentus* yn chwarae rhan hollbwysig yn strwythur cymunedau islanwol. Symudwyd nifer fawr ohonynt o Barth Cadwraeth Morol Sgomer yn ystod y 1970au, pan aeth deifwyr ati i dargedu'r boblogaeth ar gyfer y fasnach creiriau. Cynhaliwyd arolygon o'r boblogaeth yn 1979 ac 1982, ond ni chynhaliwyd arolygon wedyn tan 2003, pan gasglwyd data i bennu statws y boblogaeth *E. esculentus* a 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, 2015 ac yn ystod yr arolwg hwn yn 2019.

Cwblhawyd yr arolwg dros gyfnod o bedwar diwrnod gan dîm o 37 o ddeifwyr gwirfoddol. Cafodd *E. esculentus* eu cyfrif ar hyd trawsluniau 30 metr mewn parthau o ddyfnder gwahanol (5 metr, 10 metr, 15 metr ac 20 metr o dan ddata'r siart) 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 arfordiroedd gogleddol a deheuol yr ynys ac ar arfordir gogleddol y tir mawr. Dwysedd cymedrig *E. esculentus* ac *M. glacialis* oedd 11.11 a 2.3 fesul 100 metr^2 yn ôl y drefn honno ar gyfer y Parth Cadwraeth Morol i gyd, ond roedd y dwysedd yn amrywio o safle i safle. Daethpwyd o hyd i ddosbarthiad amlder o faint arferol ar gyfer *E. esculentus*.

Yn y samplau o blancton a gasglwyd rhwng canol mis Mai a chanol mis Medi, gwelwyd larfau Echinoderm echinopluteus, gyda'r niferoedd yn cyrraedd eu huchaf yn ystod mis Gorffennaf.

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 *E. 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 mean densities of *E. esculentus* of 5.5 individuals 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 a 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 and 2015.

The recording of ‘bald’ *E. esculentus* also began in 2007 and continued in 2011 and 2015. *E. esculentus* with ‘bald’ patches where spines are absent from the upper surface of the animal are occasionally observed within the 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

Selected starfish species were also recorded on all of the 2003 to 2015 *E. esculentus* surveys. 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 sunstar). *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 selected 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 *E. 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 sunstar, *C. papposus*, spiny starfish, *M. glacialis,* and seven-armed starfish, *L. ciliaris*;

4. To allow a time series of comparable data to develop from 2003 to 2019.

5. To record ‘bald’ *E. esculentus*.

6. To identify Echinoid larvae in plankton samples.

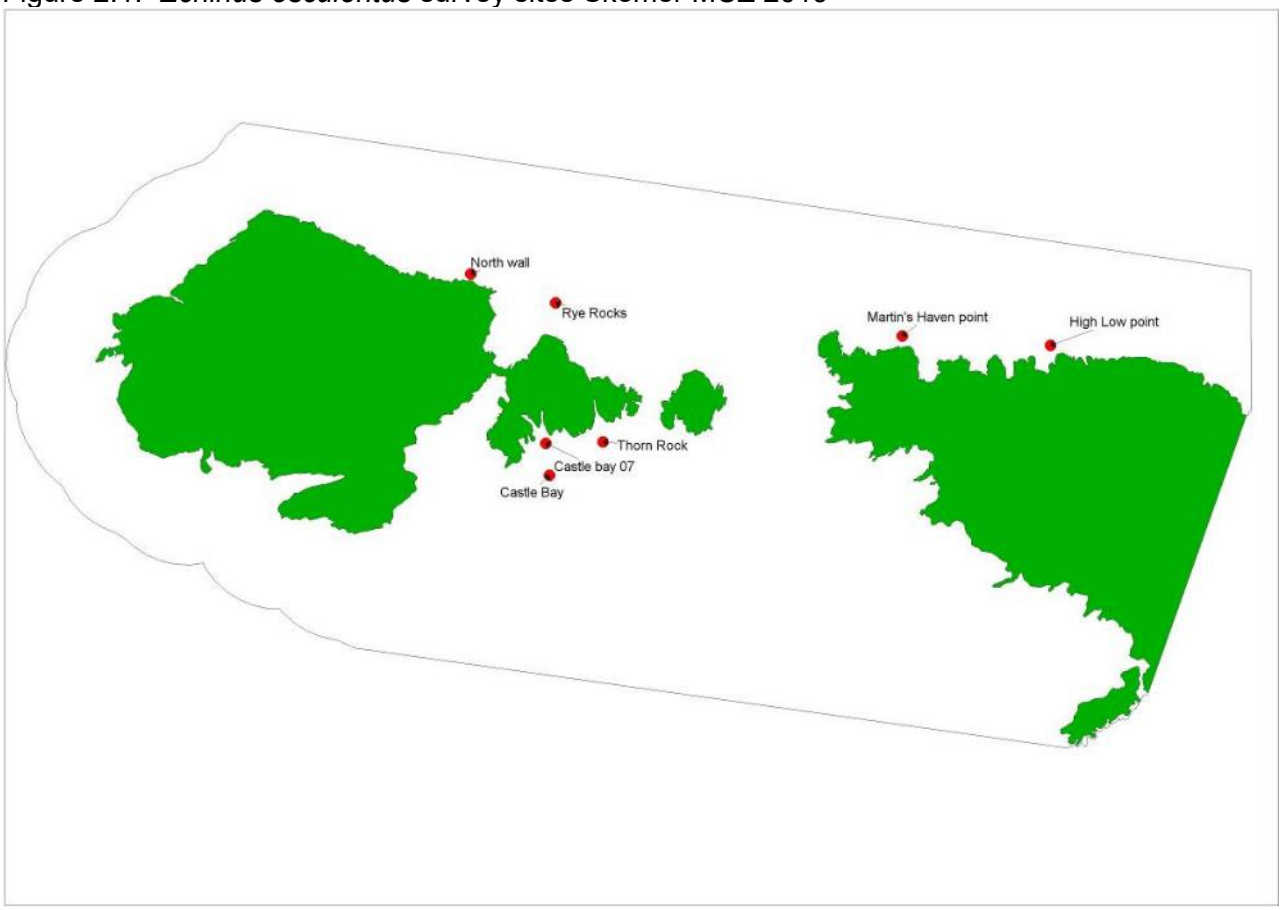
2. Method

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 and 2019 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 and 2019. 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 2019



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. At each site, markers were positioned at 15m bcd and were 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,
- 5m bcd weight secured 10m shallower than the marker.

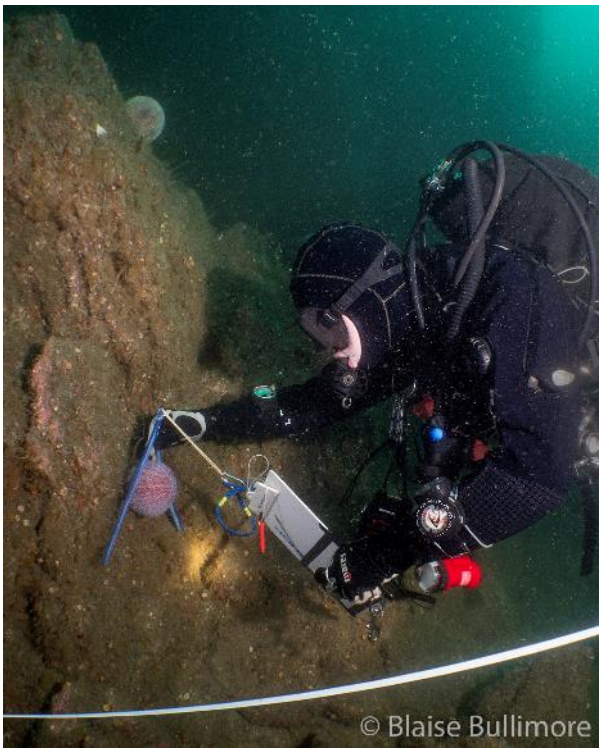
Each dive pair was allocated transects to complete before the dive with the aim to complete 2 transects per dive. The divers completed the method as follows:

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

Figure 2.2. Diver swimming along transect

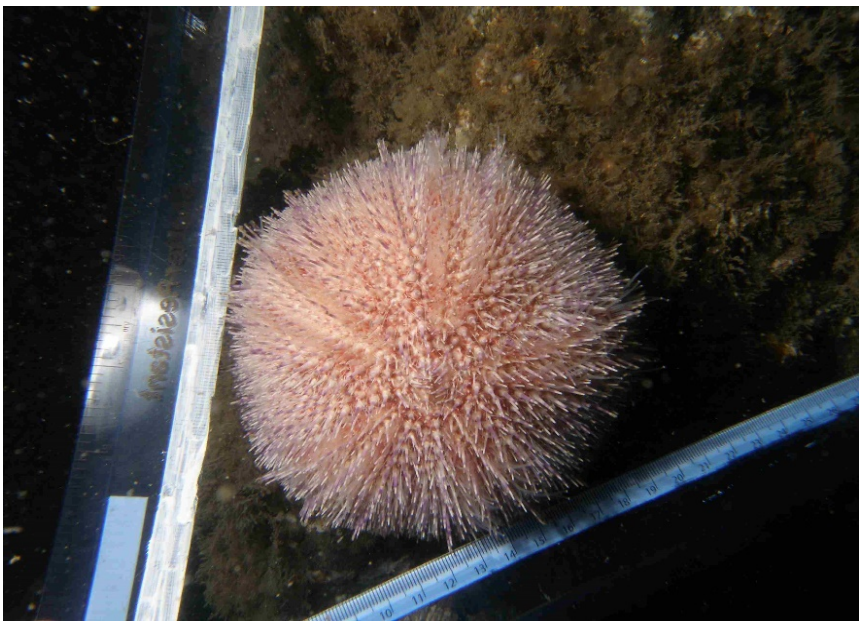
2. Dive pair swim back along the tape counting and measuring *E. esculentus* and counting starfish in a 2m corridor, 1m either side of the tape.

Figure 2.3. Diver measuring *Echinus esculentus*



3. 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:

Figure 2.4. Measuring *Echinus esculentus* with Gibbs urchin divider (photo by Rob Spray)



4. Record any ‘bald’ *E. esculentus*

Figure 2.5.. Bald *Echinus esculentus*

5. Within the 2m corridor, record the total number of each selected starfish species

Figure 2.6. Selected starfish species,
. a) spiny starfish, *Marthasterias glacialis,*

b) common sun-star, *Crossaster papposus*

c) seven-armed starfish, *Luidia ciliaris*

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

7. Repeat the survey at shallower depth.

8. 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 at each of the sites established in 2007 and 2011 (Lock *et al* 2008 & 2012). In 2019, 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). A 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 contractors at the Marine Biological Association.

Figure 2.7. Plankton net deployment.

3. Results

The 2019 survey was carried out by a team of 37 volunteer divers with 20 diving on the 15/16th June and 18 on the 29/30th June.

A total of 144 transects were completed covering an area of 8640 m^2 and a total of 953 *E. esculentus* were recorded and measured, of these 21 were 'bald urchins'. Starfish records were: 145 *M. glacialis*, and no *L. ciliaris* or *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* 2008 & 2012. It was not necessary to resurvey in 2019.

3.2. Echinus esculentus

3.2.1. Density

The mean density in 2019 for Skomer MCZ is 11.11 urchins per 100m^2. The mean density for the Skomer MCZ for each survey year is shown in Table 3.1. A similar number of transects and area surveyed was completed for each survey.

Table 3.1. Summary of density results for *Echinus esculentus* in each survey year

	2007	2011	2015	2019
Transects completed	140	139	151	144
Area covered (m^2)	8400	8340	9060	8640
Total number of Urchins	602	755	879	953
Mean density / 100 m^2	6.87	9.05	9.70	11.11

The mean density of urchins varied significantly between years P<0.1% (1 Way ANOVA F=5.09 f crit 2.62). A tukey test showed the only pair of years with significantly different means were 2007 & 2019 (P=5%), with 2019 having a higher density.

Density results at each site from 2019 are shown in Table 3.2. 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.

Table 3.2. Summary of density results for *Echinus esculentus* 2019 at each site. Site abbreviations: Thorn Rock (TRK), North Wall (NWA), Rye Rocks (RRK), Martins Haven Point (MHV), High/Low Point (HLP) and Castle Bay area (CBY).

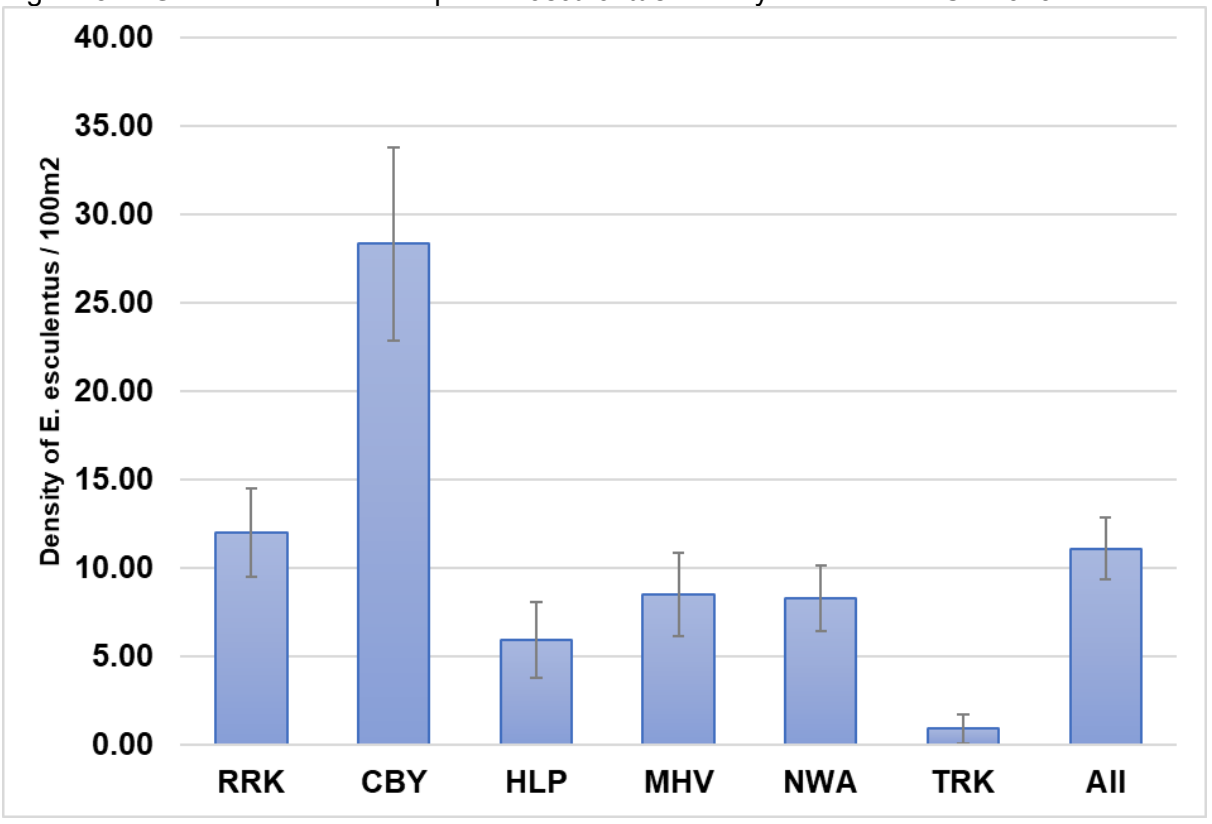
Site	Transects completed	Area covered	Total No of urchins	Mean density per Transect	95%CI (mean / Tx)	Mean Density Per 100m^2	95%CI Mean/ 100m^2	Mean size	95%CI
RRK	31	1860	223	7.19	1.49	11.99	2.49	13.42	0.41
CBY	21	1260	357	17.00	3.29	28.33	5.48	13.45	0.21
HLP	18	1080	64	3.56	1.27	5.93	2.12	13.23	0.60
MHV	27	1620	138	5.11	1.40	8.52	2.34	12.87	0.39
NWA	33	1980	164	4.97	1.13	8.28	1.89	13.72	0.37
TRK	14	840	7	0.54	0.48	0.90	0.79	14.52	1.55
All	144	8640	953	6.66	1.06	11.11	1.72	13.40	0.16

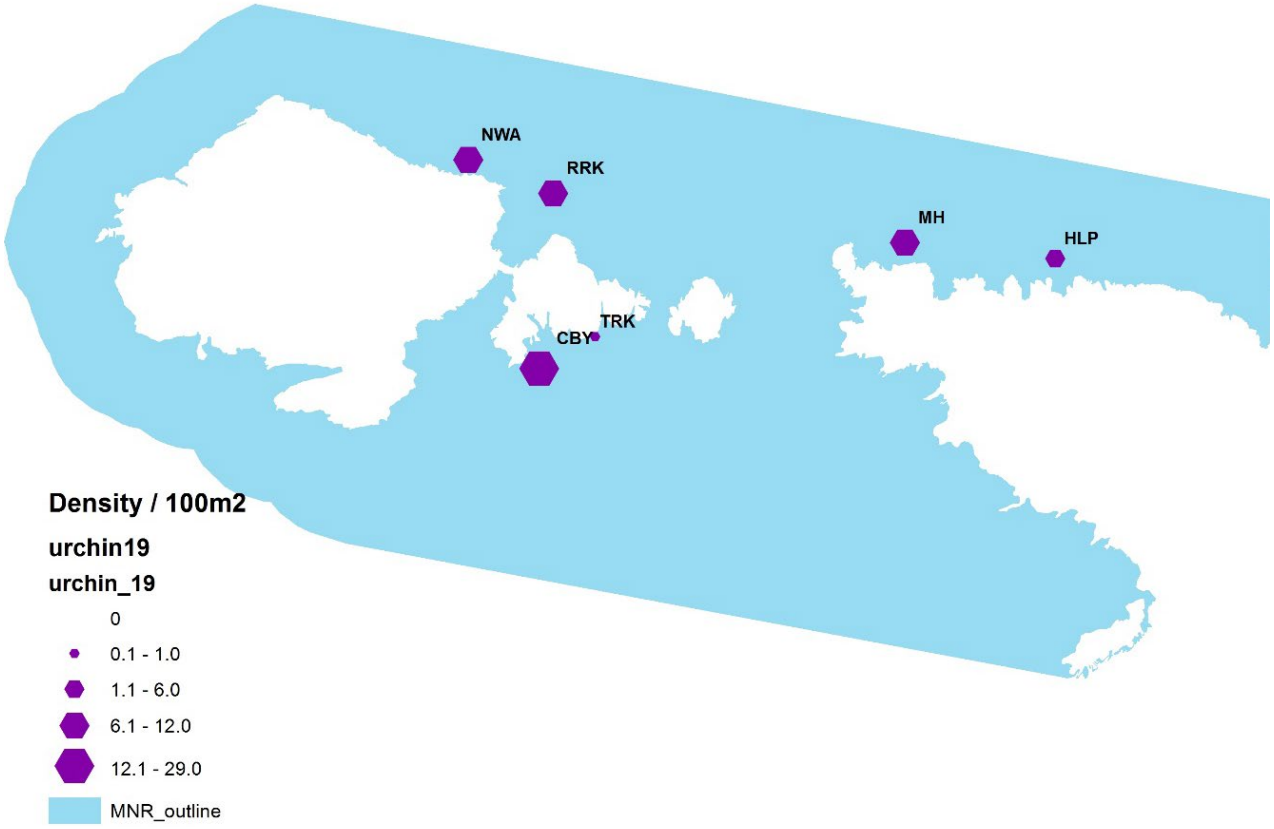
Mean density varied significantly between the sites **p<0.1%** (One-way ANOVA F= 32.7, f crit. 2.28). Castle Bay (CBY) had a significantly higher density (28.33 *E. esculentus* / 100m^2) to all the other sites. Thorn Rock (TRK) had the lowest density (0.90 *E. esculentus* / 100m^2) and this was significantly lower than all the other sites.

Figure 3.1 compares the mean *E. esculentus* densities (per 100m^2) for all the sites surveyed in 2019 with their corresponding 95% confidence intervals. Figure 3.2 gives a visual representation of how *E. esculentus* density varies spatially across the Skomer MCZ.

Figure 3.1. Mean *E. esculentus* density (per 100m^2) at each site 2019. Site abbreviations: Thorn Rock (TRK), North Wall (NWA), Rye Rocks (RRK), Martins Haven Point (MHV), High/Low Point (HLP) and Castle Bay area (CBY)

Figure 3.2. Graduated bubble map of *E. esculentus* density in Skomer MCZ 2019.



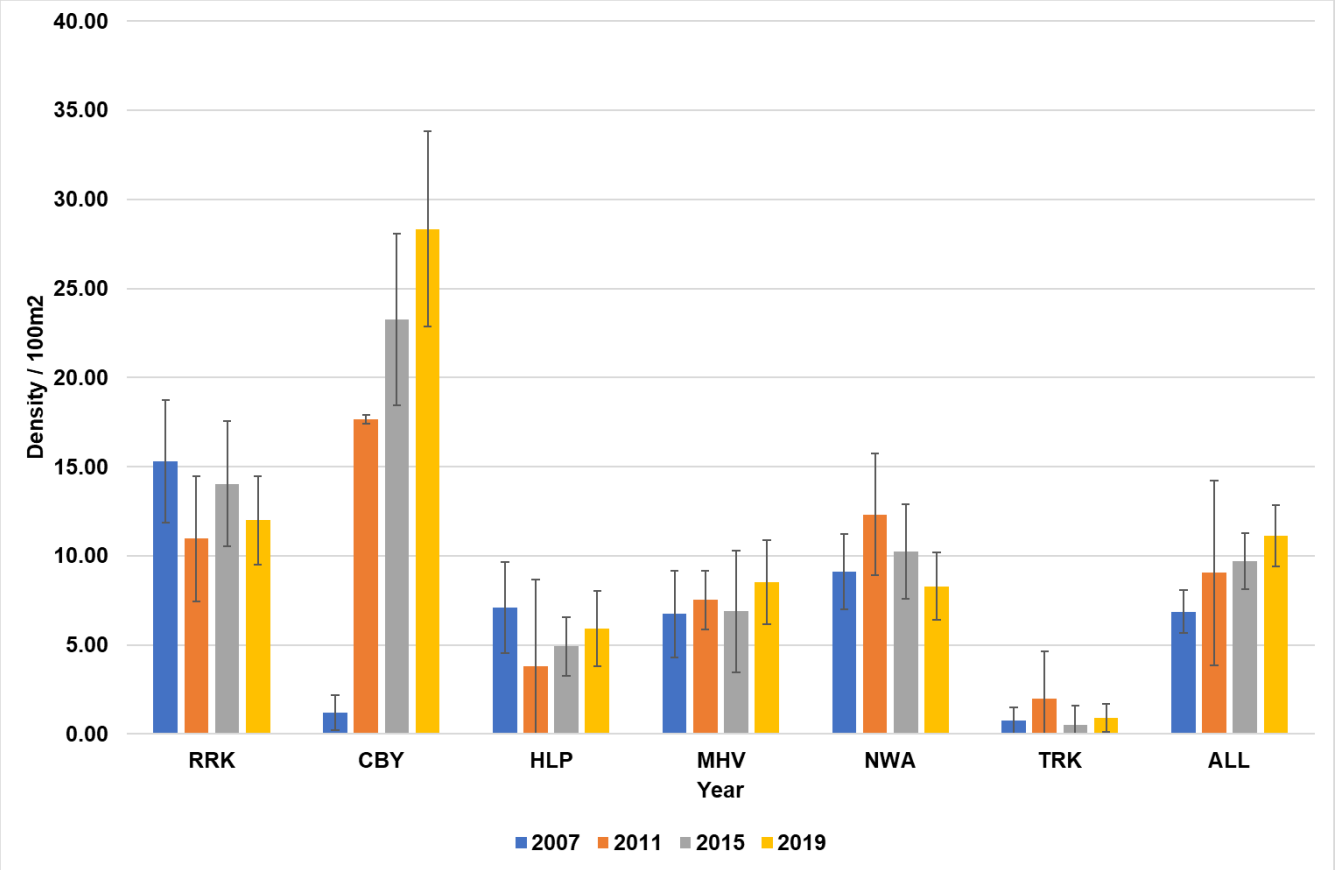


These results can be compared to the 2007, 2011 and 2015 surveys.

Table 3.3. Summary table of *E. esculentus* density results 2007 – 2019

	Mean Urchins / 100m^2				Confidence Intervals (95%)			
Year	**2007**	**2011**	**2015**	**2019**	**2007**	**2011**	**2015**	**2019**
RRK	15.32	10.96	14.05	11.99	3.43	3.50	3.50	2.49
CBY	1.20	17.67	23.25	28.33	0.98	0.26	4.82	5.48
HLP	7.10	3.80	4.94	5.93	2.54	4.87	1.65	2.12
MHV	6.73	7.53	6.90	8.52	2.45	1.65	3.42	2.34
NWA	9.11	12.31	10.26	8.28	2.11	3.42	2.64	1.89
TRK	0.75	1.98	0.53	0.90	0.77	2.64	1.07	0.79
ALL	6.87	9.05	9.70	11.11	1.21	5.18	1.58	1.72

Figure 3.4. Mean *E. esculentus* density (per 100m^2) with 95% confidence intervals at each site for 2007, 2011, 2015 & 2019. Site abbrevations: Thorn Rock (TRK), North Wall (NWA), Rye Rocks (RRK), Martins Haven Point (MHV), High/Low Point (HLP) and Castle Bay area (CBY).



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.

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.

A one-way ANOVA test showed that there was **no** significant difference between the densities of *E. esculentus* found at each depth zone (F = 1.10 f critc 2.67 **not sig @ p 5%)**. This is consistent with results from the previous surveys (Lock *et al* 2008 & 2012, Burton *et al* 2016).

Table 3.4. Summary table of *E. esculentus* density with depth.

Depths	Transects completed	Area covered	Total No of urchins	Mean density per Transect	95%CI (mean / Tx)	Mean density per 100m2	95%CI Mean/ 100m2	Mean size	95%CI
5 M bcd	13	780	75	5.77	2.24	9.62	3.74	13.1	0.5
10 M bcd	64	3840	389	5.98	1.18	9.97	1.96	13.4	0.2
15 M bcd	60	3600	458	7.63	2.01	12.72	3.36	13.5	0.2
20 M bcd	7	420	31	4.43	3.23	7.38	5.38	13.4	0.8

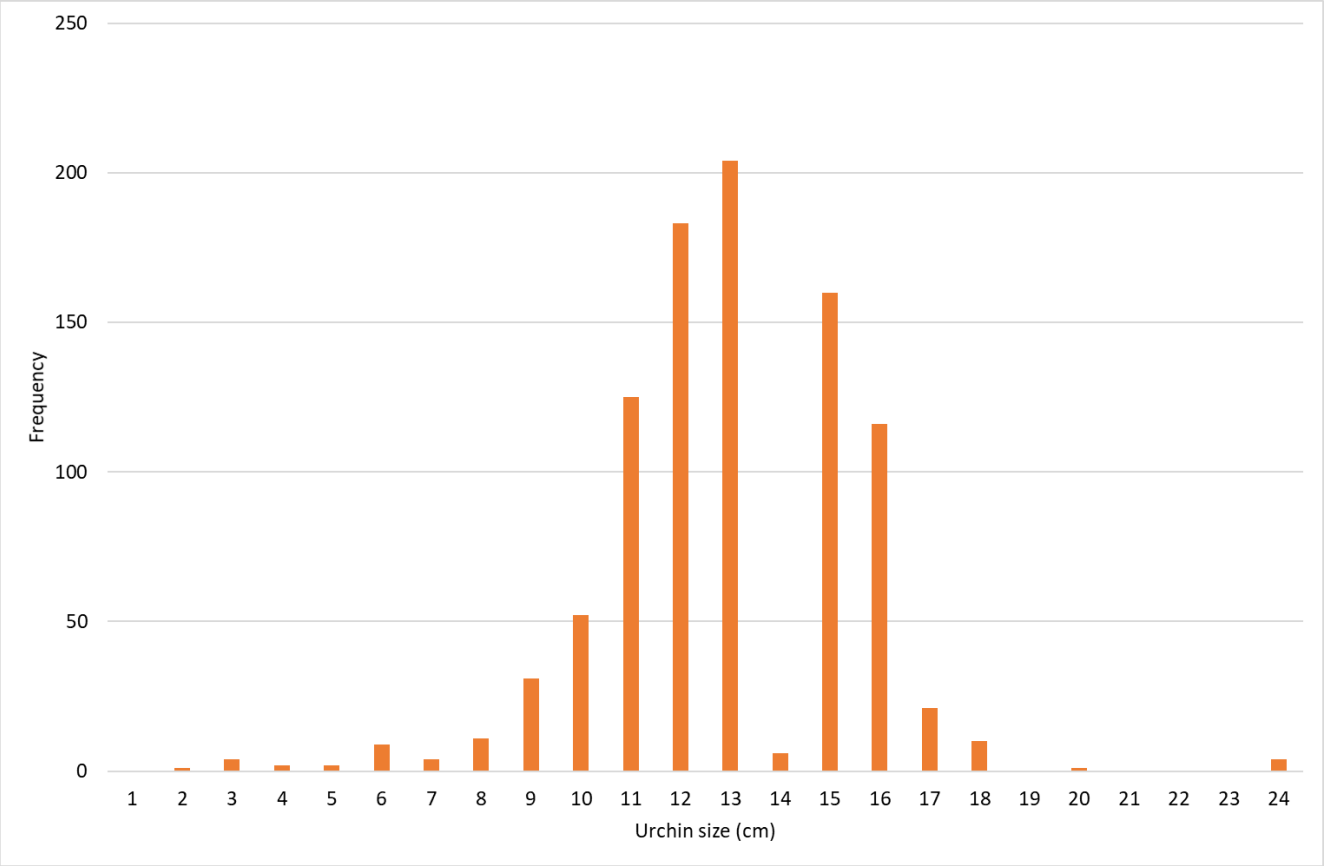
3.2.2. Size of *Echinus esculentus*.

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 3.5, shows a roughly normal distribution. The low results for 14cm are due to an artefact of the conversion from "Gibbs divider" to millimetres and the way the frequency class are constructed. The mean, maximum and minimum diameters were 13.4 cm, 24.3 cm and 2.3 cm respectively.

Figure 3.5. Size frequency distribution for whole MCZ population 2019.



The mean diameter of *E. esculentus* measured in each survey is compared in Table 3.5.

Table 3.5. Mean diameter of *Echinus esculentus* measured in each survey.

Year	2007	2011	2015	2019
Mean diameter (cm)	11.65	13.24	13.34	13.40
95% CL	0.19	0.15	0.14	0.16

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. In 2007 the mean size of urchin was about 1.5cm smaller.

Differences between sites 2007 - 2019

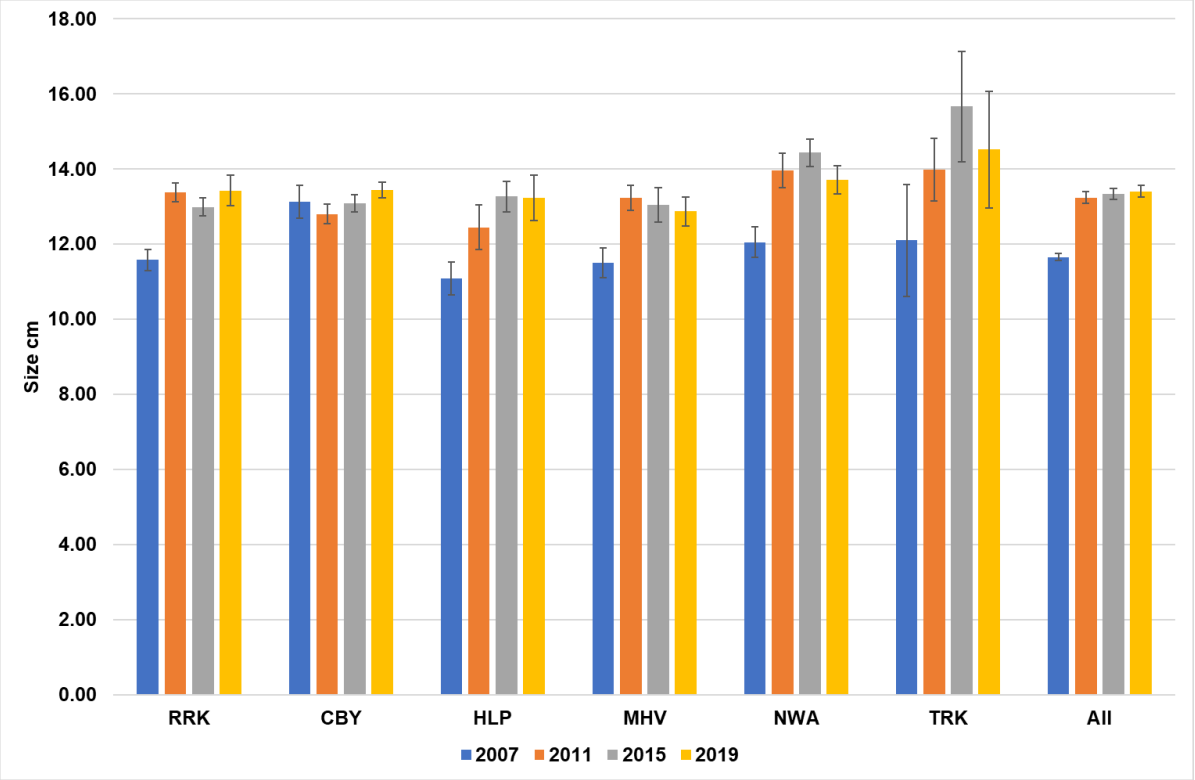
The *E. esculentus* mean diameter found at the 6 sites is compared for 2007 to 2019 results in Table 3.6 and Figure 3.6.

Table 3.6. Summary table of size (cm) differences between sites 2007 – 2019

	Mean				95% CI			
Year	**2007**	**2011**	**2015**	**2019**	**2007**	**2011**	**2015**	**2019**
RRK	11.58	13.38	12.99	13.42	0.28	0.25	0.23	0.41
CBY	13.13*	12.80	13.09	13.45	0.44	0.26	0.23	0.21
HLP	11.08	12.45	13.27	13.23	0.44	0.59	0.41	0.60
MHV	11.51	13.24	13.04	12.87	0.40	0.34	0.46	0.39
NWA	12.05	13.97	14.43	13.72	0.40	0.46	0.36	0.37
TRK	12.10	13.98	15.67	14.52	1.49	0.84	1.47	1.55
All	11.65	13.24	13.34	13.40	0.10	0.15	0.14	0.16

*Note: the 2007 Castle Bay (CBY) site was at a different location.

Figure 3.6. Graph of mean size (cm) across sites with 95% confidence intervals for 2007, 2011, 2015 & 2019



The general trend is 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. Survey results for 2011, 2015 and 2019 show no significant differences in size between any of the sites.

2019 size results between sites & depth zones

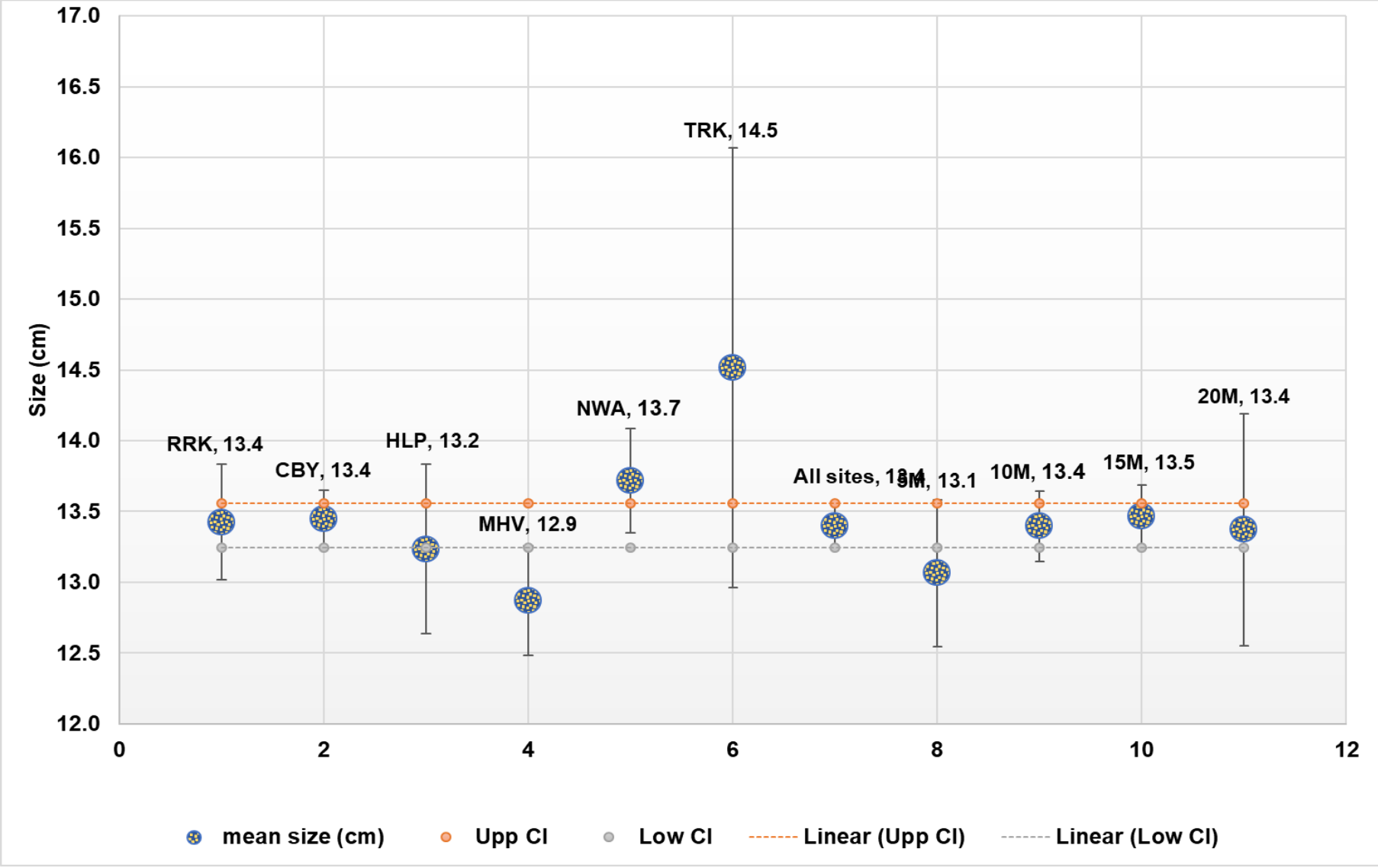
A detailed look at the 2019 results allows a comparison between sites and depth zones, see Table 3.7 and Figure 3.7.

Table 3.7. Mean size (cm) at each site and different depth zones for all sites, 2019.

Site	Mean size (cm)	95% CI
RRK	13.4	0.41
CBY	13.4	0.21
HLP	13.2	0.60
MHV	12.9	0.39
NWA	13.7	0.37
TRK	14.5	1.55
All sites	13.4	0.16
5m	13.1	0.52
10m	13.4	0.25
15m	13.5	0.22
20m	13.4	0.82

Analysis of *E. esculentus* found that there was no difference in mean size between sites or the different depth zones at P 5%.

Figure 3.7. *Echinus esculentus* mean size (cm) at each site, different depth zones and for all sites with 95% confidence intervals, 2019.



3.2.3. Occurrence of "Bald" *Echinus esculentus*

2019 has seen the highest occurrence of 'bald' *E. esculentus* since 2003. 1 record was from Thorn Rock, 3 records from Rye Rocks and 17 records come from the Castle Bay site. The numbers found are still very low, accounting for only 2.2% of the total.

Table 3.8. Numbers of "bald" *Echinus esculentus* 2003 – 2019

	2003	**2007**	**2011**	**2015**	**2019**
Total *E. esculentus*	505	609	755	869	953
Total "bald" *E. esculentus*	0	2	1	10	21

3.3. Starfish Species

In 2019 *M. glacialis* was the only starfish from the targeted list to be recorded and had a mean density of 2.79 urchins per 100m^2.There were no records of either *L. ciliaris* or *C. papposus. C. papposus* has not been recorded on a survey since 2003. *L. ciliaris* was recorded in 2007, 2011 and 2015 but in very low numbers and mainly as juveniles.

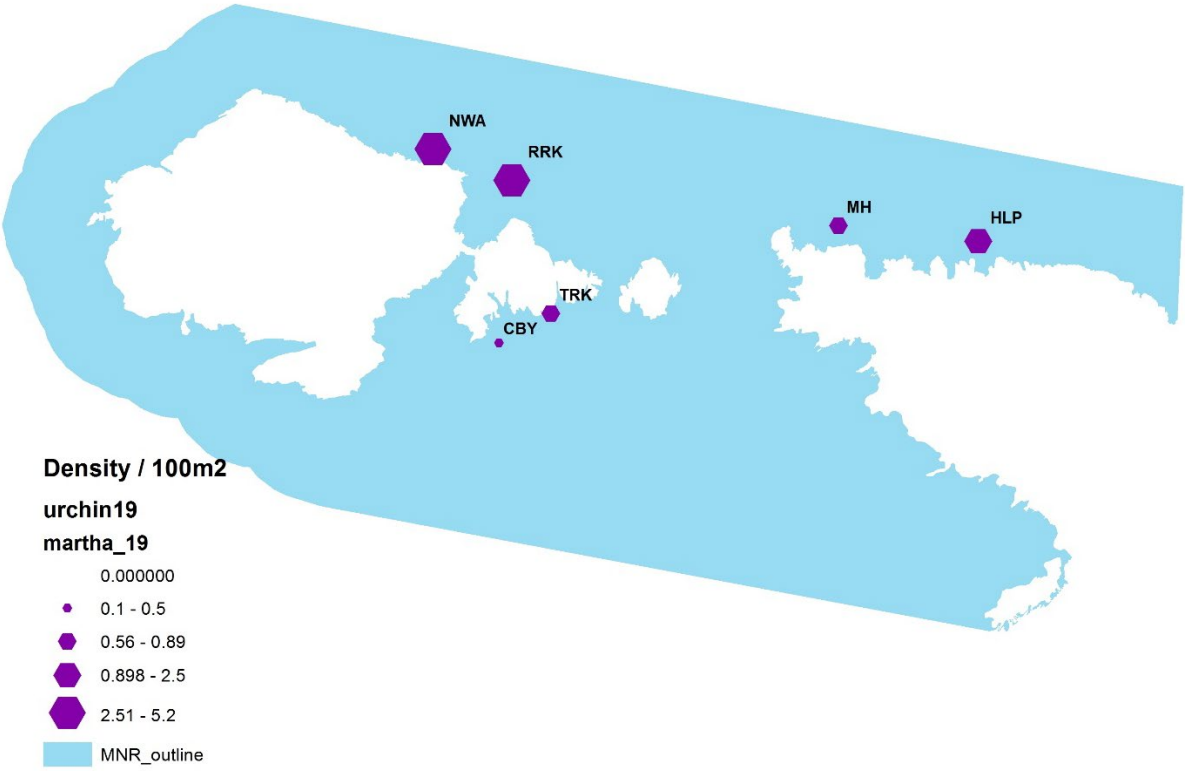
Table 3.9. Starfish records for Skomer MCZ 2003 – 2019

Year	**2003**	**2007**	**2011**	**2015**	**2019**
C. papposus - counts	21	0	0	0	0
M. glacialis – density / 100m^2	4.98	3.47	4.0	2.17	2.79
L. ciliaris - counts	0	2	10	2	0

Table 3.10. Density of *M. glacialis* / 100m^2 at each site 2003 – 2019

Site	**2003**	**2007**	**2011**	**2015**	**2019**
Whole MCZ	4.98	3.47	4	2.17	2.79
HLP	No data	2.9	2.1	1.35	2.5
MHV	No data	2.37	6	0.57	0.77
TRK	No data	1.4	0.6	0.08	0.9
RRK	No data	6.3	6.8	5.48	5.22
NWA	No data	5.3	7.25	4.23	4.44
CBY 2011	No data	No data	1.7	0.58	0.56

Figure 3.8. Graduated bubble map of *M. glacialis* density / 100m^2 Skomer MCZ 2019



3.3. Plankton

Planktonic Echinoderm larvae are seen regularly in the plankton samples taken within Skomer MCZ. In 2019 4 groups of Echinoderm larvae could be identified: echinopluteus (urchins), ophiopluteus (brittlestars), auricularia (Holothorians/sea cucumbers) and brachiolaria (starfish). Their occurrence during the year each peaked at different times. The starfish larvae were found from mid-May to mid- July, peaking in June whilst urchin larvae were found over a longer period from mid-May to mid- September, peaking in July.

Figure 3.9. Percentage abundance of Echinoderm larvae in plankton samples within Skomer MCZ 2019

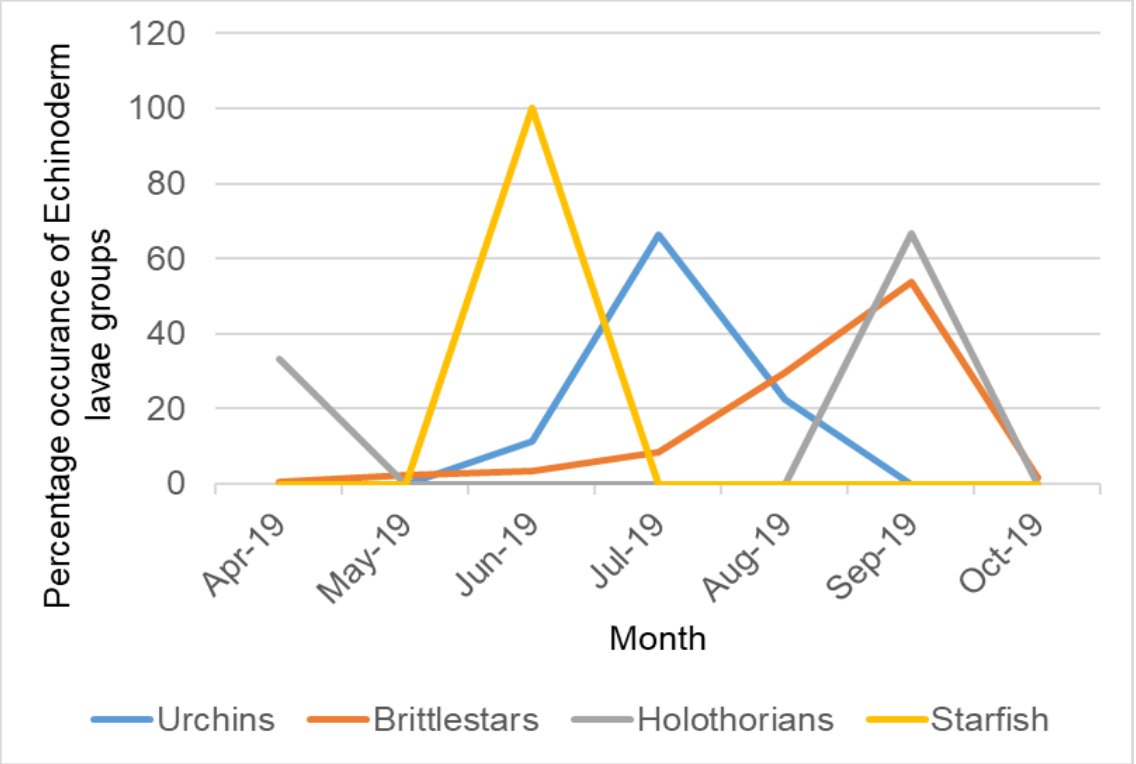
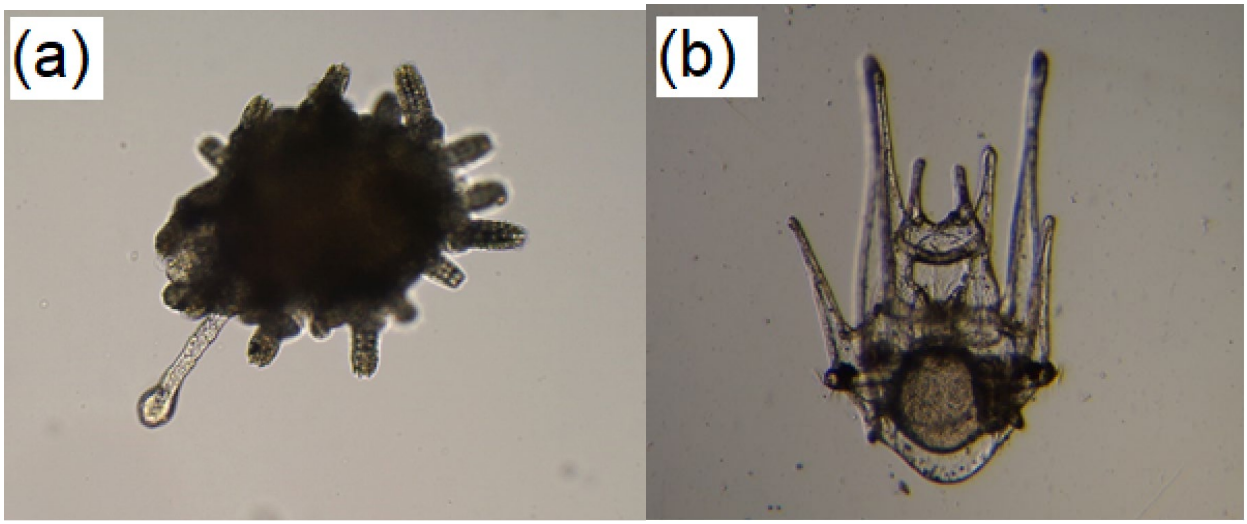


Figure 3.10. (a) *Echinus esculentus* early larva, (b) *Echinus esculentus* pluteus larva



4. Discussion

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.

Table 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	Not available	Nichols (1984)
Millport 1984	160	140 - 304	Nichols (1984)
Skomer 1982	5.5	Not available	Bishop (1982)
Skomer 2003	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)
Skomer 2019	11.1	0.9 - 28	Lock *et al* (2020)

Survey site variations in densities were observed in each of the surveys from 2003 to 2019 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 2019, the highest *E. esculentus* density was recorded at Castle Bay as was found in 2011 and 2015. The mean density in 2019 of 28.33 urchins per 100m^2 was a significant increase from the mean densities in 2015 of 23.3 urchins per 100m^2 and in 2011 of 17.67 urchins per 100m^2. 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).

Figure 4.1. *Echinus esculentus* habitat at Castle Bay

The mean densities in 2019 found at all other sites did not show a significant change to previous years, although slightly higher or lower mean densities were recorded.

Rye Rocks and North Wall are located on the north side of Skomer, mean densities at these sites were slightly lower than that recorded in 2015, Rye rocks had a density of 11.99 urchins per 100m^2 in 2019 compared to 14.05 urchins per 100m^2 in 2015, whilst at North Wall there were 8.28 urchins per 100m^2 in 2019 compared to 10.26 urchins per 100m^2 in 2015. 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.

Martins Haven located along the north Marloes Peninsula had an increase in density with 8.52 urchins per 100m^2 in 2019 compared to 6.90 urchins per 100 m^2 in 2015. High Low Point also on the north Marloes Peninsula had lower densities with 5.93 urchins per 100m^2 in 2019 and 4.94 urchins per 100 m^2 in 2015. 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 0.77 urchins 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 observed on a bedrock habitat sheltered from wave action and exposed to fast tidal streams. Luddington *et al* (2004) and Lock *et al* (2008 & 2012) both confirmed these observations and the findings of the 2019 survey were again consistent with the previous studies at Skomer.

Studies have shown variable trends of *E. esculentus* density with depth. The 2019 survey showed that there was no significant difference in density with depth and this reflected the results found in both the 2011 and 2015 surveys. These results also mirrored the findings of Nichols *et al* (1985) who showed no significant difference in density between shallow (8-10m) and deep (20-22m) sites. However, other studies have shown 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 shallow rather than deep water.

4.2. *Echinus esculentus* size

The mean diameter of *E. esculentus* at Skomer in 2019 was compared with the mean diameters recorded for Skomer and other locations in the UK.

Table 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)
Skomer 2019	13.4	Lock *et al* (2020)

Bishop & Earl (1984) observed a striking contrast between mean diameters of the St Abbs and Skomer populations. Looking at mean diameters reported at other locations those at Scottish sites, St Abbs and Isle of Skye closely match as do the southwest Britain sites, Skomer and Lamorna Cove. This 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, 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 the observations from other studies that the mean size of *E. esculentus* from Scottish waters is generally below that of urchins from southwestern Britain. The Skomer surveys from 2007 to 2015 all had individuals up to 20cm diameter and in 2019 the maximum size recorded was 24.3 cm diameter. This suggests that the growth patterns of the Skomer population more closely match those of southwest Britain populations, where sea water temperatures are similar, rather than 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 12-14 cm which could suggest an aging population. However, these surveys also show a good spread of diameters with size range in 2019 of 2.4-24.3 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 subsequent surveys the divers were briefed to search carefully for small urchins whilst completing transects. This resulted in smaller *E. esculentus* individuals being found compared to the 2003 survey.

The 2019 survey showed that the mean size of *E. esculentus* was very similar at each depth zone. The results have varied over the years, in 2015 the mean size was significantly smaller at 5m and significantly bigger at 20m, it was suggested that possibly the smaller *E. esculentus* prefer the shallower depth in the kelp forest habitat. However, the results from each survey is variable and likely due to fewer transects being completed at the 5m and 20m zones. The 20m zone is difficult to survey due to restricted dive times and the 5m zone is not available at all the sites (Thorn Rock, Castle Bay). Similar numbers of transects would need to be completed at each depth zone to be able to make a more accurate analysis.

It is possible that the larval settlement at Skomer is different to the Scottish sites. Bishop (1982) suggested that the moderate and high currents around Skomer may be completely inhospitable to larval settlement and to juveniles, whose preferred habitat may be in much deeper water (>50m) offshore. Rostron (2000) reported that deep sites offshore from 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 due to restrictions necessary for safe SCUBA diving. Plankton sampling in the Skomer MCZ during 2019 identified Echinoderm echinopluteus larvae from mid-July to mid-September with peak numbers in July. Identification of some of the larvae samples to species level was also carried out and *Echinus esculentus* larvae were present.

4.3. ‘Bald’ *Echinus esculentus*

Bald urchin disease is a bacterial disease known to affect several species of sea urchin. Jangoux (1987) showed that two pathogens were responsible for the disease. Infection generally occurs at the site of an existing physical injury causing the affected area to change colour and the spines to be lost. Jangoux (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. 21 ‘bald’ *E. esculentus* were recorded in 2019 accounting for only 2.2% of the total urchins recorded, 17 were from Castle Bay site where the highest numbers of *E. esculentus* were recorded, 3 from Rye Rocks and 1 at Thorn Rock. 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

M. glacialis was found throughout the MCZ in 2019 showing a similar distribution to those in the previous surveys. This reflects the wide range of habitats in which *M. glacialis* commonly occurs (Picton, 1993) and that *M. glacialis* is found in similar habitats to *E. esculentus*. The mean density closely matched that recorded in 2015 across all sites, but these results were lower than those recorded in 2007 and 2011.

C. papposus was not recorded in 2019. 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 several sites in Skomer MCZ and in Pembrokeshire but in very low numbers. *C. papposus* is often found with its preferred food, brittle stars. In 2019, Seasearch divers recorded a single *C. papposus* on the Collier wreck, located in Milford Haven entrances (Lock *pers. comm.*), although they have been rarely recorded on Seasearch dives at Pembrokeshire sites.

L. ciliaris was not recorded in 2019. Only very low numbers have been recorded on previous surveys: two in 2015, ten 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. 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 several 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 and used in subsequent surveys to allow comparisons between surveys.

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

4. Increased effort should be made 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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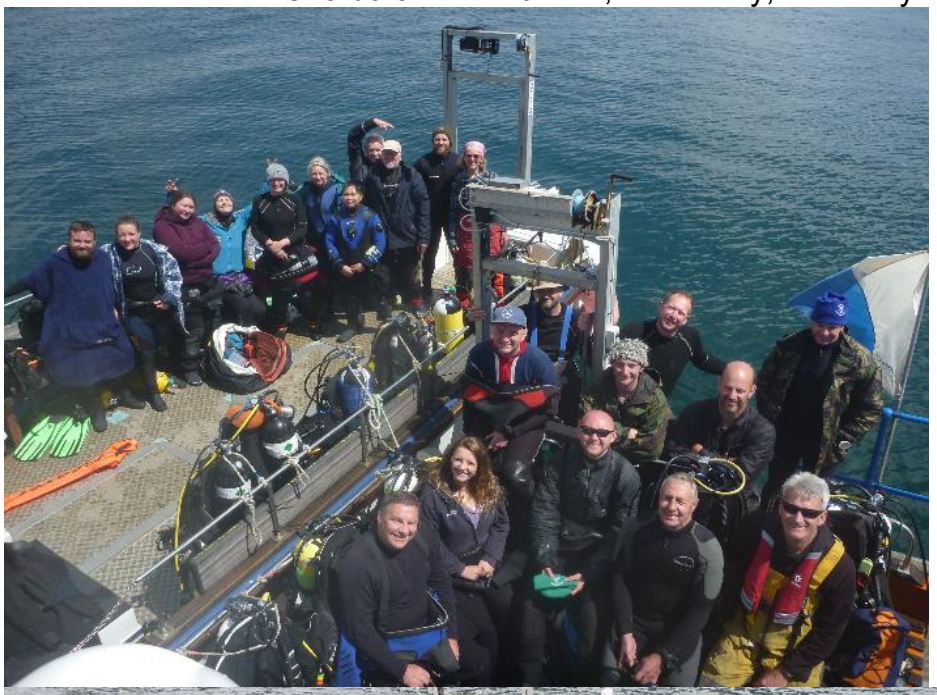

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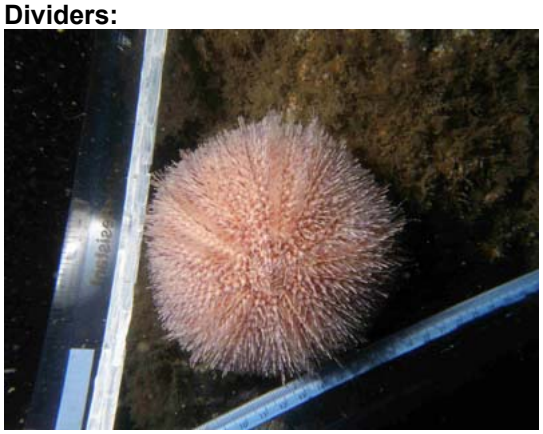
8. Appendix

‘Gibbs urchin divider’ data

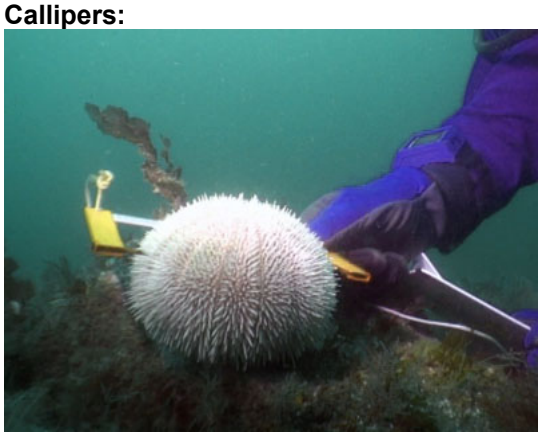
To improve size measuring of *E. esculentus* a new set of dividers were developed, constructed from two plastic rulers, which are more robust and operationally simpler than a set of callipers. The dividers are fixed at an angle of 60º with the apex of the triangle at the 4 cm mark on the rulers.

***E. esculentus* measuring techniques**

Dividers:

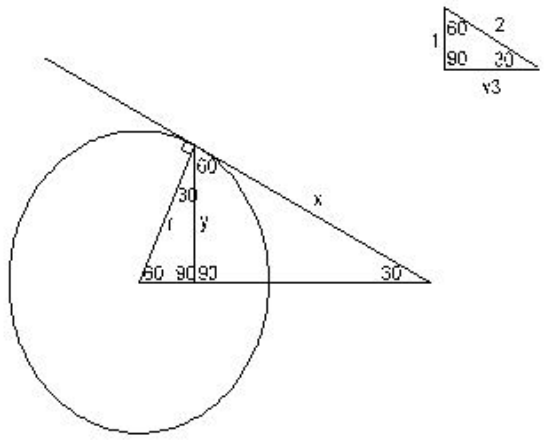


Callipers:



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.

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



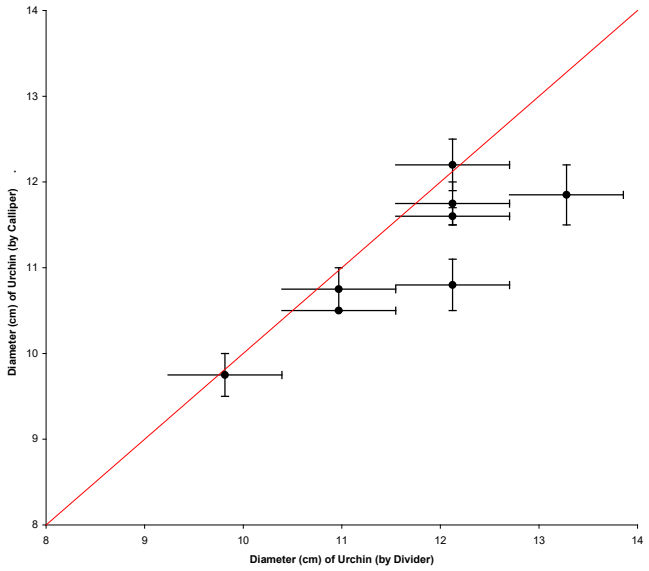
x = divider reading – 4
y = ½ · x
r = 2/(√3) · y
∴ r = x / (√3)
Circle diameter = 2r

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.

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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