Skomer MCZ Scallop Survey 2022

NRW Evidence report 655

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[Photo credit: Becky Tooby]

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Contents

Crynodeb Gweithredol

Yn 2022 cafodd arolwg o boblogaeth cregyn y brenin (*Pecten maximus*) ym Mharth Cadwraeth Morol (PCM) Sgomer ei gynnal am y chweched tro ers 2000. Mae codi cregyn y brenin “drwy unrhyw ddulliau” wedi’i wahardd o fewn PCM Sgomer ers 1990.

Cwblhaodd tîm o 23 o wirfoddolwyr 39 o drawsluniau arolwg o gregyn y brenin yn cwmpasu ardal o 2280m^2 o fewn PCM Sgomer. Casglwyd cyfanswm o 1414 o *P. maximus,* a mesurwyd pob un a’u rhyddhau, yn fyw, yn ôl i’r PCM.

- Amcangyfrifwyd mai dwysedd cyfartalog *P. maximus* o fewn PCM Sgomer oedd 62 / 100m^2 (gan ddefnyddio dull dwysedd cyfartalog syml). Mae hyn yn gynnydd o 12.4 gwaith ers 2000. Amcangyfrifir bod dwysedd cyn y dynodiad (1984) yn 1-1.2 / 100m^2. Y dwysedd uchaf o *P. maximus* a gafwyd mewn unrhyw un trawslun yn 2022 oedd 182 / 100m^2.

- Mae tystiolaeth gref o hyd o niferoedd da o *P. maximus* ifanc yn cael eu recriwtio i’r boblogaeth.

- Mae dwysedd a strwythur oedrannau yn dal i fod yn amrywiol iawn rhwng safleoedd.

- Mae cynnydd o hyd yn nifer yr achosion o’r brennig ymledol *Crepidula fornicata*. Yn arolwg 2022, roedd 7.6% o’r achosion o *P. maximus* a ddarganfuwyd o fewn safleoedd PCM wedi’u coloneiddio gan *C. fornicata*.

Mae’r canlyniadau hyn yn dangos bod yr is-ddeddfau sy’n amddiffyn *P. maximus* o fewn PCM Sgomer wedi bod yn effeithiol wrth ganiatáu i’r boblogaeth wella o’r dwysedd isel iawn a gafwyd cyn y dynodiad.

Ychydig a wyddys am o ble y daw unigolion newydd a ble mae larfâu yn setlo yn y pen draw. Prin y ceir unrhyw enghreifftiau o *P. maximus* o ddosbarth oedran 1 i 2 flynedd yn unrhyw un o’r arolygon. Efallai y bydd angen dull gwahanol ac ardal chwilio wahanol er mwyn dod o hyd i’r unigolion newydd ifancaf hyn.

Executive Summary

In 2022 a survey of the population of the King scallop (*Pecten maximus*) in the Skomer Marine Conservation Zone (MCZ) was repeated for the sixth time since 2000. The removal of King scallops “by any means” has been prohibited within the Skomer MCZ since 1990.

A team of 23 volunteers completed 39 scallop survey transects covering an area of 2280m^2 within the Skomer MCZ. A total of 1414 *P. maximus* were collected which were all measured and released, alive, back into the MCZ.

- The average density of *P. maximus* within the Skomer MCZ was estimated to be 62 / 100m^2 (using simple average density method). This is a 12.4-fold increase since 2000. Densities pre-designation (1984) are estimated at 1-1.2 / 100m^2. The maximum density of *P. maximus* in any one transect in 2022 was 182 / 100m^2.

- There remains strong evidence of good recruitment of young *P. maximus* in to the population.

- Densities and age structure remain highly variable between sites.

- There continues to be an increase in the occurrence of the invasive slipper limpet *Crepidula fornicata*. In the 2022 survey 7.6% of *P. maximus* found within MCZ sites were colonised with *C. fornicata*.

These results show that the byelaws protecting *P. maximus* within the Skomer MCZ have been effective in allowing the population to recover from very low densities found before designation.

Little is known about where recruits come from and where larvae end up settling. Hardly any 1 to 2 year age class *P. maximus* are found in any of the surveys. A different method and search area may be required to find these youngest recruits.

1. Introduction

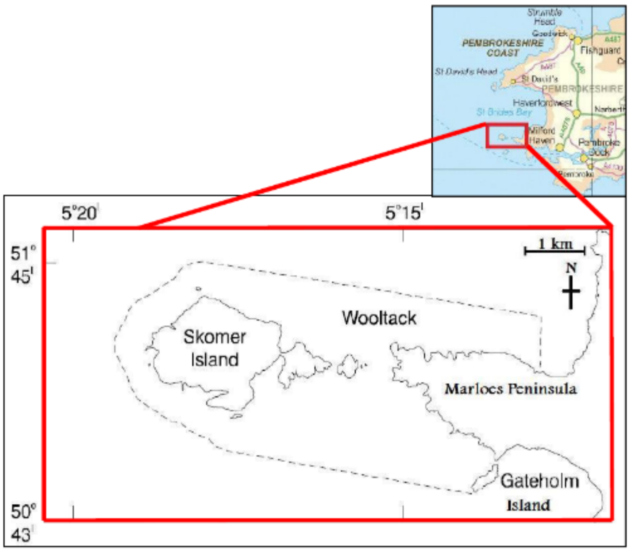
Pecten maximus (Linnaeus, 1758), the King scallop, is found in the Skomer Marine Conservation Zone (MCZ) (Figure 1). The *P. maximus* population in the Skomer MCZ has been protected since July 1990 upon designation of the, then, Marine Nature Reserve (MNR).

Inshore fisheries around South Wales were regulated by The South Wales Sea Fisheries Committee (SWSFC). In April 2010, the implementation of the Marine and Coastal Access Act 2009 in Wales effectively abolished the two Sea Fisheries Committees in Wales and their duties and functions were taken on by Welsh Government. The Skomer MCZ byelaws originally created by the SWSFC were among those adopted by the Welsh Government and continue to be in force.

Welsh Assembly Government Inshore Fisheries Legislation byelaws numbers 27 and 28 (Appendix 1) prohibit the use of dredges or beam trawls as well as the removal of *P. maximus* and *Chlamys opercularis* (now *Aequipecten opercularis*) from the Skomer MCZ by any means.

Seabed protection outside the MCZ was further enhanced by the introduction of the Scallop Fishing (Wales) Order 2010, which has prohibited dredging for King scallop within 1 nautical mile of the Welsh coast.

Figure 1. Map indicating the boundary limits of the Skomer Marine Conservation Zone (dashed line). Map adapted from Rogers, 1997. Scale map from Ordnance.



Prior to designation as a Marine Nature Reserve in 1990 the sea bed around Skomer was dredged commercially for scallops, and scallops were collected by divers.

Bullimore (1985) reviewed the *P. maximus* survey data that were available from the MCZ between 1979 and 1984 and assessed the status of the population at that time. These surveys estimated extent of habitat suitable for *P. maximus* in Skomer MCZ; *P. maximus* density; age frequency distribution; first year growth bands and annual growth rates for individuals. These results suggested very low densities of scallops of 1 to 1.2 scallops / 100m^2 (Lock 2001 & Bullimore 1985).

Repeat surveys have been carried out in an attempt to monitor recovery of the population since the creation of the SWSFC bylaw in 1990. The 2000 survey of *P. maximus* was carried out by a team of volunteer divers guided by MCZ staff and established the field methods at three survey sites. In 2004 the survey was repeated at these three sites and a further four sites were established (Luddington *et al* 2004). These field methods were used at the seven sites in the surveys of 2008, 2012, 2016 and 2022.

The scallop survey is scheduled on a 4-yearly basis. However, the 2020 survey was delayed until 2022 due to suspension of fieldwork during the Coronavirus pandemic.

Survey results in 2000 showed an increase in *P. maximus* density compared to the 1984 survey data. Subsequent surveys show a continuation of this trend, with an overall increase in *P. maximus* density. Two spat collectors were deployed in 2005 and 2006, but only a single *P. maximus* spat was found. Further collectors were deployed in 2012 (Apr- Sep) but no *P. maximus* spat were found.

In 2012 a survey area was set up outside the boundary of the MCZ in an area known to have been dredged in 2008.

Crepidula fornicata, the slipper limpet is a non-native species first introduced to the UK in the late 1800s from America. It lives in groups, forming curved chains of up to 15 animals attached to stones and shells mainly in mixed sediment habitats. Its UK northern limit of distribution is in Wales and it is abundant in parts of the Milford Haven Waterway where its invasive nature competes with and displaces other filter-feeders like oysters and mussels (Bohn 2012). It was first found in the Skomer MCZ during the 2008 survey when two individuals were found attached to a *P. maximus* shell. It has been found attached to scallop shells in all subsequent surveys.

1.1 Survey objectives

This survey aimed to establish the current status of the *P. maximus* population in the Skomer MCZ and compare the results to previous surveys. It also aimed to repeat the 2012 and 2016 study area outside of the Skomer MCZ boundary, a site where scallop dredging occurred in 2008.

Survey objectives:

1. To determine the density of *P. maximus* at selected sites;

2. To determine *P. maximus* population dynamics: age distribution and size distribution and growth rates;

3. To compare results with previous surveys;

4. To record the invasive slipper limpet, *Crepidula fornicata*;

5. To re-survey the study site in St Brides Bay (outside of the Skomer MCZ boundary).

2. Method

2.1 Site selection

The 2000 survey of *P. maximus* established the field methods at three survey sites within the MCZ.

In 2004 an additional four sites were added within the MCZ following reconnaissance dives to assess their suitability as *P. maximus* survey sites. These seven sites have been used for all subsequent surveys. Sites have a recorded GPS position and are marked with a buoyed sinker for the duration of the survey.

In 2012 a new site was established in St Brides Bay as a study site outside of the MCZ in an area which was known to have been dredged for scallops in 2008. In 2016 the seabed at this site was found to have changed, sediments had shifted and it was no longer a suitable habitat for scallops. The site was therefore relocated in 2016 (200m away from the original site) and this new site was re-surveyed in 2022.

Pecten maximus is deemed a “sensitive species” exempt from general data release, meaning the exact locations of these sites cannot be published in this report.

2.2 Diving field method

In 2000 a method suitable for volunteer divers was established and this has been repeated in the 2004, 2008, 2012, 2016 and 2022 surveys.

Survey transects are conducted from each site marker, following compass bearing directions: N, NE, E, SE, S, SW, W and NW where topographic features allow. Survey transects are completed by divers working in buddy pairs. Each pair is equipped with a surface marker buoy (SMB), a compass, net bags, a torch and a 50m tape measure.

The divers attach the tape measure to the fixed marker on the seabed and swim together laying out the tape for 50m on an allocated compass bearing. The divers swim back along the length of the laid tape, scallops are collected with one diver positioned on either side of the tape. The divers search for all *P. maximus* found in 2m wide corridors on either side of the tape (giving a total width of 4m) collecting the animals into net bags. This is repeated by swimming back along the tape collecting any *P. maximus* missed during the first pass. The divers return to the boat with the collected *P. maximus* where they are kept alive in labelled buckets of clean aerated seawater.

At some sites it is not appropriate to complete full 50m transects due to changes in benthic substrate and in these cases transects are omitted or reduced in length. At sites where high densities are found or if diving conditions are difficult due to low visibility then transects are reduced to 30m in length and transect width may also be decreased to a 2m band. On completion of every dive the direction, length and width of each transect is recorded to enable the survey area to be calculated for each transect.

In the 2022 survey poor diving conditions and low visibility on the volunteer survey weekends meant that the survey transects at all the Skomer MCZ sites were reduced to 30m long x 2m wide (1m either side of tape). St Brides sites remained 50m long x 4m wide.

2.3 Field recording on the surface

On the boats, part of the flat side of each *P.maximus* shell is cleaned using a scrubbing brush until the series of growth rings are clearly visible.

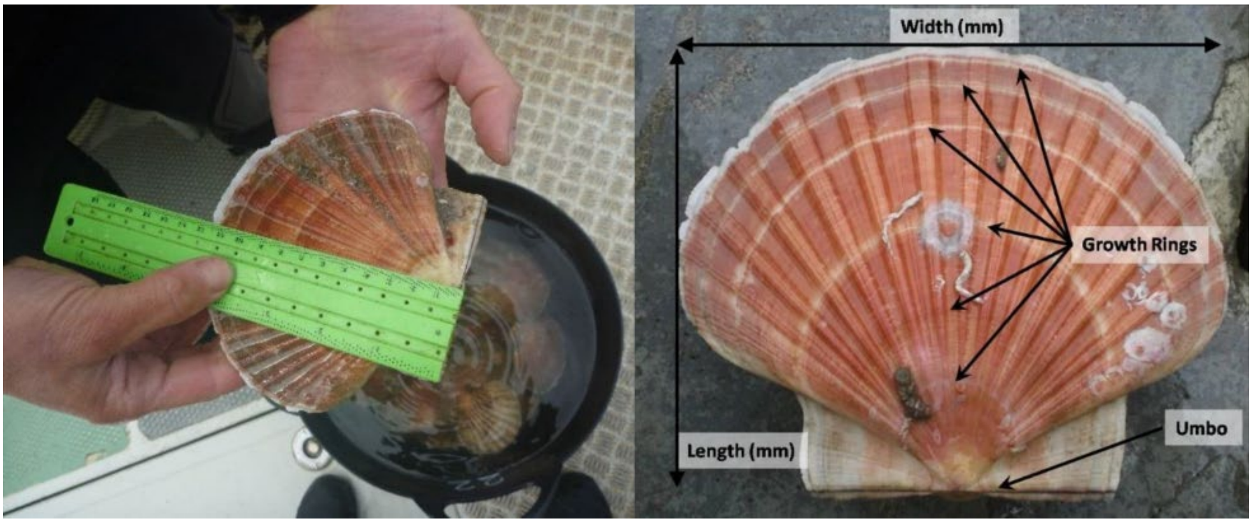
Length and width measurements are recorded. Growth rings are measured from the umbo (hinge line) to each annual growth check ring on the flat valve, as shown in Figure 2.

Each *P. maximus* is marked with a filed notch 2-3mm into the edge of the hinge to ensure that no scallop is measured twice during the survey (as surveys are conducted every four years, notches from previous surveys are far less obvious and cannot easily be mistaken for “current year” notches).

Once *P. maximus* from each transect have been measured, recorded and marked they are returned alive to the sea in the area immediately surrounding the site marker buoy from which they have been removed.

During subsequent transects any *P.maximus* collected bearing a notch is omitted from further recordings.

Figure 2. Length and width dimensions measured and the position of the annual growth rings relative to the umbo of the shell.



2.4 Recording *Crepidula fornicata*

All *P. maximus* brought to the surface are inspected for the presence of *C. fornicata* (Figure 3). Any *C. fornicata* found are counted before being carefully removed from the scallop and destroyed (by desiccation and disposal to domestic composting bin). *C. fornicata* are not returned to the sea.

Figure 3. *P.maximus* with *C.fornicata* attached [Photo credit: Becky Tooby].

3. Results

In 2022 a total of 39 transects were completed across 7 sites within the Skomer MCZ and a further 9 transects were completed at the St Brides Bay site.

Due to poor weather conditions on one survey weekend, one day had to be cancelled and as a consequence, the number of volunteer survey dive days was reduced from 4 to 3 days. The number of volunteer divers participating in the survey was also lower than in previous years. Consequently, fewer transects were completed during the volunteer weekends. Additional surveys were completed by the Skomer MCZ team however the total number of transects surveyed in 2022 were less than the previous four surveys (2004-2016).

Skomer MCZ sites:
Total number of scallops counted - **1414**
Total area surveyed - **2280m^2**
Crepudila fornicata present at all sites with the exception of site 3.

St Brides Bay site:
Total number of scallops counted - **42**
Total area surveyed - **1720 m^2**
Crepidula fornicata found only on one scallop at this site.

The survey effort completed from 1984 to 2022 is shown in Table 1.

Table 1. Survey effort at Skomer MCZ

Year	*P.maximus* Total	Survey Area (m^2)	MCZ Transects Completed	Notes
1984	36	*Not applicable (Timed Searches)*	10	Not a comparable method. Density estimate of 0.01 / m^2
2000	155	3400	17	3 sites surveyed.
2004	1292	11120	63	7 sites surveyed including the original 3 sites from 2000 and 4 new sites.
2008	1661	9780	61	7 sites surveyed
2012	913	3480	49	7 sites surveyed. Transect area reduced due to poor visibility. St Brides survey site added
2016	2534	8620	60	7 sites surveyed. Good visibility. St Brides survey repeated
2022	1414	2280	39	7 sites surveyed. Transect area reduced due to poor visibility. St Brides survey site added. St Brides survey repeated

3.1 Density of Scallops in Skomer MCZ

3.1.1. Average densities

Comparable data exist for scallop density at sites within the MCZ from 2000 onwards but an estimate of density for 1984 can also be made (Lock 2000).

In 2000 only 3 sites were surveyed; 7 sites were used in all subsequent surveys.

For the 2016 report, data from previous surveys were re-analysed to ensure consistency in how the densities are calculated:

- All notched *P. maximus* were removed from the density counts.
- *P. maximus* with erroneous measurement data were included in the density counts but excluded from the size / age class analysis.
- Extra transects on which *P. maximus* were counted but no biometric data was measured were included in the density counts.
- Zero transects (no *P. maximus* found) were included in the density count.

The above criteria were applied to the 2016 data and again to the current 2022 data.

There are different methods of calculating the overall average density of scallops per m^2 for the entire surveyed area within the Skomer MCZ (Table 2):

1. **Simple average**: Total number of *P. maximus* / total area surveyed.

2. **Simple site density average**: Total number of *P. maximus* at each site / total area surveyed at each site. Then average these values to obtain an overall average.

3. **Site transect density average**: Calculate a density for each transect at each site then average these densities. Then average the 7 site average densities to get an overall average.

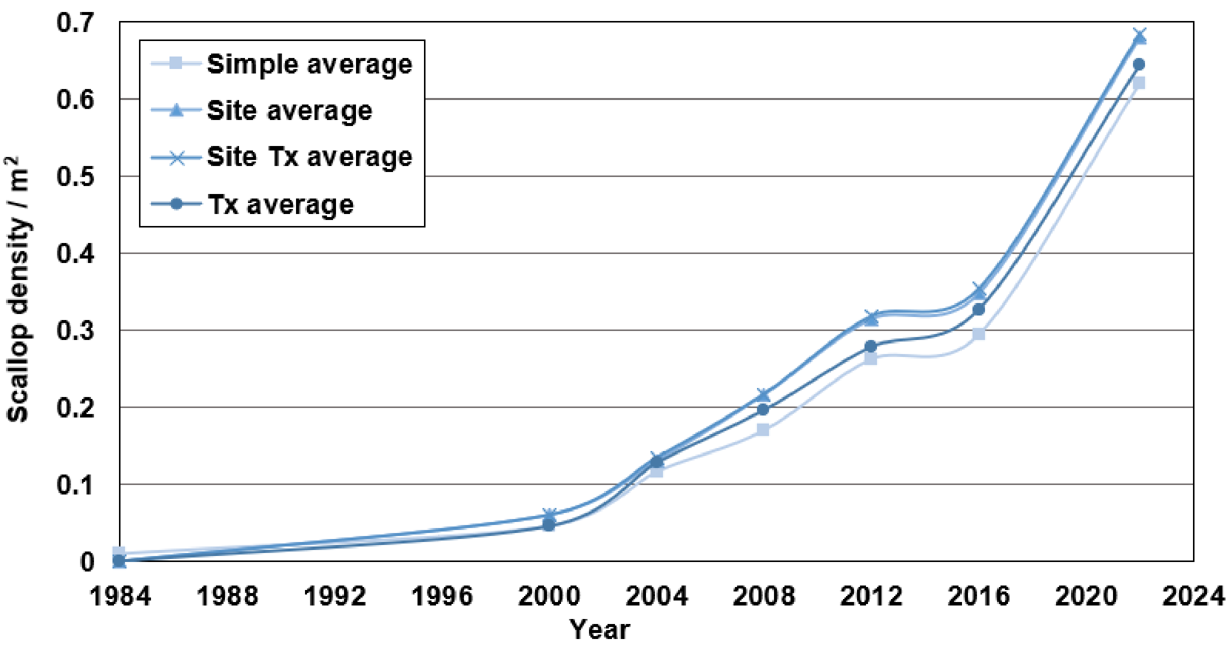
4. **Transect average for whole MCZ:** Calculate densities for all transects completed that year and then average these.

Table 2. Densities of *P. maximus* / m^2 for the surveyed area within MCZ 1984 – 2022

Year	Simple Average Density	Simple Site Density Average	Transect Site Density Average	All Transect Average
1984	0.01	*Not applicable*	*Not applicable*	*Not applicable*
2000	0.05	0.06	0.06	0.05
2004	0.12	0.13	0.13	0.13
2008	0.17	0.22	0.22	0.20
2012	0.26	0.31	0.32	0.28
2016	0.29	0.35	0.35	0.33
2022	0.62	0.68	0.68	0.64

If the sampling effort (area surveyed) was identical for all transects and at all sites surveyed in a year then the different in-year averages would agree. Because sampling effort has varied across sites there is a slight discrepancy between the calculated averages (Figure 4).

Figure 4. Average density *P. maximus* / m^2 for the MCZ survey area 1984 – 2022



The trend is the same whichever method is chosen to calculate the annual average density (Figure 4). An increase in density was seen between 2000 and 2012 then appeared to level off in 2016, but a dramatic increase in density is shown in 2022.

The simple average is always the lowest estimate of density and shows similar densities between 2012 (0.26/m^2) and 2016 (0.29/m^2). The density estimated in 2016 is 5.8 times greater than in 2000 (0.05/m^2). The density in 2022 (0.62/m^2) is just over double that found in 2016 and 12.4 times greater than in 2000.

Each method for calculating the annual density average has its own pros and cons;

- **Simple average** is easy to understand but it is just a number and cannot be tested statistically. The result is highly dependent on how the sampling effort is split between the different sites.

- **Simple site density average** has the effect of adjusting for differences in transect area within each site. It can be statistically tested and you can choose which sites to include when testing between years.

- **Site transect density** gives similar results to the "simple site density average". Small discrepancies are down to variation in effort between transects (i.e. transect area can vary). This same method can be used to statistically test for differences between sites as well as between years.

- **Transect average for whole MCZ** ignores which site the individual transects come from and treats the whole MCZ as one site. If all sites had similar densities / distributions then this may be valid but the results for each site (Section 3.2) show that there is a lot a variation between sites. This is therefore, not a recommended way of producing an annual average density estimate. The increased sample number (n) has the effect of increasing the power of a chosen statistical test but really this is pseudo replication.

Data was analysed to assess whether density has significantly changed across the MCZ between survey years.

3.1.2. Statistical analysis of transect density data

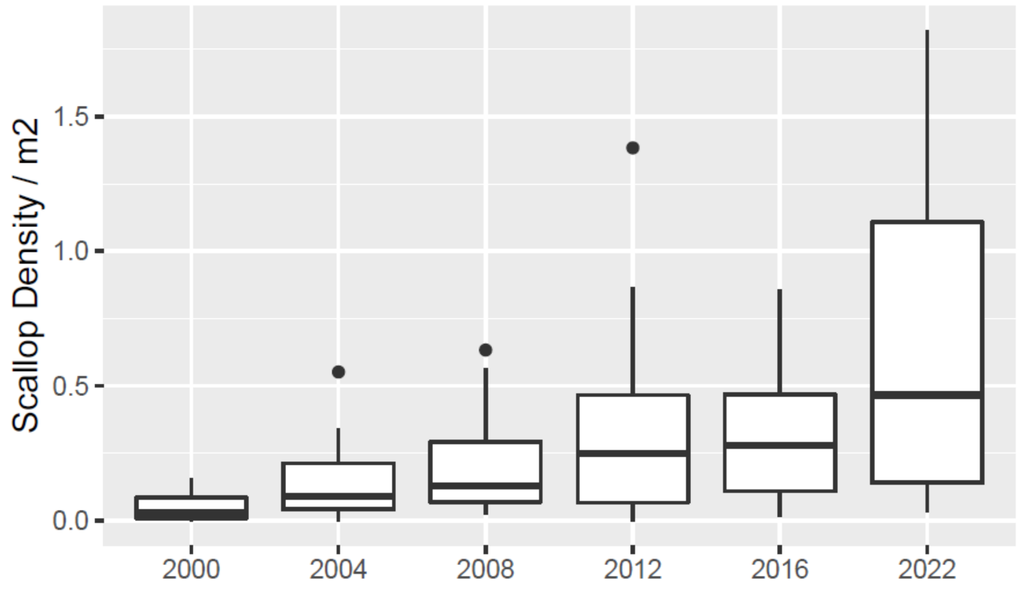
When transect data is NOT averaged to site (i.e. treating each transect as a 'site' within the MCZ) this gives lots of replicates (caution should be used with the results as this is pseudo-replication of sites).

Statistical tests were applied to the density data and showed that the density data are not normally distributed (a **Shapiro-Wilk normality test** W=0.74212, p-value <2.2e-16). Log (x+1), transformed data is also not normal (a **Shapiro-Wilk normality test** W=0.83825, p-value = <2.2e-16).

As the density data is not normally distributed then parametric tests are unsuitable and non-parametric tests need to be applied. Non parametric alternatives were conducted using the R (Version 3.6.1) statistics package.

Figure 5 is a graphic representation of the non-parametric properties of the transect densities by year.

Figure 5. Box plot of medians, quartiles, mins & max values for all transect density values 2000 – 2022.



A greater variability of densities between sites was found in 2022 compared to all previous years.

A significant difference in density was shown between some years 2000 to 2022 (**Kruskal-Wallis test** of transect densities vs year: $Chi^2 = 70.127$, d.f. = 5, p-value = 9.642e-14).

A **pairwise Wilcox test** was used to test for individual differences between the years, significant differences were shown between some years (Table 3).

Bonferroni adjustment was used to take into account running 15 separate tests (with a p = 0.05, 1/20 tests would be expected to give a false result, the Bonferroni adjustment adjusts the p-values to take into account the number of multiple tests performed and reduce the chance of a false positive).

Table 3. Results of a pair Wilcox test to analyse for significant differences between paired years

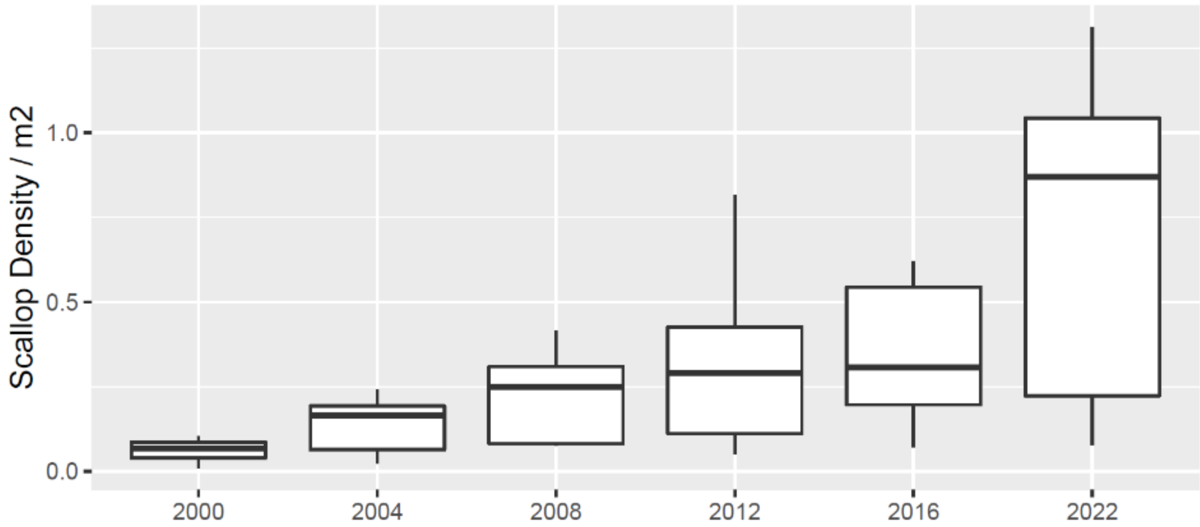
	2000	**2004**	**2008**	**2012**	**2016**
2004	Significant	n/a	n/a	n/a	n/a
2008	Significant	Not significant	n/a	n/a	n/a
2012	Significant	Significant	Not significant	n/a	n/a
2016	Significant	Significant	Significant	Not significant	n/a
2022	Significant	Significant	Significant	Significant	Not significant

Densities in 2000 are significantly different to all subsequent years, however this 1may be because only 3 sites were surveyed in 2000.

3.1.3. Statistical analysis of site average density data

When density data is averaged by site, the number of replicates is reduced to just 7 per year (3 replicates for 2000).

Figure 6. Box plot of medians, quartiles, mins & max values for average site density values 2000 – 2022.



A significant difference in average site density is shown somewhere between all years (**Kruskal-Wallis test** of average densities vs year: Chi^2 = 11.959, d.f. = 5, p-value = 0.03536).

However a **pairwise Wilcox test** (with **Bonferroni** adjustment) did not show any significant differences between any two years. This is likely because there is not enough power (only 7 samples per year) to separate out which years are different to one another and the fact that 4 sites show a clear trend of increasing density whilst 3 sites do not (Figure 7)

3.2 Density of scallops at individual sites

3.2.1 Densities at MCZ sites

The annual average density results show an increasing trend in *P. maximus* density (Figure 4), however this trend is not uniform across the individual sites (Figure 7). There continues to be variability in how each site responds over time.

The lowest site-average density in 2022 was found at site 3 (0.08/m^2) with the highest site-average density found at site 2 (1.31/m^2), see Table 4.

Sites1, 3 and 7 had the lowest transect densities ranging from 0.03 to 0.67 per m^2, whilst transect densities at the other sites ranged from 0.30 to 1.82 per m^2. A similar pattern is seen in previous surveys where sites 1,3 and 7 have consistently had lower densities than all other sites. In 2022 the range of densities recorded was much wider than in all previous years.

With the exception of site 7 (where density has decreased by 32% since 2016) densities at all other sites have increased since the previous survey in 2016. Five sites show a dramatic (>70%) increase compared to 2016.

Site 1: has seen only a gradual increase since 2004. Whilst density remains low, 2022 was 340% higher than in 2000; 190% higher than 2004 and 74% higher than 2016.

Site 2: shows a steady year on year increase with an exceptionally large increase since 2016. Densities in 2022 are 1160% higher than those in 2000; 560% higher than 2004 and 110% higher than 2016.

Site 3: low densities of scallops were found in 2000. There has been a slight increase in density which peaked in 2012. Density in 2022 is 680% higher than in 2000, but only 9% higher than 2016.

Site 4: 2012 stands out as a high-density year which is matched by 2022. 2022 density is 360% higher than 2004 and 180% higher than 2016.

Site 5: large increases are seen in 2008 and 2022. In 2022 density was 310% higher than 2004 and 110% higher than 2016.

Site 6: large increases are seen in 2016 and 2022 with density now 560% higher than 2004 and 77% higher than 2016.

Site 7: A large increase was found in 2016, but this must be treated with caution as it is due to a single transect result. 2022 density was 460% higher than 2004 but 32% less than 2016.

Figure 7. Individual site density changes (*P. maximus* / m^2) 2000 – 2022 with 95% confidence intervals.

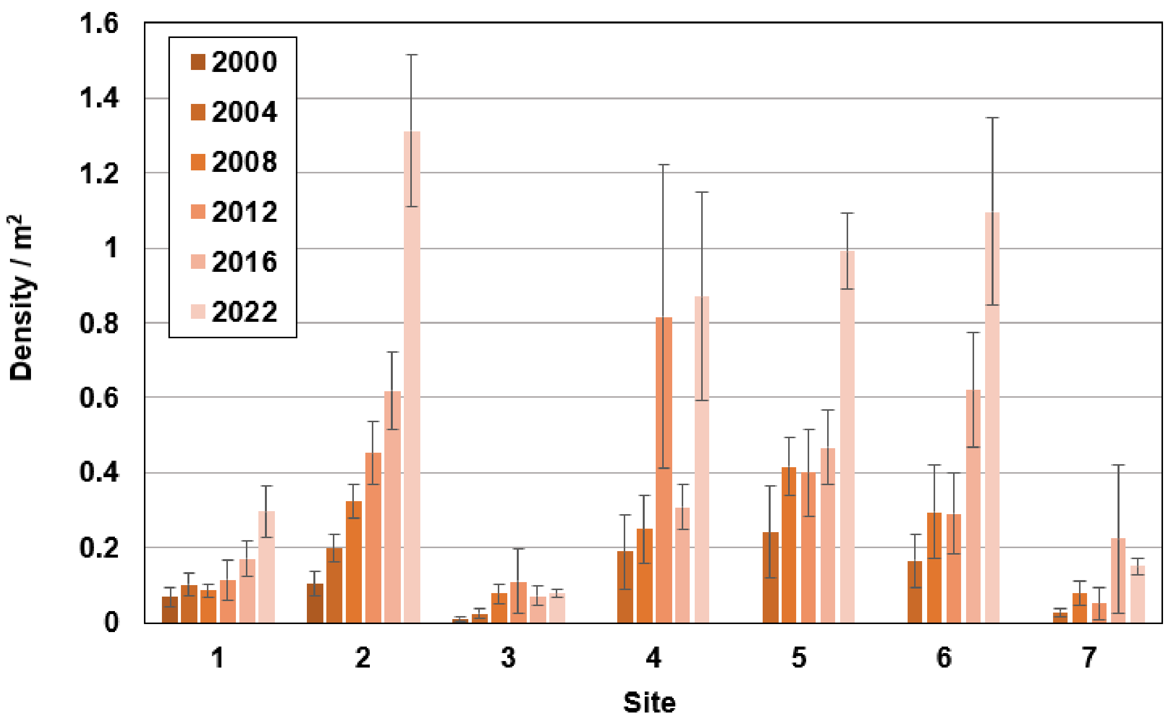


Table 4. Average densities per site in 2022.

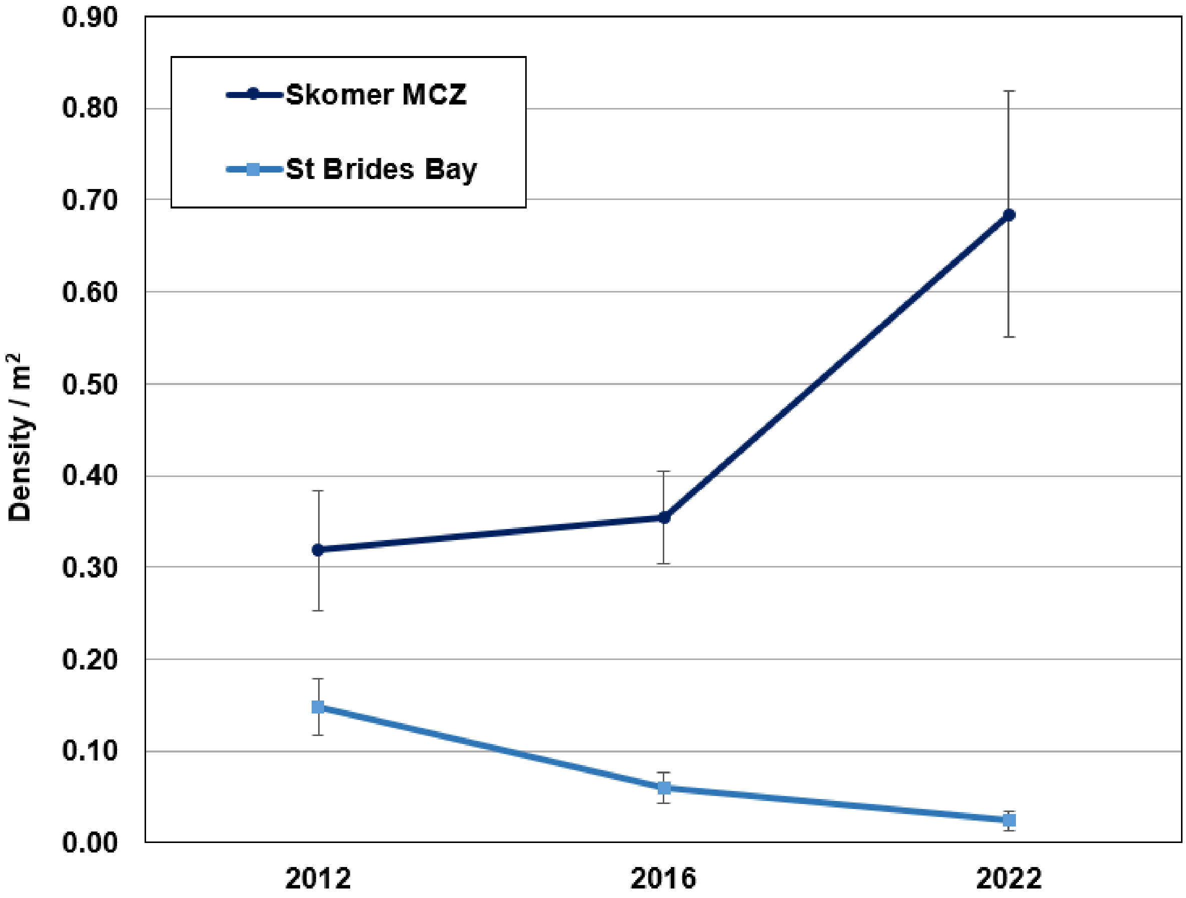
Site	Average Density (scallops per m²)	Standard Error	95% Error
1	0.30	0.07	0.14
2	1.31	0.20	0.40
3	0.08	0.01	0.02
4	0.87	0.28	0.54
5	0.99	0.10	0.20
6	1.10	0.25	0.49
7	0.15	0.02	0.04

3.2.2 Density at St Brides Bay site

In 2012, 2016 and 2022 surveys were carried out outside the MCZ in St Brides Bay. In 2016 the site was moved from the original 2012 site by around 200m due to a change in seabed habitat, the 2016 site was repeated in 2022.

In 2012 the average density was 0.15 *P. maximus* / m^2. In 2016 this dropped to 0.06 and in 2022 surveyed density was 0.02 *P. maximus* / m^2 (Figure 8).

Figure 8. Density of *P. maximus* inside and outside the MCZ boundary 2012, 2016 & 2022 (SE error bars).



There is not enough of a time series to interpret trends at the St Brides sites but densities are consistently lower than those found within the MCZ boundary. The St Brides sites are dominated by coarse clean sand with occasional life and as such are a less favourable habitat for *P.maximus*.

Both king and queen scallops are found at the St Brides sites but their numbers are sparse. *Arctica islandica* (ocean quahog) numbers are also recorded and separately entered into the Marine Recorder Database.

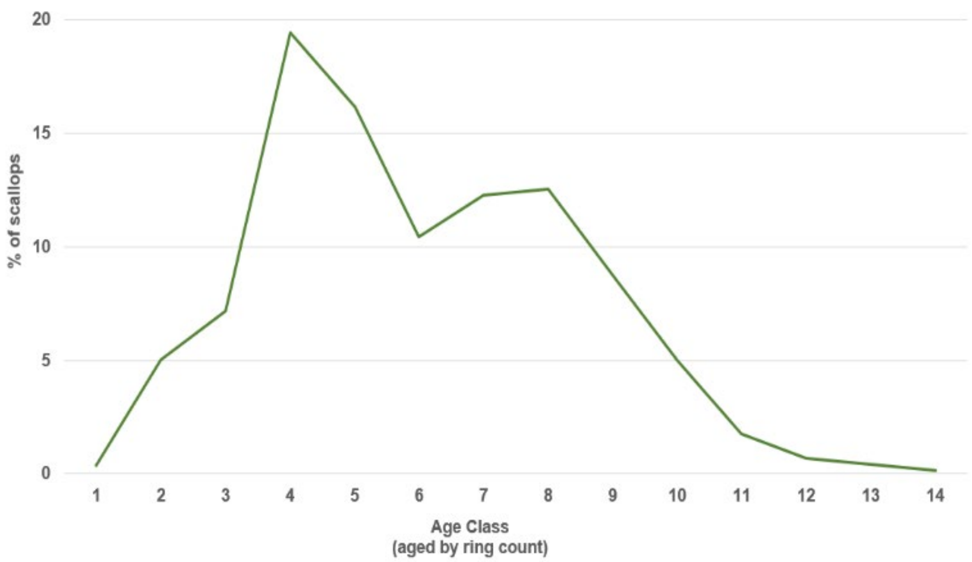
3.3 Size and age structure

Individuals were measured and aged. Two methods were used to estimate age; estimation from growth ring counts and estimation from overall length.

3.3.1 Age estimation from growth ring counts

The 4-year-old size class is strongly represented (Figure 9), suggesting good recruitment in 2018. The peak of 4-year-old scallops seen in 2016 is not seen as a peak of 10-year-old scallops on this graph. However a peak of 7 and 8-year-olds is seen. Using ring-count method the oldest recorded scallop was aged at 14 years. Older *P. maximus* are difficult to age by counting the age rings, because beyond a certain age the rings on the shell are very close together and hard to differentiate. For this reason this method is probably only accurate in estimating age up to the 7 or 8-year-old age class.

Figure 9. Age structure of *P. maximus* in 2022, sampled across all MCZ sites. Aged using growth ring count method.



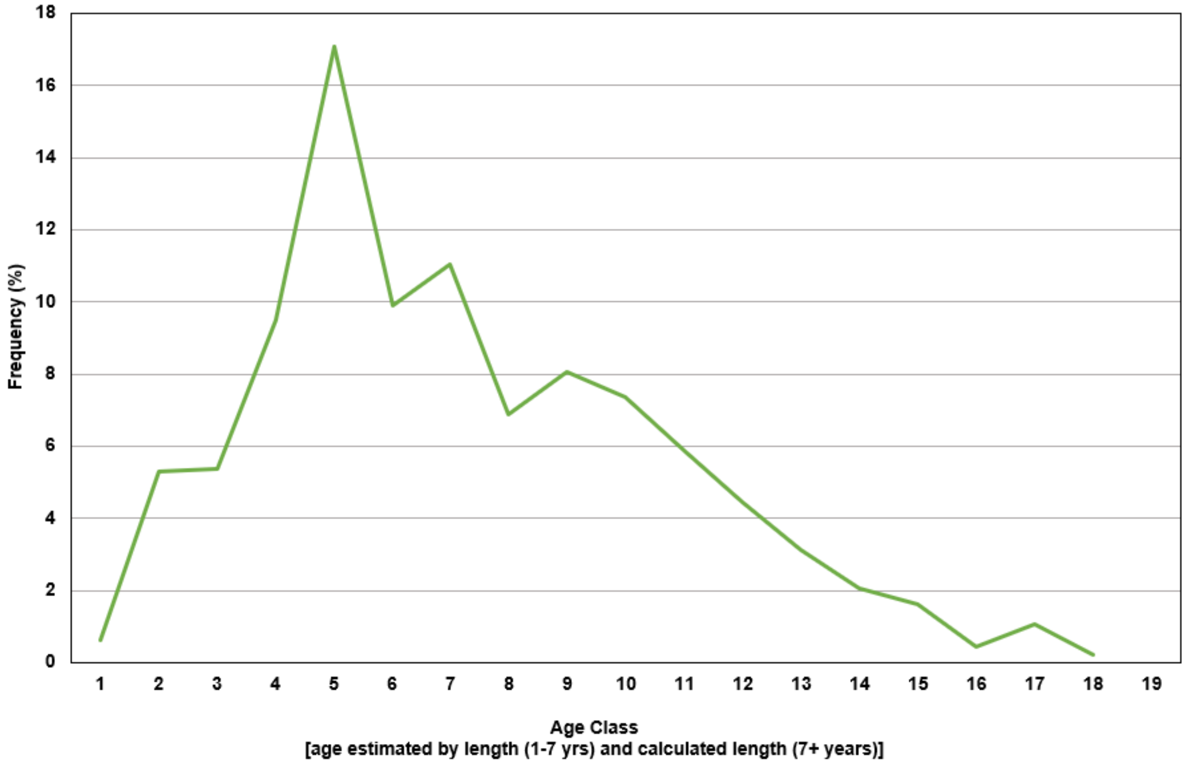
3.3.2 Age estimation from overall length

To improve the accuracy for ageing older scallops an average annual growth rate was derived from that year’s actual measured growth rates (Table 6) for all scallops of the age range seven and over. This growth rate was used to calculate theoretical overall length of scallops at age seven and over for the specific year.

This method is more consistent than the ring count method. It removes some of the user error and provides a more reliable comparison between different surveys.

The results (Figure 10) show ages extending out to 18-year-old scallops. The largest peak (and modal age-class) is 5-years-old and small peaks are now seen in the 7, 9 and 10-year old age classes. The peak of 10-year-olds correlates with the peak of 4-year-old scallops seen in 2016.

Figure 10. Age structure of *P. maximus* in 2022 across all MCZ sites. Scallops aged using estimated age from mean length (age 1-7 yrs) and calculated mean length (age 7+yrs).



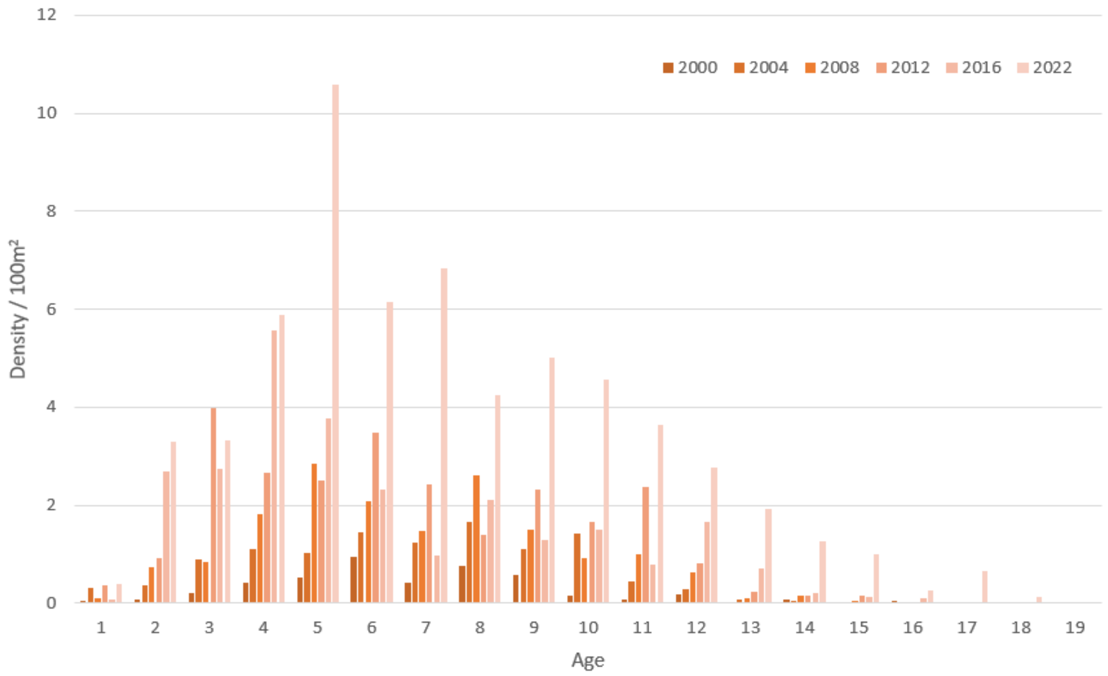
In 2000 there were only 155 *P. maximus* to measure so these data may not be comparable to estimates from the following years. Since 2004 the has been a shift of the modal size class towards younger *P. maximus* (Table 5)

Table 5. Modal age class of *P.maximus* within MCZ sites.

Year	**2000**	**2004**	**2008**	**2012**	**2016**	**2022**
Modal age class, years (aged by calculated length after 7yrs)	6	8	5	3	4	5

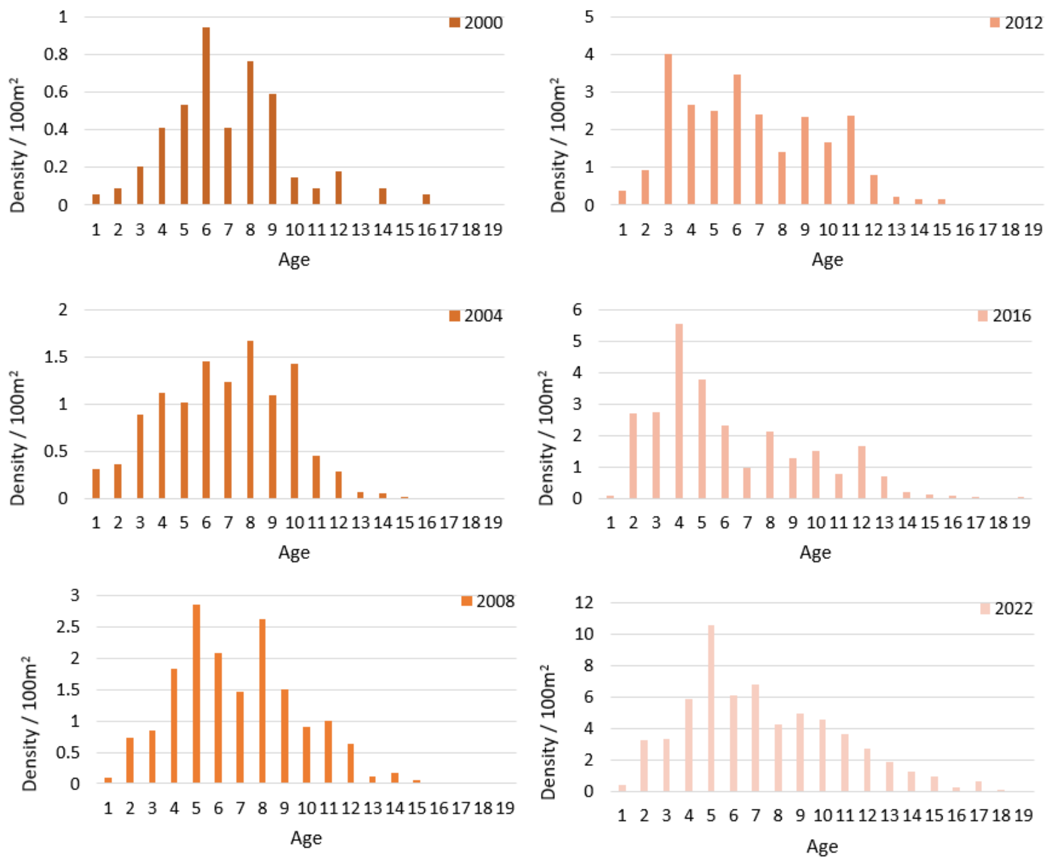
A plot of scallop density at age clearly shows an increase in scallop numbers in all but one age-class (class 3) in 2022 (Figure 11).

Figure 11.Scallop density by age 2000-2022. Simple density: number of scallops per $100m^2$ within MCZ survey sites. Aged from mean length (age 1-7 yrs) and calculated mean length (age 7+yrs)



There is an increasing trend in the number of older scallops. This is more clearly seen when the density graphs are plotted for individual years (Figure 12).

Figure 12. Density by age graphs for individual survey years, 2000-2022.



3.3.3 Age class structure at individual sites

The age structure of the scallops found at each individual site was plotted, Figure 13.

Figure 13. Frequency (%) of each age class (1-18) at each site 2022 (site densities also shown). Aged from mean length (age 1-7 yrs) and calculated mean length (age 7+yrs).

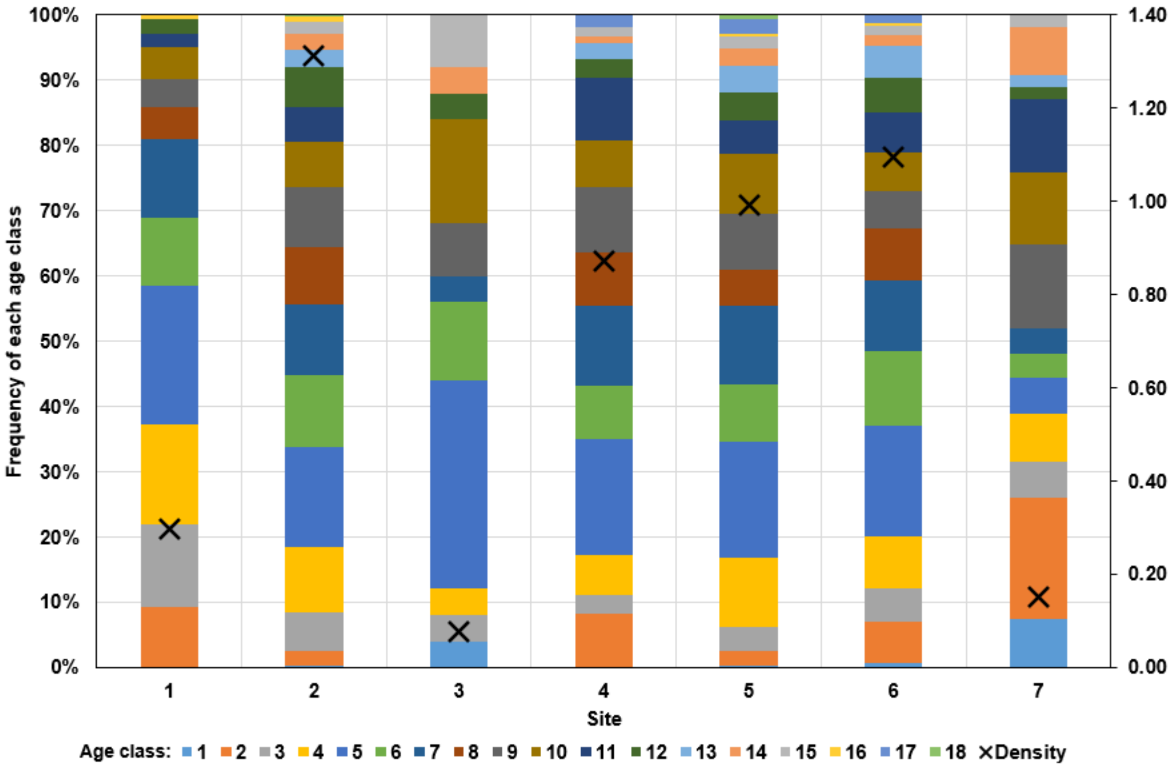


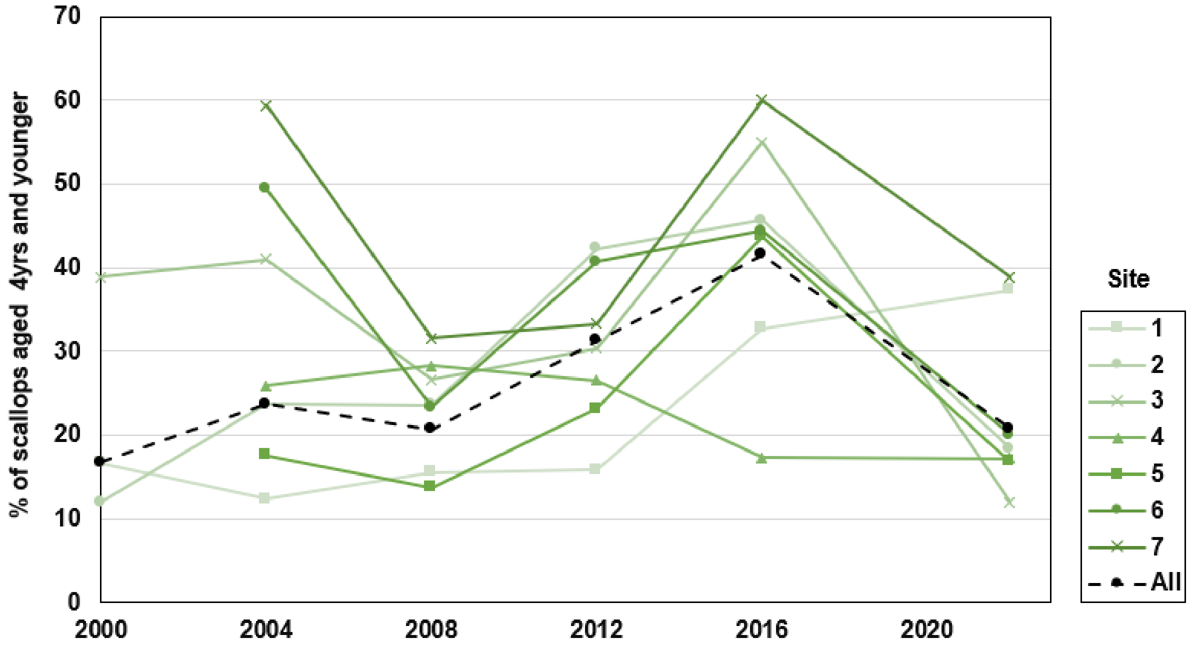
Figure 13 contains a lot of information to interpret on a single graph, it can be summarised as follows:

Age structure is not uniform across all sites, for example despite similar densities, sites 3 and 7 show considerable differences in age composition. At site 7 38% of *P. maximus* are aged 4 or younger whilst at site 3 only 12% are aged 4 or younger.

Similar to the findings for the site density results there is little to no continuity at sites between years.

The proportion of *P. maximus* 4 years old and younger at each site gives a variable picture of change over time (Figure 14). In addition to looking at the proportion (percentage) of scallops less than or equal to 4 years old, the density (scallops / m^2) of *P. maximus* <= 4 years old can be calculated (Figure 15). When sites are combined a clear trend of increasing density across the MCZ sites is shown since 2008. This will be linked in part to the overall increase in density of all *P. maximus* but it is also down to an increase in the proportion of <=4 year olds in the whole population as seen in the percentages graph (Figure 14).

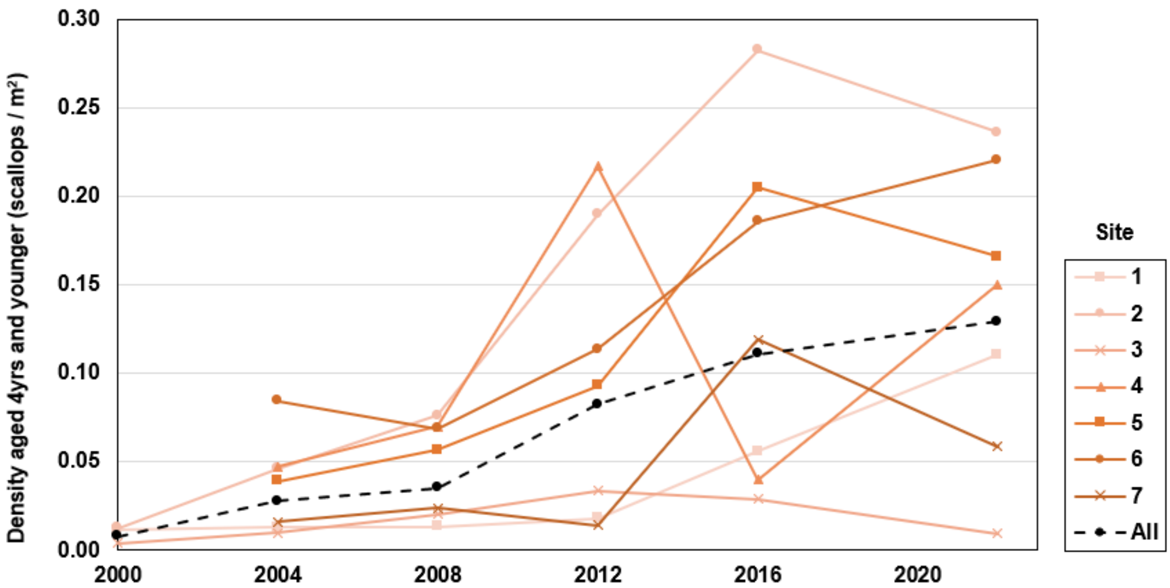
Figure 14. Percentage of *P.maximus* 4 years old and younger at each site 2000-2022.



In 2022 the density of <=4-year-olds had decreased at four sites and the proportion (%) of <=4-year-olds decreased at all sites, with the exception of site 1 where a slight increase was shown.

Site 4 experienced a dramatic rise in density in 2012 followed by a sharp drop in 2016 and subsequent rise in 2022 (Figure 15). Sites 1, 4 and 6 are the only sites to show increased density of <=4 year olds in 2022 and site 6 is the only site to have shown a continued steady increase since 2004.

Figure 15. Density of *P.maxiumus* aged 4 and younger 2000-2022



3.3.4 Growth rates

The rate of change in size can be calculated between each age class to show how growth varies as *P. maximus* ages. Growth rates have been calculated using the formula: '*size at t +1 / Size at t = proportional change in size' (where t = year by ring count)*. Growth rates for 2000-2022 and associated 95% confidence limits are shown in Table 6,

Table 7 and Figure 16.

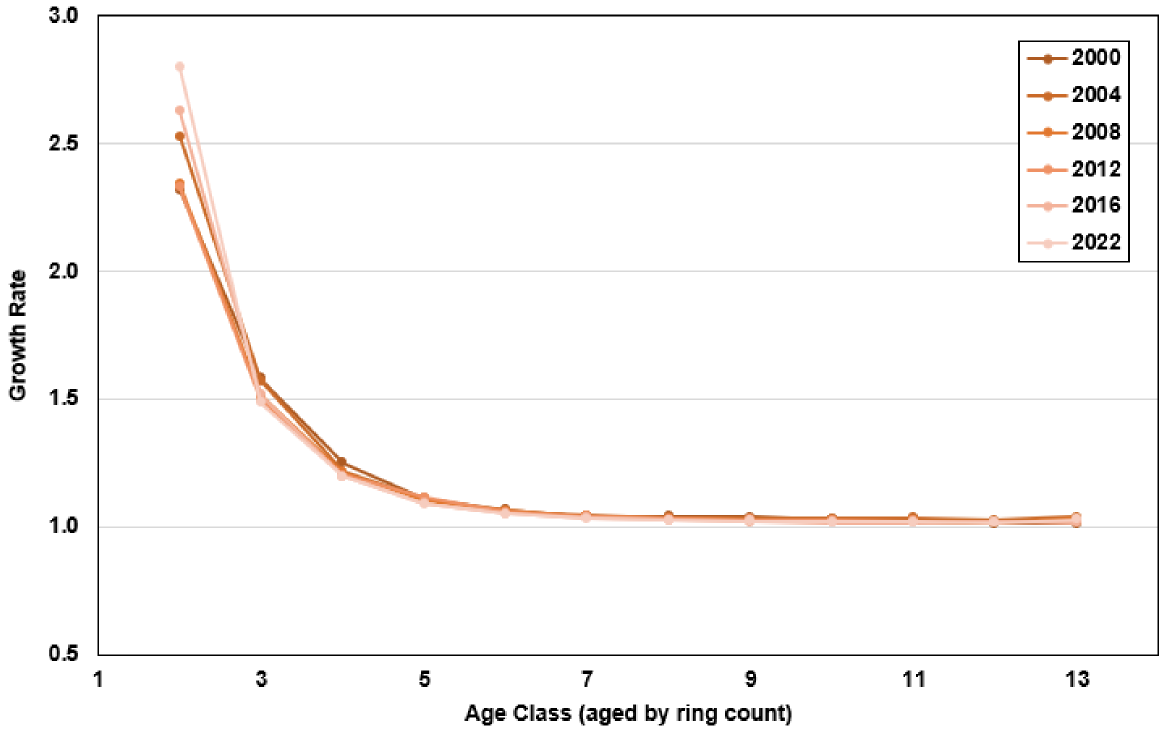
Table 6. Growth rates between age classes (2000-2022).

Year	Age 1 to 2	Age 2 to 3	Age 3 to 4	Age 4 to 5	Age 5 to 6	Age 6 to 7	Age 7 to 8	Age 8 to 9	Age 9 to 10	Age 10 to 11	Age 11 to 12	Age 12 to 13
2000	2.320	1.581	1.250	1.108	1.066	1.043	1.040	1.037	1.029	1.023	1.013	1.014
2004	2.530	1.570	1.217	1.112	1.059	1.044	1.035	1.032	1.032	1.034	1.025	1.038
2008	2.340	1.515	1.212	1.105	1.062	1.042	1.033	1.027	1.023	1.022	1.017	1.031
2012	2.328	1.494	1.203	1.114	1.056	1.040	1.031	1.027	1.026	1.022	1.019	1.018
2016	2.627	1.516	1.196	1.093	1.052	1.034	1.025	1.020	1.016	1.016	1.021	1.015
2022	2.799	1.486	1.196	1.088	1.052	1.032	1.026	1.021	1.021	1.018	1.017	1.029

Table 7. 95% Confidence limits for growth rates between age classes (2000-2022).

Year	Age 1 to 2	Age 2 to 3	Age 3 to 4	Age 4 to 5	Age 5 to 6	Age 6 to 7	Age 7 to 8	Age 8 to 9	Age 9 to 10	Age 10 to 11	Age 11 to 12	Age 12 to 13
2000	0.116	0.045	0.025	0.011	0.009	0.006	0.007	0.007	0.006	0.012	0.006	0.000
2004	0.089	0.032	0.010	0.014	0.003	0.002	0.002	0.002	0.003	0.008	0.004	0.017
2008	0.032	0.012	0.007	0.004	0.003	0.003	0.002	0.002	0.004	0.003	0.003	0.018
2012	0.045	0.015	0.010	0.028	0.003	0.003	0.002	0.005	0.005	0.010	0.008	0.013
2016	0.031	0.009	0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.002	0.009	0.005
2022	0.038	0.011	0.009	0.004	0.003	0.002	0.001	0.001	0.002	0.003	0.007	0.031

Figure 16. Changes in growth rates with age (2000-2022)



All survey years show a similar trend of growth rate, with the rapid growth rates seen in scallops aged 2 and 3, slowing down in 4 and 5-year-olds and almost stopping by age 6.

3.4 *Crepidula fornicata*

All *P.maximus* shells were checked for the presence of the non-native limpet *Crepidula fornicata*. Individuals found were counted and then removed from the *P. maximus* shell and destroyed.

The % of *P.maximus* found with *C .fornicata* in 2012, 2016 and 2022 are shown in Table 8. In 2022 for some transects at sites 3 and 4 only the total number of *Crepidula* (rather than *Crepidula* per scallop) was recorded, this data has not been included.

Table 8. % of *P.maximus* found with *C .fornicata* (2012-2022)

Site	2012	2016	2022
1	0	2.7	5.6
2	0.9	3.2	10.3
3	0	6.5	0
4 (2022 data from 3 transects only)	0	0	3.7
5 (2022 data from 4 transects only)	0.6	1.3	4.3
6	1.2	2.1	5.1
7	0	2.6	24.1
All MCZ Sites (TOTAL)	**0.4**	**2.6**	**7.6**

2016 saw an increase in the number of sites where *C. fornicata* was found (from 3 to 6 sites) and an increase in the % of *P. maximus* found with *C. fornicata*. In 2022 *C.fornicata* was found at 6 sites and the % of *P.maximus* found with *C.fornicata* has again increased.

Only one scallop was found with *C. fornicata* at the St Brides site.

Two researchers from Aberystwyth university joined the survey to collect water samples in order to test the ability of eDNA analysis to detect the presence of *C. fornicata.* Further work is proposed to fine-tune the method and subsequent analysis.

4. Discussion

4.1 Survey method

Due to poor weather and reduced visibility the volunteer survey weekends in 2022 were reduced from 4 to 3 days and survey transects were reduced to 30m x 1m either side of tape (2m total width) giving a total survey area of 2280m^2. This was lower than 2012 when reduced visibility also restricted the survey to a 2m width but 4 survey days completed giving a survey area of 3480m^2. Much higher survey areas were achieved when good visibility allowed the planned transect width of 4m to be completed in 2004 (11120m^2) 2008 (8620m^2) and 2016 (8620m^2).

A reduction in survey transect length (from 50m to 30m) has also been a necessity in 2022 due to very high densities being found at many sites. The numbers of *P. maximus* collected, cleaned and measured by the survey teams needs to be manageable for each survey day.

4.2 Density

The trend of increasing *P. maximus* density is clear (Figure 4), no matter how the overall density is calculated. Simple average density was 0.05/m^2 in 2000, rising to 0.62/m^2 in 2022 (a 12.4 times increase). Since 2016 density has effectively doubled (0.29 /m^2 to 0.62/m^2).

Port Erin Bay Marine Nature Reserve (Isle of Man), was closed to scallop fishing in 1989. A survey in 2016 (27-years after closure) reported maximum *P.maximus* densities of 0.92/m^2 with an overall average of 0.27/m^2 (Garratt *et al*, 2022). This increase in densities following a closure is very similar to the survey results at Skomer MCZ. The Skomer MCZ was closed to scallop fishing in 1990 (following introduction of the byelaw), 32 years later 2022 results show a maximum density 1.82/m^2 and overall average of 0.68/m^2.

Density results are highly variable between sites and years (Figure 7) suggesting a clumped and patchy distribution of *P. maximus* across the MCZ, giving rise to large variances around the averages. The high variances associated with these densities make statistical testing difficult without falling foul of pseudo replication. Density does not change uniformly across all of the sites surveyed in the MCZ, this suggests that certain sites have more suitable substrate and habitat to promote settlement and growth of *P. maximus* (assuming there is no significant removal of *P. maximus* and mortality is uniform across all sites). A similar patchy distribution of scallops has been observed in Cardigan Bay (Lambert *et al,* 2013) and Isle of Man (Beukers-Stewart *et al*, 2005) scallop surveys.

Compared to 2016, density has increased at six of the seven sites. Site 7 was the only site to show a reduced density compared to 2016, however the high density seen at site 7 in 2016 was a result of just one transect having a very high density (as highlighted by the size of the standard error bar).

Density at individual sites.

Burton *et al* (2016) reported some significant differences in *P. maximus* densities between the 7 survey sites and sites showed a different response in density change over time, this again was shown in the 2022 results. *P. maximus* settlement and mortality must vary between the sites. This may be due to environmental conditions at the sites and / or due to random recruitment / mortality events. There are no data available on annual settlement rates and there has been no success with the use of spat collectors in previous years (Lock *et al,* 2012) to provide information on settlement rates.

Only site 2 shows a consistent year-on-year increase in density over time. Site 2 is within a few hundred metres of sites 5 and 6. There is no real difference in the habitat type found at site 2 compared to sites 5 and 6 and it is quite similar to site 7. However these sites do show quite different responses over time, this suggests random or non-measured factors are affecting *P. maximus* density.

Site 3 consistently has the lowest densities. It has potentially good scallop habitat, but it is shallower than the other sites and it has been observed by the Skomer MCZ team that scallop density increases with depth away from the survey location at site 3, indicating that depth may have an influence on habitat selection by scallops.

Site 4 had a dramatic increase in density in 2012 which was followed by a significant decrease in 2016. The raw data and field sheets from 2012 have been checked to ensure the data has been accurately recorded and that there was no obvious change in the method used at that site. The results for site 4 transects in 2012 did vary with one outlying transect having roughly double the density of the other 3 surveyed. Once again showing how the naturally patchy occurrence of scallops can affect the data analysis. In 2022 density at this site has increased again back to 2012 levels.

At site 7 the proportion of young recruits (<=4 yrs old) in 2016 was 60%, and this was coupled with a significant rise in density. The large rise in 2016 is down to a single transect result from a dense area of scallops (0.8 /m^2 compared to an average of 0.12 /m^2 for all the other transects at that site), again demonstrating the highly clumped dispersion of scallops. In 2022 the proportion of young recruits at site 7 was 38% and there was a slight reduction in overall density at this site.

Density inside MCZ compared to St Brides

There is not enough of a time series to interpret trends at the St Brides sites, however densities are lower than those found within the MCZ boundary. Whilst individual site habitats have not been formally described, the Skomer MCZ sites were initially selected based on their habitat type being suitable for colonisation by scallops (Lock, 2000) and were described as mixed sediment habitat (‘*muddy gravelly sands and mosaics of cobbles and pebbles embedded in or lying upon sand, gravel or mud*’ JNCC Website) with moderate currents. In comparison the St Brides sites are characterised by coarse, mobile clean sand.

Isle of Man scallop surveys revealed significant spatial variation across different habitat types with the highest scallop densities found in gravel and mixed sediments characterised by hydroids and bryzoans (Garrat *et al*, 2022). Lower densities were found at sites where the substrate was clean mobile sand or muddy sand (Garrat *et al,* 2022). These observations are consistent with the varying densities observed between Skomer MCZ and St Brides sites.

4.3 Size, age class and growth rate

In fished areas, population structure typically skews towards younger age classes (below 6 years) with very low numbers of older scallops, as observed in the Isle of Man scallop fisheries (Bloor et al*, 2021*). A different picture is seen in the Skomer MCZ closed scallop fishery where the 2022 results show a skew towards younger age classes but also a good representation of older ages through to 18 years.

In 2022 numbers of young (<=4 year old) *P. maximus* have increased since 2016 within the Skomer MCZ but at a slower rate than the older *P. maximus*. In a growing population with healthy recruitment a greater increase in density of younger *P. maximus* might be expected (as was seen in the 2004, 2012 and 2016 surveys).

Whilst the proportion (%) of scallops aged <=4 yrs has decreased since 2016 (Figure 14) their density has increased (Figure 15). Meaning that whilst the populations contain a lower proportion of younger scallops there has been a consistent increase in recruitment across the MCZ sites, this is clearly shown on the 'Site: All' line in Figure 15.

The age structure of the sampled population differs between sites and between years. It also differs at each site over time, no consistent pattern is shown between sites. However, when densities are averaged across the MCZ sites a pattern of increasing density of older scallops is shown (Figure 11 and Figure 12). This is consistent with the population structure changes seen in recovering populations in the Isle of Man closed areas (Bloor *et al,* 2021).

Due to the relatively long period the larvae spend in the water column (20 – 40 days Salomonsen *et al.* 2015) recruitment may not necessarily be coming from the resident population. There are strong tidal currents around the west Wales coast and it is not known where recruits into the Skomer MCZ population come from. Likewise we do not know where the larvae produced at Skomer end up settling. Research of *P. maximus* larvae dispersion in the Irish sea would be beneficial to furthering the understanding of dynamics of *P. maximus* populations in Wales and neighbouring areas.

Very few 1-2 year old individuals are ever found at the survey sites. It is possible that that they are too small to be easily seen by the divers or they may be inhabiting a different habitat before moving onto the main beds as they grow older.

As suggested by Burton *et al,* 2016, the low numbers of 1-2 year old *P. maximus* need further investigation. Surveys in Lamlash Bay in the Isle of Arran (Howarth 2011) found *P. maximus* of this age group settling onto seaweeds in the shallows. This is a habitat which is not surveyed for *P. maximus* in the Skomer MCZ and it would be worth expanding the methodology to look for young recruits in other habitats.

4.4 *Crepidula fornicata*

Although numbers remain low, *Crepidula fornicata* would appear to be increasing within the *P. maximus* population in Skomer MCZ. *P. maximus* must provide a suitable substrate for settlement and could provide stepping stones for the spread of *C. fornicata* from the high densities found in the Milford Haven estuary.

5. Conclusions

The population of *P. maximus* within the boundary of the Skomer MCZ would appear healthy and densities are increasing.

- Densities of *P. maximus* have increased over the 22 year survey period (2000-2022). 2022 density across the MCZ is 12.4 times greater than in 2000.
- There is strong evidence of good recruitment into the Skomer MCZ population but it is unclear whether these recruits are from the resident population or from further afield.
- The number of older scallops (>10yrs) has markedly increased since the 2016 survey.
- Density and recruitment are variable between years and sites.

6. Recommendations

- Continue with the same methodology, next survey due in 2026.
- Continue to compare the Skomer MCZ results to other studies on *P. maximus* around the UK.
- Survey other habitats for the presence of young (1-2 year old) *P. maximus*.
- Support *P. maximus* research, in particular dispersion and recruitment studies.

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Appendices

Appendix 1: Inshore Fishery Legislation – Skomer

BYELAW 27. PROHIBITED AREA FOR USE OF DREDGES AND BEAM TRAWLS - SKOMER

No person shall use in fishing for sea fish any fishing dredge or any beam trawl within the area detailed below.

From the northern point of Gateholm Island due North to the mainland. From the southern point of Gateholm Island a straight line in a direction of 278°(T) to a position 2.75 cables due south (T) of the western extremity of the Mew Stone thence 2.75 cables off the mainland shore of Skomer around the west coast of the Island to a position 2 cables due north (T) of the Garland Stone, thence a straight line in a direction of 098° (T) to a position 51°44.5'N,05°13'W, thence due south (T) to the mainland coast.

BYELAW 28. PROHIBITED AREA FOR SCALLOP FISHING - SKOMER

No person shall fish for, take or land any scallop of the species *Pecten maximus* or of the species *Chlamys (now Aequipecten) opercularis* from the area detailed below.

From the northern point of Gateholm Island due North to the mainland.

From the southern point of Gateholm Island a straight line in a direction 278° (T) to a position 2.75 cables due south (T) of the western extremity of Mew Stone, thence 2.75 cables off the mainland shore of Skomer around the west coast of the Island to a position 2 cables due north (T) of the Garland Stone, thence a straight line in a direction of 098° (T) to a position 51°44.5'N,05°13'W, thence due south (T) to the mainland coast.

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