Teign Estuary
Cockle Stock Assessment 2024

Sarah Curtin
Environment Officer
Devon and Severn Inshore Fisheries and Conservation Authority

Research Report
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Contents

Version control history			
Author	**Date**	**Comment**	**Version**
S.Curtin	26/02/2025	Draft report	0.1
	17/03/2025	Updated following comments & additional analysis from J. Stewart	0.2
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1. Introduction

The Teign Estuary is situated on the south coast of Devon, and consists of an East-West aligned, broad tidal river channel. It has no current Marine Protected Area (MPA) designation. There has been shellfish harvesting and aquaculture in Devon's estuaries for hundreds of years. The main harvest has been mussels and oysters. Commercial harvesting of mussels (*Mytilus edulis*) and Pacific oysters (*Magallana gigas* - formally known as *Crassostrea gigas*) occurs in the Teign under the River Teign Mussel Fishery Order 1966 and the River Teign Mussel Fishery (Variation) (Oysters) Order 1995. Figure 1 – Figure 3 show the classified shellfish waters and production areas of the Teign Estuary, and the harvesting areas for *M. edulis* and *M. gigas*.

Cockles*, Cerastoderma edule,* are present within the estuary and are known to be collected at low levels both historically and to the present day (Edwards, 1987; Cefas, 2013, 2020). Unlike mussels and Pacific oysters, the cockle stock has never reached a large enough level to be harvested commercially from within the estuary. The cockle beds have not been classified by Cefas for commercial exploitation (Figure 2) (Cefas, 2013), and assessments carried out for the 2000 Water Framework Directive (WFD) do not mention the presence of cockles within the estuary. However, there are concerns about the recreational collection of cockles and potential over-exploitation particularly from 'The Salty', a mid-channel sediment bank that is often accessible from the shore over low water; these concerns have been documented as far back as 2008 (Teign Estuary Partnership, 2008) and continue to date.

Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) understands the social and ecological importance of these beds and has undertaken survey work to establish the population structure, biomass, and distribution of cockles within the areas of the estuary where cockles are known to be present. This report will assist with monitoring the cockle stock in the Teign Estuary and may inform future development of a D&S IFCA Hand Working Permit Byelaw.

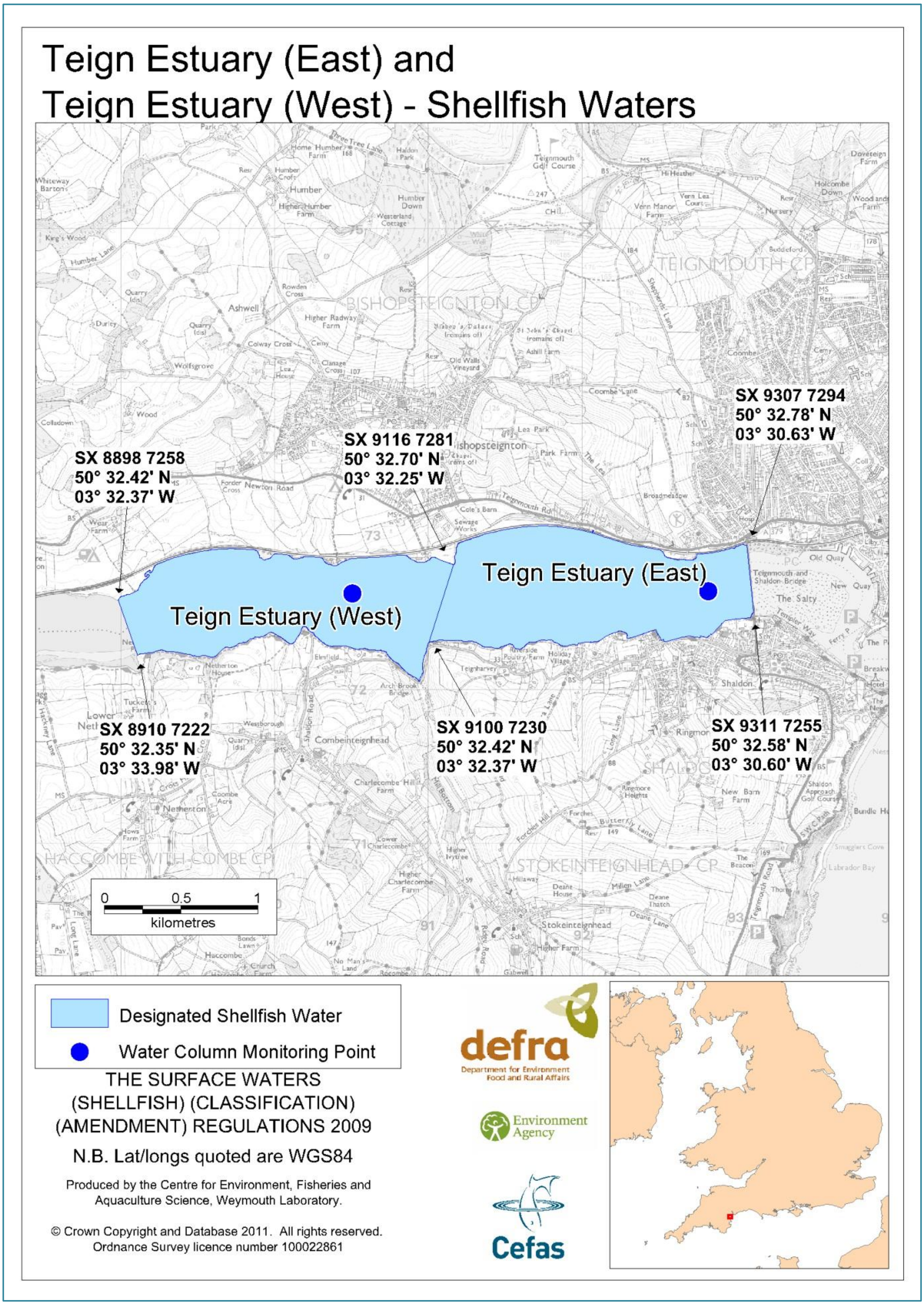
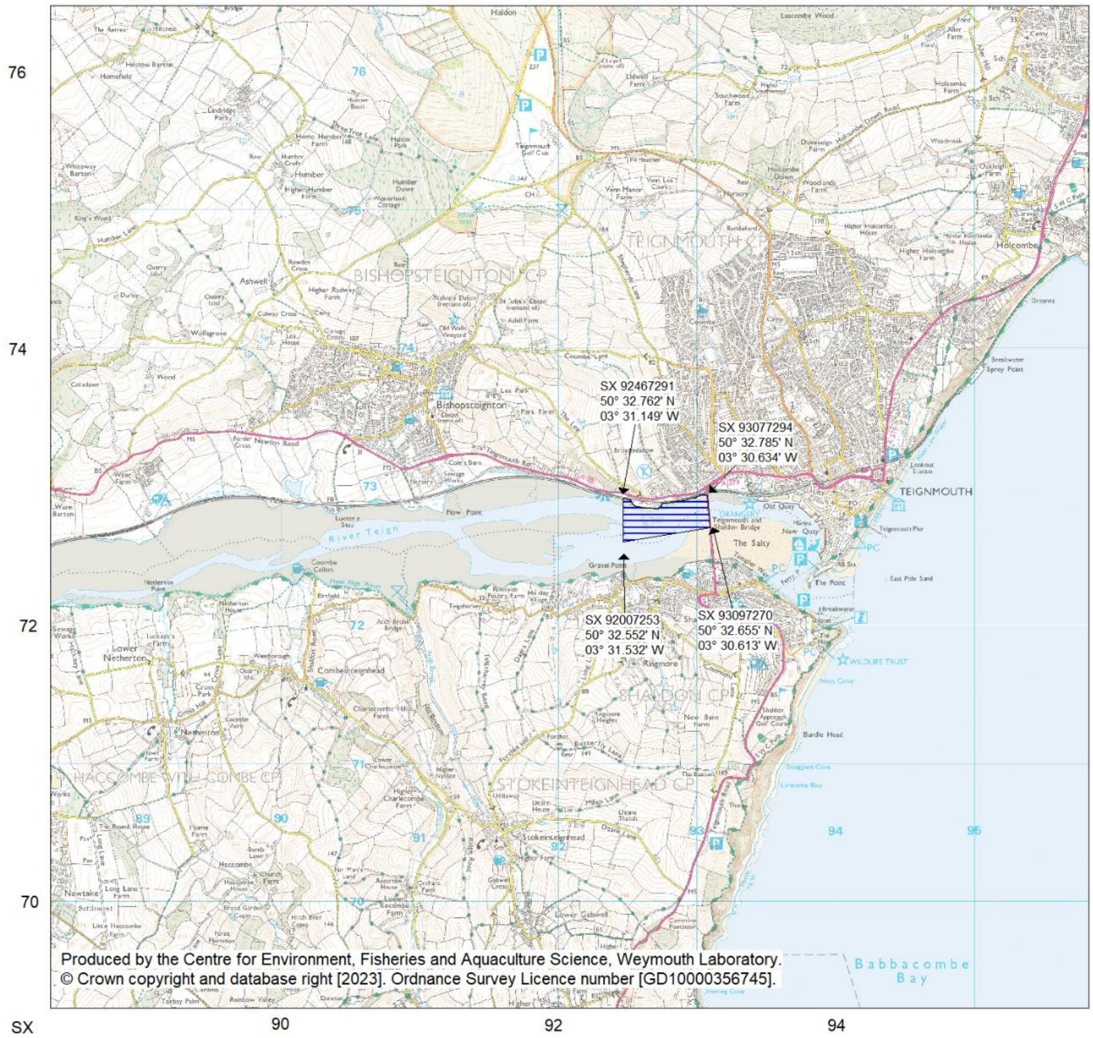


Figure 1 – Shellfish Waters Protected Areas of the Teign Estuary 2016. The eastern limit of the Teign Estuary (east) designated shellfish water is the Teignmouth and Shaldon Bridge. The Salty is predominantly downstream of the bridge.

Teign - Mytilus spp.

Scale - 1: 35000



Classification: Status — Class A, Class B, Class C, Prohibited, LT Class B, Seasonal Class B/C

<u>Classification of Bivalve Mollusc Production Areas: Effective from 6 July 2023</u>

The areas delineated above are those classified as bivalve mollusc production areas under Regulation (EU) 2019/627.

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Unless otherwise stated, non-straight line boundaries between co-ordinates follow the OS 1:25,000 mean high water line.

Food Authority: Teignbridge District Council

Figure 2 - Classified Mussel Harvesting Areas on the Teign Estuary as they were classified during the surveys reported here (Cefas, 2023). Up to date classification zone maps are available on the Cefas website.

Teign - C. gigas

Scale - 1: 35000

Classification: Status — Class A, Class B, Class C, Prohibited, LT Class B, Seasonal Class B/C

Classification of Bivalve Mollusc Production Areas: Effective from 2 September 2024

The areas delineated above are those classified as bivalve mollusc production areas under Regulation (EU) 2019/627.

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)
N.B. Lat/Longs quoted are WGS84

Food Authority: Teignbridge District Council

Figure 3 - Classified Pacific Oyster Harvesting Areas on the Teign Estuary as they were classified during the surveys reported here (Cefas, 2024). Up to date classification zone maps are available on the Cefas website.

2. Methods

Surveys have been conducted annually between 2018–2020, and every two years since. Each survey is completed in one day at low water spring tides. The surveys conducted in 2018 and 2019 occurred in November and October, respectively, whereas in 2020 and 2022 the surveys were conducted in August, and in 2024 the surveys were conducted in September. In 2020 the earlier timing of the surveys was due to the uncertainty in timings around the Covid Pandemic, whereas in 2022 and 2024 August and September were chosen due to the timings of other molluscan surveys throughout the year. The survey typically covers the following areas of the Teign estuary: The Salty (predominantly east of Shaldon bridge, with a small area upstream of Shaldon bridge), and five stations at Polly Steps (at the north end of Shaldon bridge, separated from the Salty by the main channel of the River Teign). The same survey stations (that are approximately 73.3 m x 73.3 m apart) are sampled each year, although in 2018 the survey stations covering The Salty were approximately 115 m x 115 m apart (Figure 4), whereas in later years the survey stations were made denser with additional survey stations. The five stations at Polly Steps were added to the survey in 2019 (Figure 4). The survey area was selected over the area historically known to contain cockles and where harvesting has previously been observed.

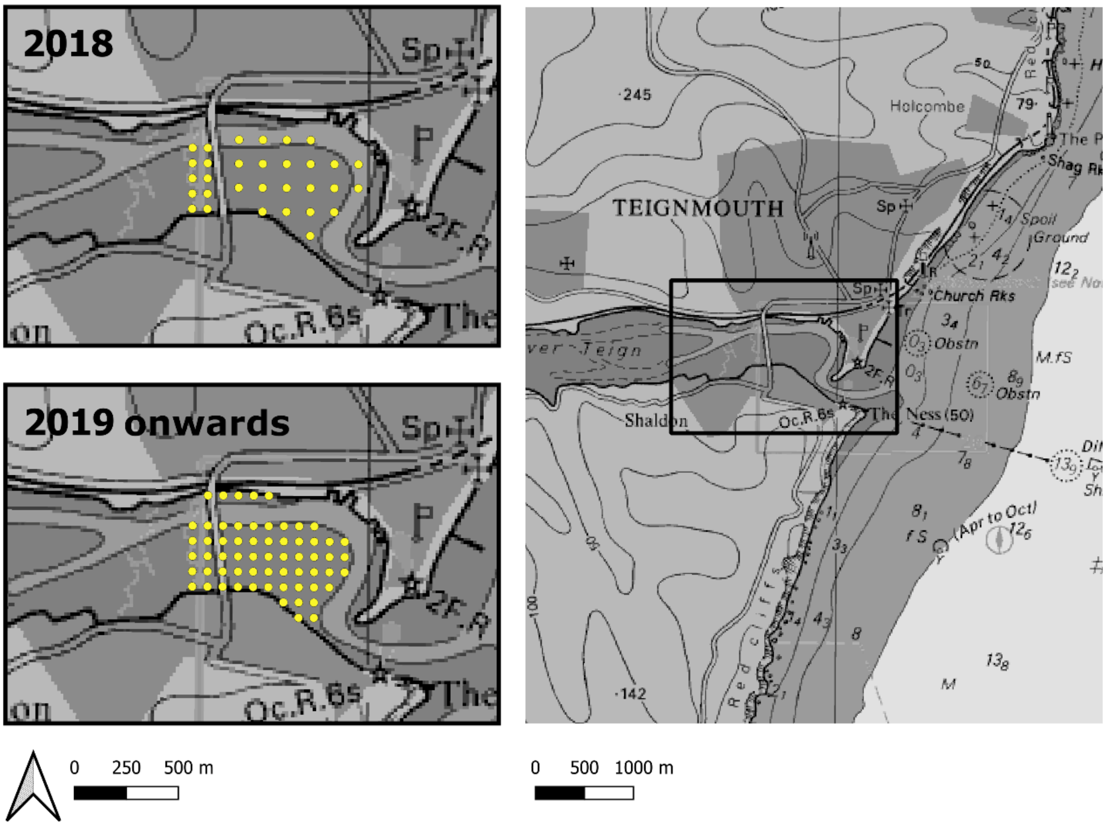


Figure 4 – Teign Estuary cockle survey stations. The sites that are (in)accessible can vary each year.

Each survey station was located using a handheld GPS. A 0.1m^2 quadrat was randomly placed within 10m of the target position for the station. Using a trowel, the sediment was removed from the quadrat (to approximately the depth of the quadrat ~ 6 cm) into a sieve, and was then sieved in water nearby (Figure 5). The cockle(s) were put into a sample bag with a label of the station name (one bag per station). If no cockles were found or the station was unable to be surveyed it was noted as such.

Figure 5 – Photos showing the cockle sampling method. (a) a 0.1m^2 quadrat is randomly placed within 10m of the target position for the sampling station, where sediment is dug out of the quadrat and placed in a sieve. (b) The sediment is sieved in water so that (c) the contents of the sieve are visible.

For each station sample, all cockles were measured by callipers to the nearest millimetre for length and width (Figure 6).

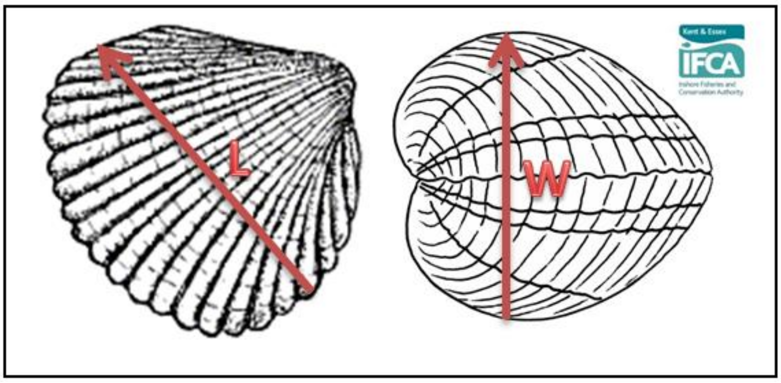


Figure 6 - Cockle length (L) and width (W) measurements.

For each station sample, after measuring, cockles were sorted into age classes by determining how many annual growth rings were present on the shell. Growth rings usually appear each winter (0 rings = current year, 1 ring = 1st winter /1 year, 2 rings = second winter/ 2 years and so on). Each year group, from that station, was weighed separately (to the nearest 1g) and recorded. This was repeated for all station samples and once finished all the cockles were returned to the estuary.

2.1 Data Analysis

R v3.6.1 or later (R Core Team, 2020) and QGIS v3.1 or later (QGIS, 2020) were used for data analyses.

Although there is no minimum size limit applied to cockles in the D&SIFCA's District, the results presented in this report divide the stocks into two size groups (cockles that are 15 mm length and over and those that are under 15 mm length). 15 mm is the suggested minimum size at maturity for cockles (Tyler-Walters, 2007). These groups are therefore sometimes referred to in the report as “adult” (≥ 15 mm) and “juvenile” (< 15 mm) stocks, but it is important to note that cockle size and maturity can be influenced by several factors in addition to age. These size categories do, nevertheless, give an indication of the overall condition and structure of the stock.

A generalised linear mixed model (GLMM) with survey station included as a random effect and year included as a fixed effect was used to assess whether there was any variation in average adult and juvenile cockle density across years whilst accounting for variation in cockle density between survey stations. The relevant contrasts (years) were evaluated using the ‘emmeans’ package (Lenth R, 2024), to establish which years were significantly different from one another. Data from 2018 were excluded from these models due to differences in sampling approach which led to a high level of variation within the data. To visualise the variation in density across the sample sites in each year, the density of cockles at each sample location was plotted on a map using Inverse Distance Weighted interpolation of per-station density.

Differences in the size frequency distributions (length and width) of cockles were visualised and the median length of cockles at each sample location was plotted on a map to visualise variation in the average size of cockles across survey locations.

Total biomass of cockles across the sampled area (25.5 ha – excluding Polly Steps) was calculated by scaling the mean cockle weight per station (0.1m^2) to the total area of the cockle bed. Any stations which could not be surveyed were not included in the calculation, but the calculation assumes a homogeneous density across the whole bed (including sampled and non-sampled areas).

2.2 Incorporating Anecdotal Information

D&S IFCA were aware of anecdotal reports of recreational cockle gathering in the estuary. In order to obtain more information on effort, charts of the estuary with a grid overlay were supplied to individuals who had contacted D&S IFCA regarding hand-gathering activity, for them to indicate where the cockle gathering is taking place. In total, seven regular users of the area completed charts to indicate where they had observed hand-gathering for cockles. These charts were georeferenced in QGIS and overlaid with the survey stations. It is important to note that these observations have not been independently verified by D&S IFCA Officers. Survey stations which overlapped with areas where harvesting had been identified to occur were assigned a ‘harvesting status’ of ‘harvested’, stations where no harvesting had been identified in anecdotal reports were recorded as such. Several GLMMs using the 2019-2024 data were run to test for effects of year and harvesting status (as fixed effects) whilst controlling for survey station (as random effects). The modelling approach initially used assumed that spatial distribution of effort is consistent across all years (ie that the areas with harvesting activity in 2024 also had harvesting activity in 2018, 2019, 2020, and 2022). As this may not be a valid assumption a linear model (LM) was used to test whether cockle density differed between 2022 and 2024, based on the harvesting status of each station.

3. Results

The total number of stations surveyed varied each year (Table 1). This is due to fact that the number and location of inaccessible stations vary yearly and because the number of potential survey stations increased between 2018 and 2019. Table 1 shows a summary of the number of samples taken across all stations for all years surveyed.

Table 1 – Number of stations surveyed/ not surveyed and number of stations in which cockles were present in each year on the Teign Estuary, 2018 – 2024.

	2018	2019	2020	2022	2024
Number of stations surveyed	34	51	47	51	56
Number of stations with cockles present	15	33	31	39	41
Number of stations not surveyed	7	12	15	12	7

The density of adult and juvenile cockles has varied across the six year survey period (2018-2024) (Figure 7a,b). Adult and juvenile cockle density appears to have been higher in 2022 compared to 2020 and 2024. Post-hoc analysis suggests that the increase in adult cockle density between 2020 and 2022 is significant but the decrease between 2022 and 2024 is not significant (Table 3a). In contrast the increase in juvenile cockle density between 2020 and 2022 is not significant but the decrease in density between 2022 and 2024 is significant (Table 3b). P values from the model (not shown) also suggest that both adult and juvenile cockle density in 2019 and 2022 were significantly different to the long term mean (Table 2a,b). However it should be noted that there is high variation within years shown by the error bars (Figure 7a,b) and this should be considered when interpreting the results. In addition, there was high variation in cockle density between survey stations (Figure 8a,b). In particular the density of cockles appears to be highest in the centre of The Salty and north-eastern locations of the survey site (Figure 8). Cockle density was lower upstream of Shaldon Bridge and in the southern extent of The Salty (Figure 8a,b). This pattern has been similar since 2018.

The anecdotal data supplied on the spatial distribution of hand gathering were used in a GLMM to test for effects of year and harvesting status on cockle densities. This analysis indicated that there is no evidence for an effect of harvesting on the density of adult cockle: density did not differ significantly between harvested and non-harvested areas across years (Appendix 1). In addition, the follow-up LM which tested for change in density between 2022 and 2024 across harvested versus non-harvested locations also suggests there is no evidence for an effect of harvesting (Appendix 1). It should be noted that the information supplied for this analysis has not been independently verified and may be subject to a range of potential unquantified observer biases including for example biased timing of observations in relation to tidal cycles or time of day. The GL(M)Ms are also based on existing data of cockle densities and, while confidence in results may be improved by increased density of sampling stations, this is outside of the scope of the resourcing capabilities of D&S IFCA. This should be taken into consideration when interpreting the results.

Table 2 - Summarising AIC analyses for GLMMs explaining the variation in adult (a) and juvenile (b) cockle density (number of cockles per $0.1m^2$) from 2019-2024 M_{test} denotes the model testing for an effect of year on cockle density. Also presented for comparison is the null model (M_{null}). Parameter estimates (with standard errors) are shown for the intercept (β_0), and year (Year). K is the number of parameters, LL is the log-likelihood of the model and σRE is the standard deviation of the random effect (sample station). ΔAIC is the difference in AIC between M_{null} and M_{final}. All models fitted with Poisson error distribution and log link function. * denotes the most parsimonious model.

(a)

Model	β_0	$Year_{2019}$	$Year_{2020}$	$Year_{2022}$	$Year_{2024}$	k	LL	σRE	ΔAIC
M_{test}*	0.698 (0.187)	-0.172 (0.064)	-0.063 (0.065)	0.223 (0.056)	0.013 (0.060)	5	-546.2	1.29	0
M_{null}	0.701 (0.188)	-	-	-	-	2	-555.1	1.30	11.91

(b)

Model	β_0	$Year_{2019}$	$Year_{2020}$	$Year_{2022}$	$Year_{2024}$	k	LL	σRE	ΔAIC
M_{test}	-0.301 (0.201)	-0.338 (0.169)	0.258 (0.134)	0.411 (0.126)	-0.331 (0.174)	5	-204.8	1.08	0
M_{null}*	-0.278 (0.214)	-	-	-	-	2	-213.3	1.12	11.00

Table 3. Estimated marginal means of pairwise comparisons for cockle density of adults (a) and juveniles (b) between years. Significant differences are denoted with *

(a)

Contrast	Estimate	SE	z ratio	p value
2024 - 2022	-0.210	0.093	-2.262	0.107
2024 - 2020	0.075	0.103	0.736	0.883
2024 - 2019	0.185	0.103	1.803	0.272
2022 - 2020	0.286	0.098	2.902	0.019*
2022 - 2019	0.395	0.097	4.071	0 *
2020 - 2019	0.110	0.108	1.018	0.739

(b)

Contrast	Estimate	SE	z ratio	p value
2024 - 2022	-0.742	0.247	-3.006	0.014*
2024 - 2020	-0.589	0.255	-2.310	0.096
2024 - 2019	0.007	0.297	0.024	1.000
2022 - 2020	0.153	0.194	0.784	0.862
2022 - 2019	0.749	0.241	3.114	0.010*
2020 - 2019	0.597	0.247	2.415	0.074

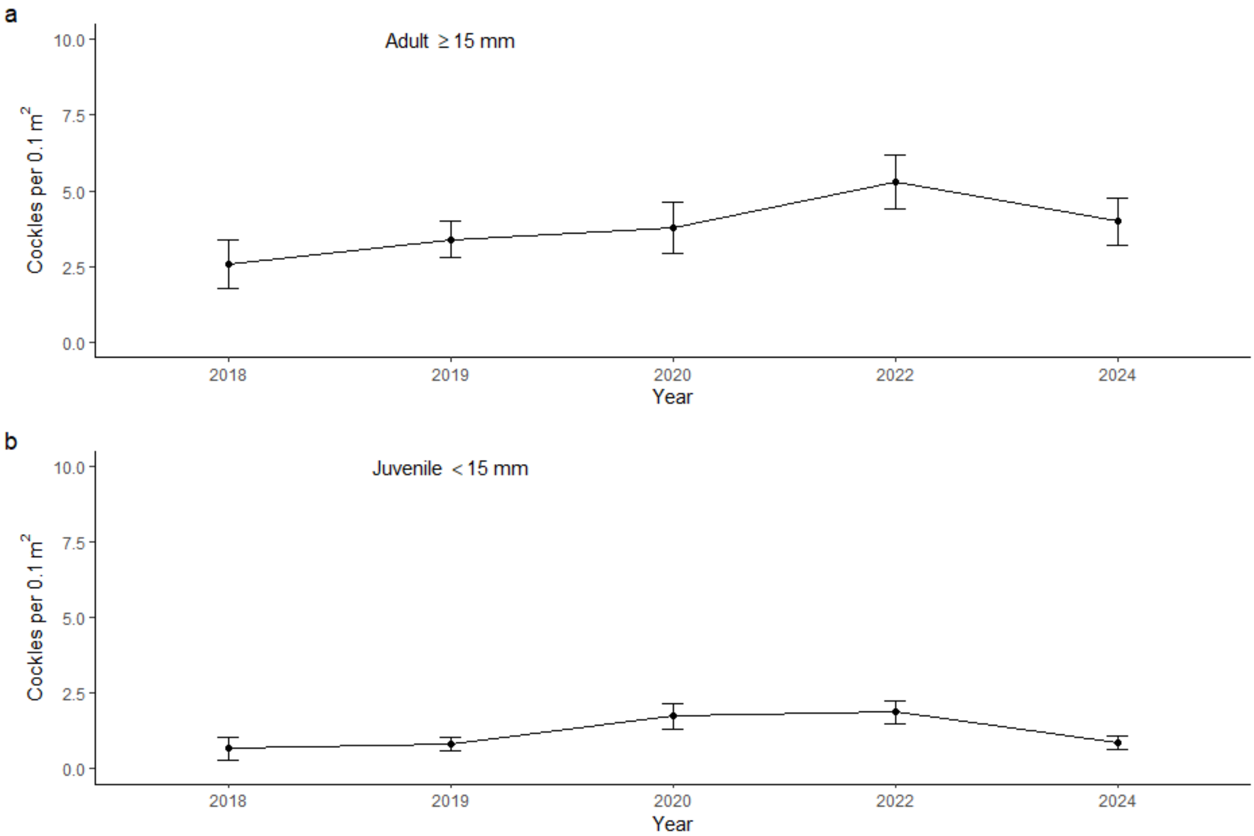


Figure 7 – Mean density (±SE) of (a) adult cockles ≥15 mm and (b) juvenile cockles <15 mm, on the Teign Estuary from 2018–2024.

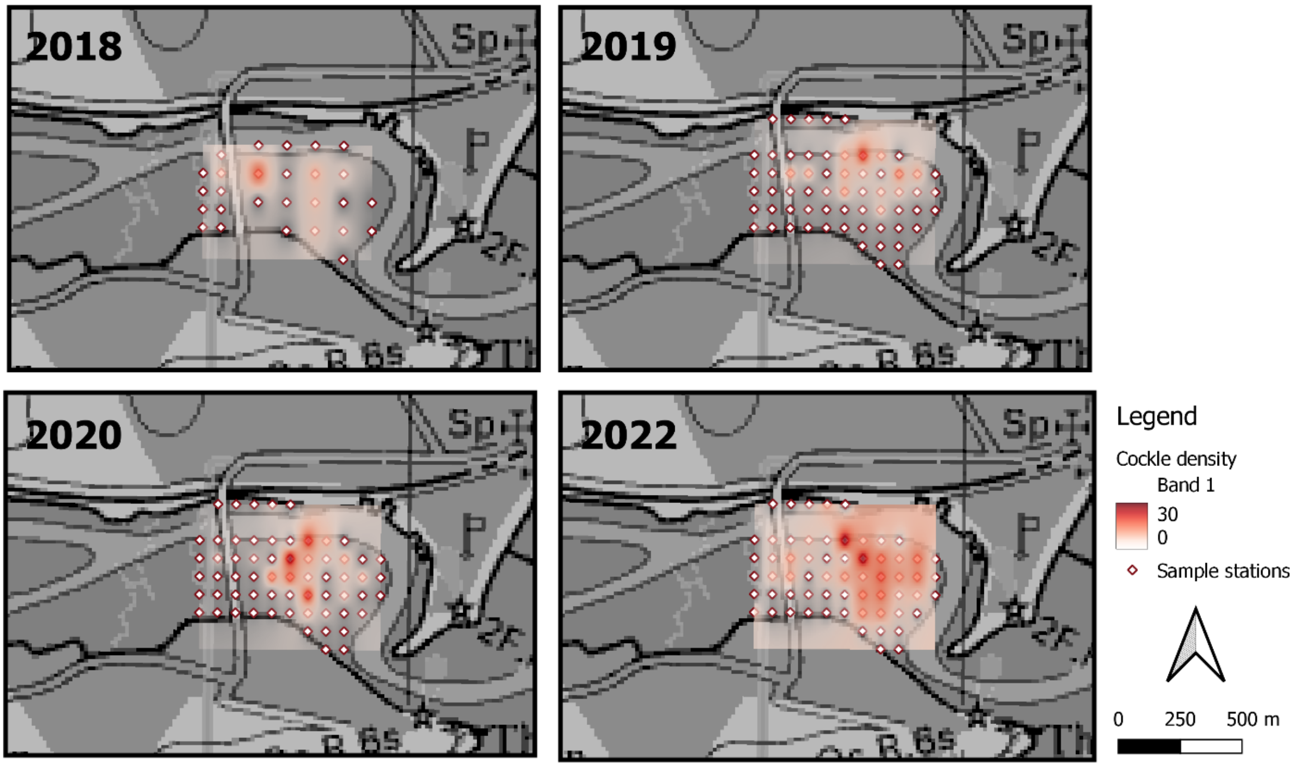


Figure 8a – Cockle density (number of cockles per 0.1m^2 quadrat) on the Teign Estuary in autumn 2018–2022 mapped using Inverse Distance Weighted interpolation on all surveyed stations. * www.ukho.gov.uk/copyright

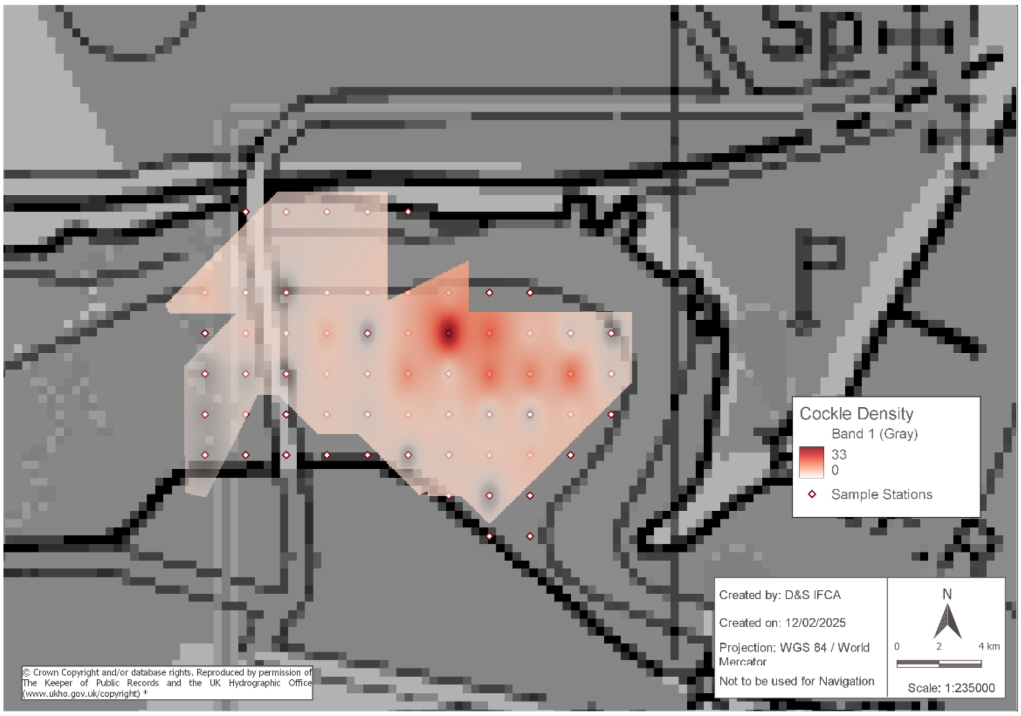


Figure 8b – Cockle density (number of cockles per 0.1m^2 quadrat) on the Teign Estuary in autumn 2024. Mapped using Inverse Distance Weighted interpolation based around a buffer of 36.5m on the stations sampled where cockles were present. * **www.ukho.gov.uk/copyright**

The average length of cockles across all survey stations has remained stable across the six year period (Figure 9), but the distribution of sizes around the average varies across years (Figure 9, Figure 10, Figure 11). The shapes of the frequency distributions of cockle length and width (Figure 10, Figure 11) show some variations across years. The low number of cockles sampled in 2018 (probably due to the lower number of survey stations) has resulted in a frequency distribution that does not have a clear shape (Figure 10a, Figure 11a). The frequency distributions of cockle length and width in 2019 (Figure 10b, Figure 11b) have a clear unimodal distribution (distribution with one clear peak), whereas those in 2020 and 2022 (Figure 10c,d, Figure 11c,d,) appear to have a bimodal distribution (distribution with two clear peaks). The high degree of variation in the 2024 data has resulted in a frequency distribution for length that does not appear to have a clear shape but width appears to have more of a bimodal distribution (Figure 10 and 11e). The average length of cockles varies between sample locations (Figure 12). In particular, larger cockles tend to be found in the west and some in the south east of the survey site, whereas smaller cockles are found in the centre of the site. In 2024 some of the larger cockles were also located at Polly Steps (Figure 12).

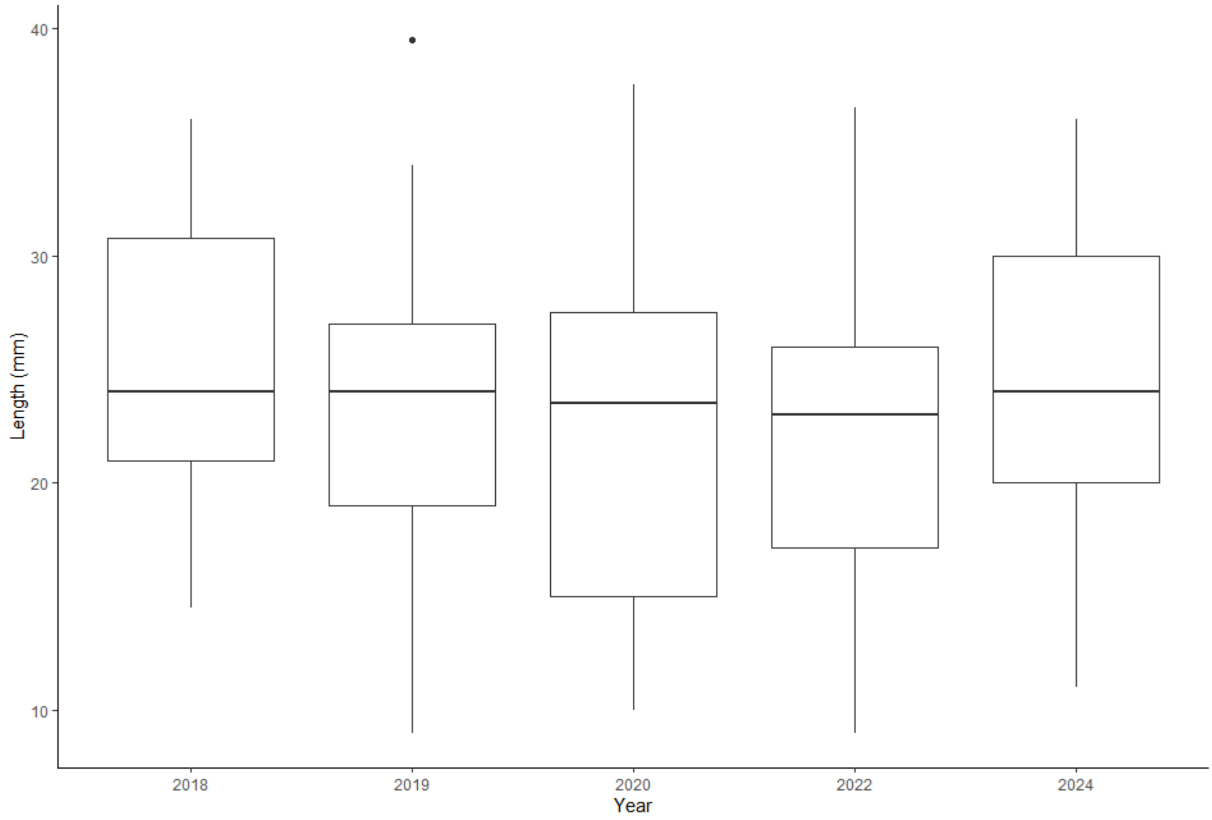


Figure 9 - Length (mm) (median, inter-quartile range and range) of cockles on the Teign Estuary from 2018–2024.

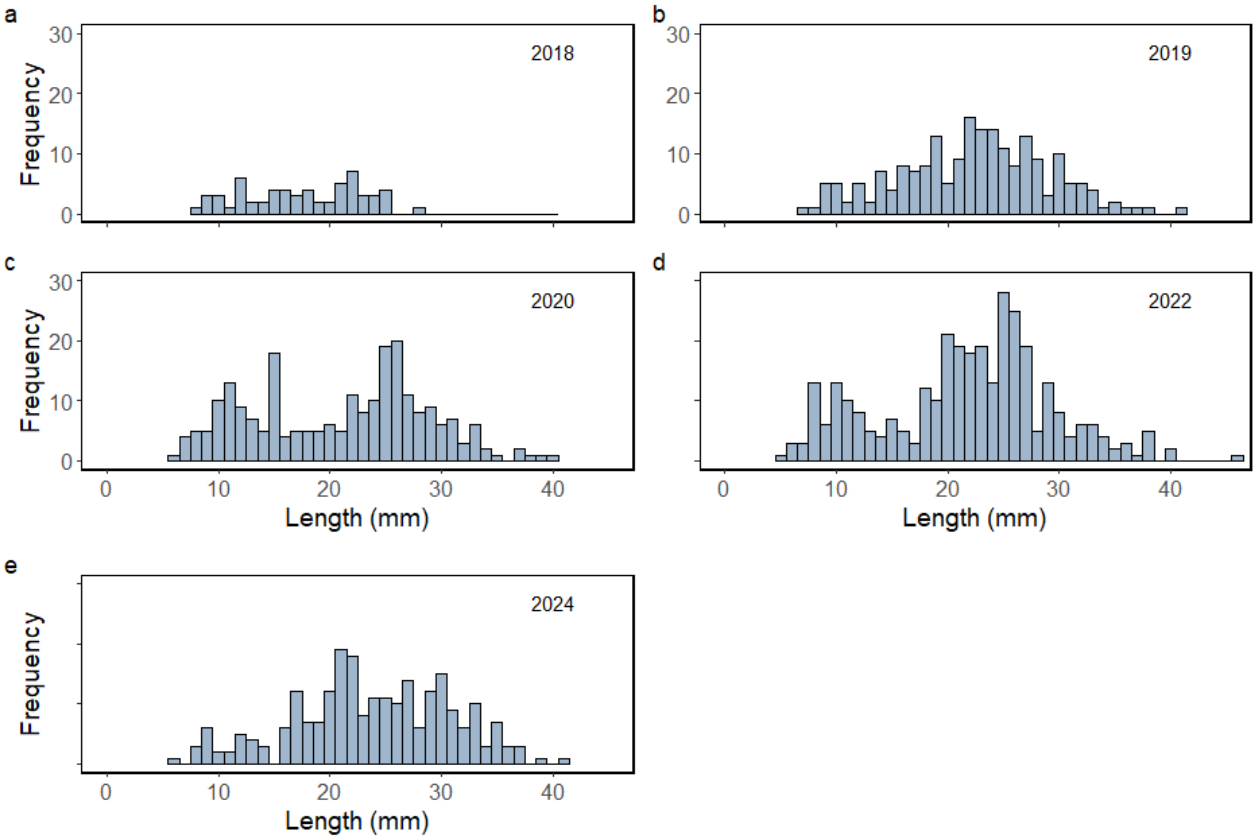


Figure 10 – Frequency of cockle lengths (mm) in each survey year on the Teign Estuary.

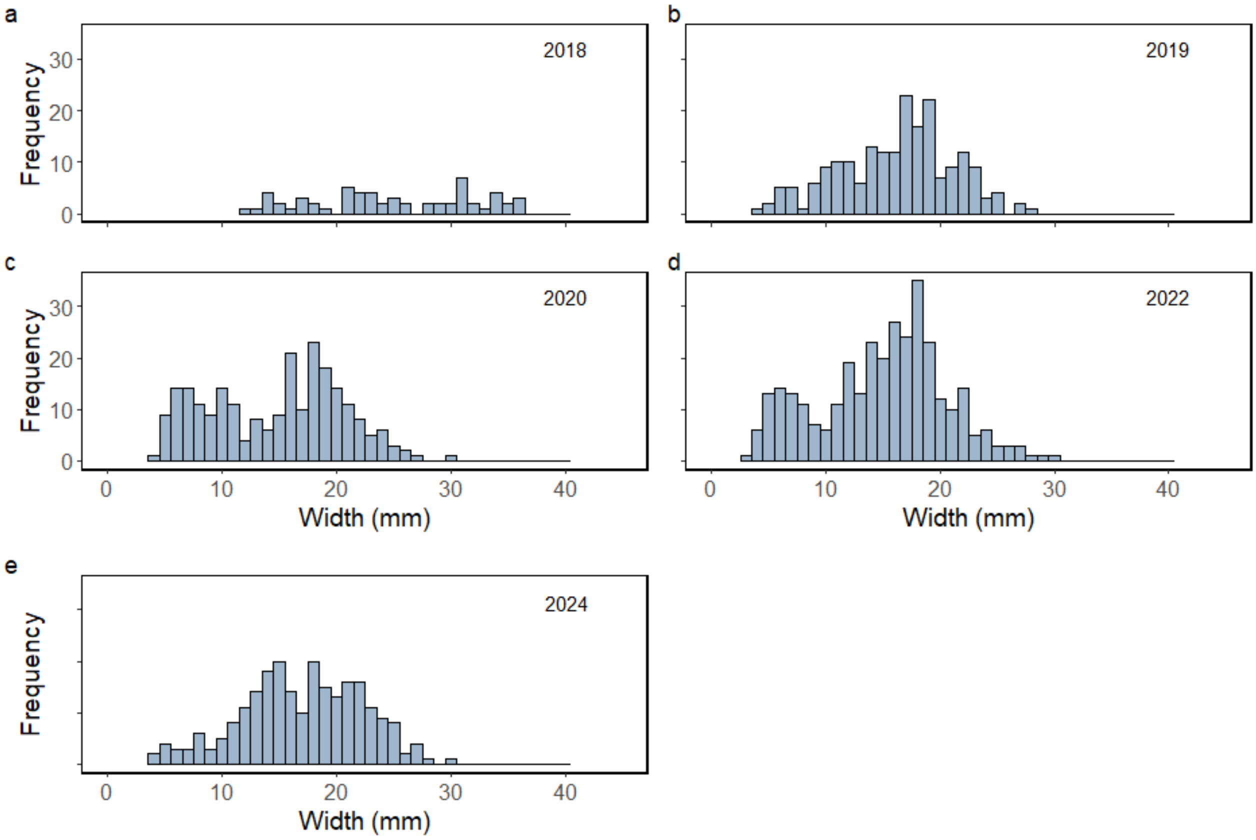


Figure 11 – Frequency of cockle widths (mm) in each survey year on the Teign Estuary.

Figure 12 - Median cockle size (mm) at each sampling station on the Teign Estuary in autumn 2018–2024. Sampling sites that were not surveyed or that contained no cockles are not shown on the map. * www.ukho.gov.uk/copyright

The total tonnage of cockles across the surveyed area in 2024 was estimated at 64 tonnes (Figure 13). This is an apparent decrease of around 26% in estimated total tonnage since the 2022 survey, where total biomass was estimated as 87 tonnes. Note that the tonnage calculation methods have been updated since the 2022 report, so the equivalent figure in previous reports will not be comparable to Figure 13. The number of observed cockles in each year class except year 1 have decreased in the 2024 survey compared to the 2022 survey, with year class 5 being absent from the 2024 survey (Figure 14).

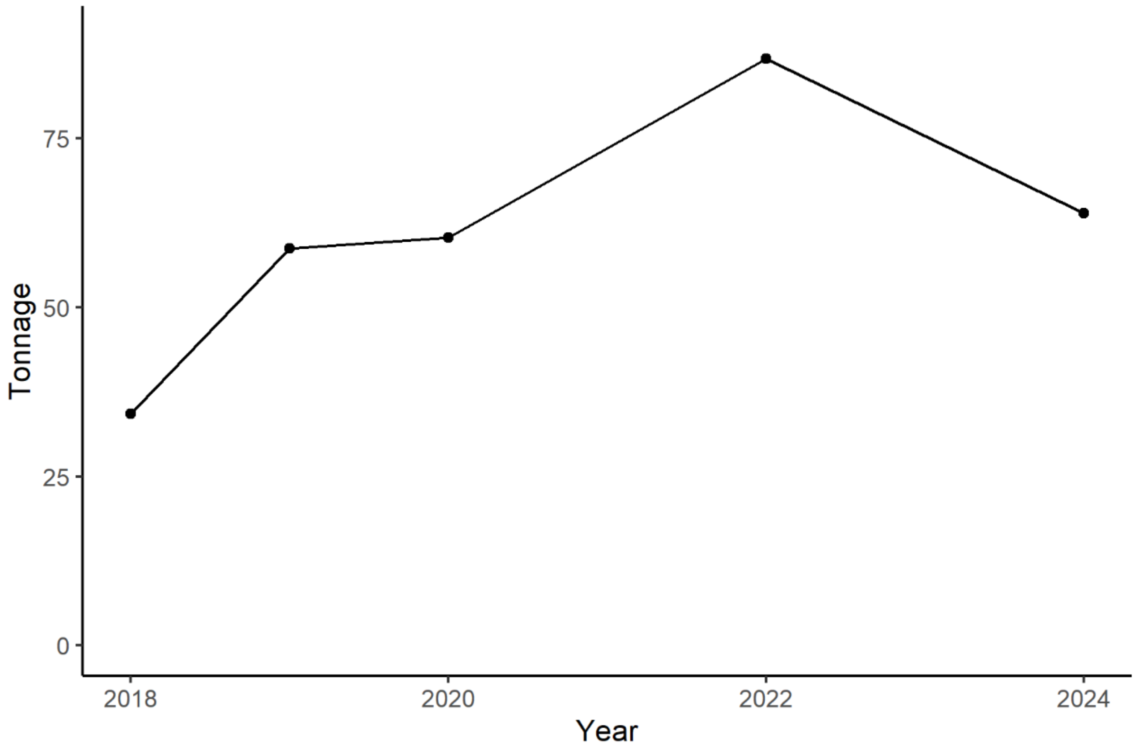


Figure 13 – Total estimated tonnage of cockles across the total area of the cockle bed (25.5 ha – excluding Polly Steps) 2018–2024.

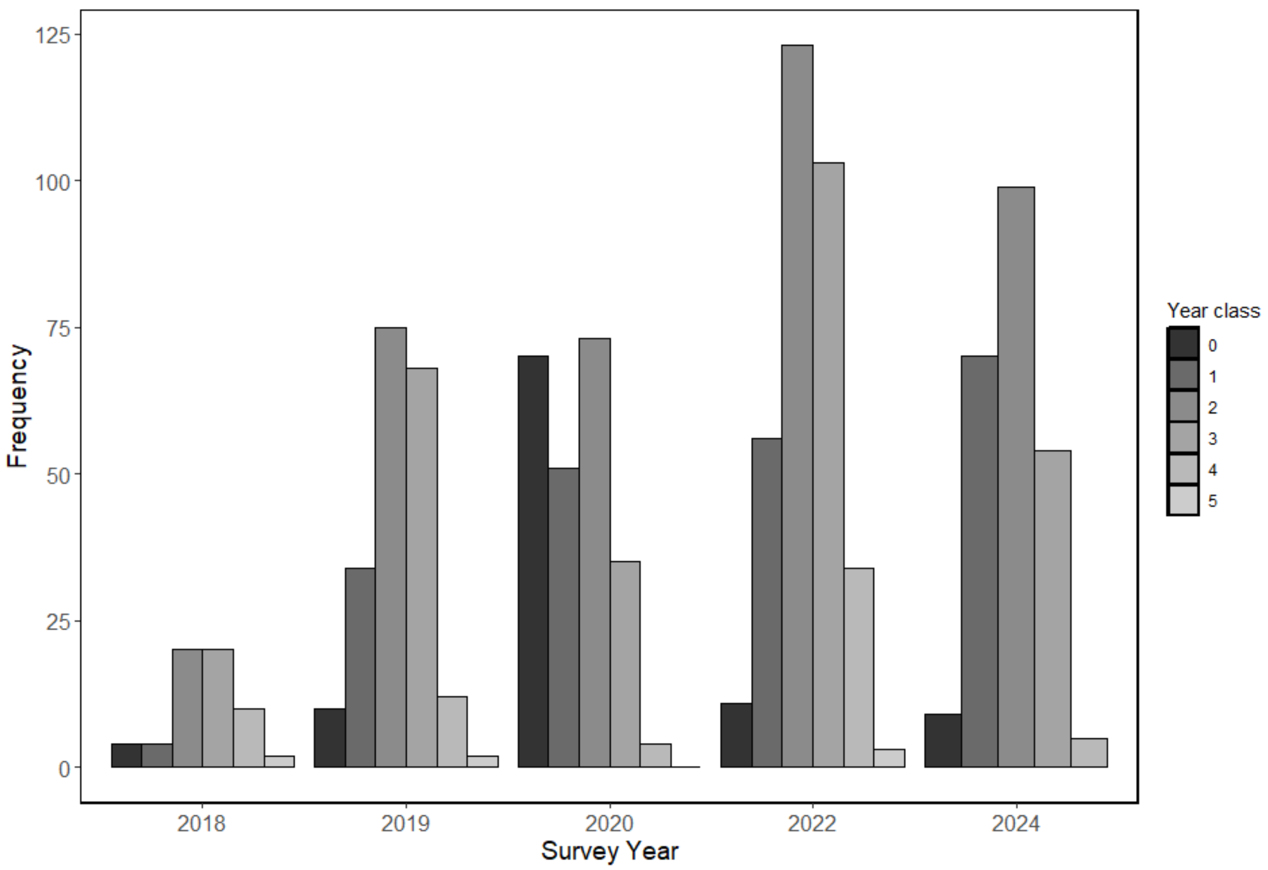


Figure 14 – Number of cockles in each year class for each survey year. Year classes are determined by counting the number of growth rings on a cockle's shell (0 rings = year 0, 1 ring = year 1, etc).

4. Discussion

D&S IFCA has carried out annual autumn cockle surveys on the Teign Estuary since 2018. This report monitors the change in density and average size of cockles across The Salty and surrounding areas on the Teign Estuary between 2018 and 2024 and discusses the implications for the users of the estuary who gather cockles recreationally.

The density of juvenile cockles decreased significantly between 2022 and 2024, but there was no significant difference in adult density between these years. Despite this more recent decrease in juvenile density, to levels similar to the six-year mean, the average size of cockles has remained stable across the six year period. There was a high degree of variation in cockle density (both juvenile and adult) between sample sites, which highlights the importance of accounting for or considering this variation when conducting analysis and interpretation of data. The density of cockles appears to be highest in the centre to north-east of the survey site. Differences in hydrology across the study area could explain the variation in cockle density, as cockles prefer moderately strong (1–3 knots) tidal flow (Tyler-Walters, 2007). Cockle density is also shown to be higher in intertidal areas subject to increased submergence times and in proximity to and within local hydrological features such as channels and tidal pools (Tyler-Walters, 2007). Cockles typically display preference towards stable submerged or intertidal muddy and sandy habitats, where if conditions are favourable (salinity, access to food, temperature, recruitment of juveniles can be facilitated etc) then populations can thrive (Boyden and Russell, 1972; Brock, 1979; Guillou and Tartu, 1994; Whitton *et al.*, 2015). The sediment (a mix of sandy gravel) in the central location is also more stable than the sediment by the bridge and seaward extent of the sand bank. The fringing sediments are subject to increasing scour by the tide and as a result are more mobile than the packed sediment towards the centre of the sandbank (Dalrymple and Rhodes, 1995).

D&S IFCA has received a number of reports of hand-gathering of cockles, some of which report large quantities being removed. Larger cockles are likely to be targeted and therefore an increase in landings could impact the density of adult cockles in the estuary. Information supplied to D&S IFCA indicate hand-gathering is taking place either side of Shaldon Bridge and in the middle of the Salty. These areas overlap with current survey stations, allowing for initial statistical analysis of cockle densities in harvested versus non-harvested areas, though it is important to note that the anecdotal information on hand-gathering has not been independently verified by D&S IFCA Officers. Results from the statistical analyses (GLMM and LM) indicate that at the current level of effort, cockle gathering does not appear to be having an impact on the density of adult cockles. Whilst there is a temporary closure of shellfish beds in the Teign, this only applies to mussel. There are currently no D&S IFCA Byelaws that manage the collection of cockles from estuaries within D&S IFCA's District.

The variation in the distribution of cockle sizes around the stable average could be due to a number of reasons. Firstly, the addition of more survey sites in 2019 – 2024 compared to 2018 increased the total number of cockles sampled, which means that the overall sample of cockles is likely to be more representative of the population on the Teign Estuary. The bimodal distribution of sizes observed in the 2020 and 2022 samples of cockles may suggest that these years were particularly strong for cockle recruitment, although this additional peak in smaller sized cockles did not impact the overall average cockle size for those years.

However, it is also important to consider the possible variation in cockle size across years that arises from the different sampling stations that are surveyed each year (e.g. due to the differences in (in)accessible survey stations across years). The GLMMs fitted for adult and juvenile cockle density highlighted the high level of variation in density between sampling locations. It is also possible that there are similarly high levels of variation in cockle size across sampling locations within the survey site. It was not possible to model cockle size in this way as the data did not conform to the prerequisites of the modelling approach.

In addition to this variation in cockle size and density, the total biomass of cockles on the bed has also varied year on year. However, when interpreting the results it is important to consider the high variability between stations and across years, as these factors may hinder the accurate detection of subtle changes in the cockle population. Cockle populations are naturally subject to high levels of variation, which is considered a normal feature of *Cerastoderma edule* populations. Therefore, long-term monitoring is required to detect potential trends in the population dynamics of any given cockle population (Jensen, 1992; Whitton *et al.*, 2015).

Although there is currently no commercial fishery for cockles on the Teign Estuary, D&S IFCA will aim to continue the autumn survey every two years to monitor the cockle stocks and to inform future development of a potential Hand Working Byelaw.

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Appendix 1: Results of statistical tests for effects of harvesting status on density of adult cockles

Table A1: AIC summary of candidate Generalised Linear Mixed Models (Poisson error distribution with log link) testing for effects of harvesting on density of adult cockles. ● indicates when each variable was included in the candidate model. The random effect of survey station was included in all stations to account for repeat sampling between years. Lower AIC value indicates better fit of the model to the data. No models have an AIC value lower than that of the null model, indicating no evidence to support effects of year or harvesting status on the density of adult cockles between 2019 – 2024.

Model	Year	Harvesting Status	Year : HarvestingStatus Interaction	Survey Station	AIC
$GLMM_a$	●	●	●	●	990.19
$GLMM_b$	●	●		●	990.24
$GLMM_c$	●			●	988.76
$GLMM_d$		●		●	1000.06
$GLMM_{Null}$				●	998.60

Table A2: AIC summary of candidate Linear Models (Gaussian error distribution, identity link) testing for effects of harvesting on change in density of adult cockles between 2022 – 2024. ● indicates inclusion of the variable in the model. Lower AIC value indicates better fit of the model to the data. No models have an AIC value lower than that of the null model, indicating no evidence to support effects of year or harvesting status on the density of adult cockles between 2019 – 2024.

Model	Harvesting Status	AIC
LM_a	●	251.72
LM_{Null}		250.21