Teign Estuary
Cockle Stock Assessment 2026



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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.

Cockles*, Cerastoderma edule,* are present within the estuary and are known to be collected at low levels both historically and to the present day (Cefas 2013). 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 (Cefas 2013, Carcinus Ltd 2021), 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's Hand Working Permit Byelaw.

2. Methods

Surveys were conducted annually from 2018 to 2020 and have subsequently been undertaken every two years. Each survey is completed over a single day during low-water spring tides. The 2018 and 2019 surveys were conducted in November and October, respectively, while the 2020 and 2022 surveys took place in August. The 2024 survey was conducted in September, and the 2026 survey was undertaken in July. The variation in survey timing reflects the need to coordinate these surveys with other molluscan surveys conducted 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), 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). The survey area was selected over the area historically known to contain cockles and where harvesting has previously been observed.

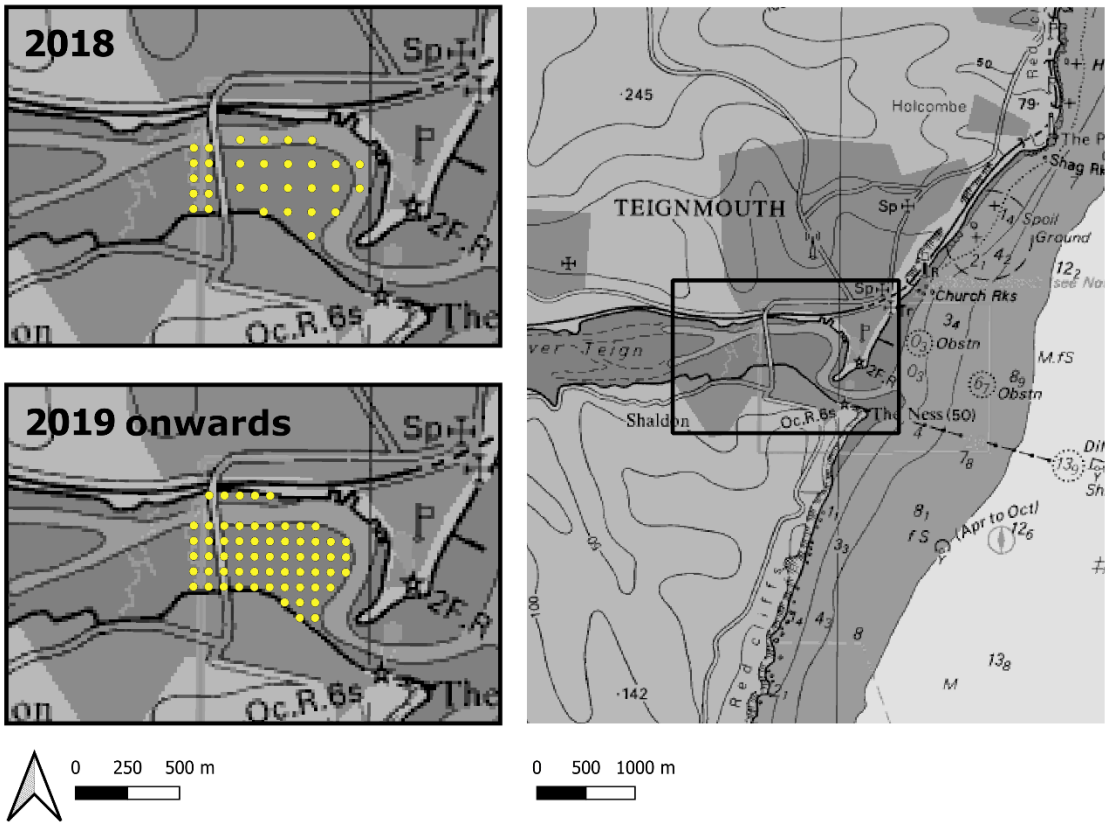


Figure 1– Teign Estuary cockle survey stations. The sites that are (in)accessible can vary each year.

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). 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 2– 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).

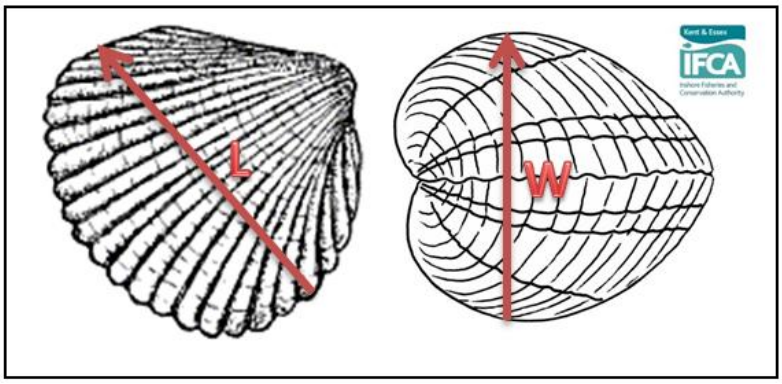


Figure 3 - Cockle length (L) and width (W) measurements.

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 v4.4.2 or later (R Core Team 2024) and QGIS v3.44 or later (QGIS 2022) 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 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

Prior to the 2024 survey, D&S IFCA received anecdotal reports of recreational cockle gathering within the Teign Estuary. To obtain information on the location and distribution of hand-gathering activity, charts of the estuary with a grid overlay were provided to individuals (in 2024) who had contacted D&S IFCA regarding cockle gathering. Seven regular users of the area completed the charts, indicating locations where they had observed cockle hand-gathering. These charts were georeferenced in QGIS and overlaid with the cockle survey stations.

It is important to note that the reported observations have not been independently verified by D&S IFCA Officers and therefore provide an indication of reported harvesting activity rather than confirmed levels of fishing effort. Survey stations overlapping areas identified through these anecdotal reports were previously assigned a harvesting status of 'harvested', while stations for which no harvesting activity had been reported were classified as 'not harvested'.

In the 2024 assessment, these harvesting-status classifications were incorporated into statistical analyses to investigate potential differences in cockle density between areas subject to reported harvesting and areas where no harvesting had been reported. The analyses used data from 2019–2024 and accounted for survey year and survey station. However, no additional analysis of harvesting activity was undertaken as part of the 2026 assessment. The previously identified harvesting areas are therefore retained as contextual information when interpreting the current survey results, rather than being used to infer an effect of harvesting on cockle density in 2026.

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 – 2026.

	2018	**2019**	**2020**	**2022**	**2024**	**2026**
Number of stations surveyed	34	51	47	51	56	54
Number of stations with cockles present	15	33	31	39	41	32
Number of stations not surveyed	7	12	15	12	7	8

Adult cockle density varied across the survey period, increasing from approximately 2.5 cockles per 0.1 m² in 2018 to a peak of approximately 5.2 cockles per 0.1 m² in 2022. Adult density subsequently declined to approximately 4.0 cockles per 0.1 m² in 2024 and 2.8 cockles per 0.1 m² in 2026. Juvenile cockle density remained low in 2018 and 2019 (approximately 0.7–0.8 cockles per 0.1 m²), before increasing to approximately 1.7 and 1.9 cockles per 0.1 m² in 2020 and 2022, respectively. Juvenile density then declined to approximately 0.9 cockles per 0.1 m² in 2024 and 0.5 cockles per 0.1 m² in 2026 (Figure 4).

Post-hoc analysis suggests that the increase in adult cockle density between 2020 and 2022 is significant and the decrease between 2022 and 2026 is also 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 2026 is significant (Table 3b). Adult cockle density in 2022 appears to have been substantially higher than the 2019 – 2026 average, while adult cockle density in 2026 appears to have been substantially lower than the 2019 – 2026 average (Table 2a). The same is true of juvenile cockle density, with estimates also suggesting that juvenile cockle density was substantially in 2019 than the average across 2019 – 2026 (Table 2b). However, there was considerable variation in cockle density was observed both within and between survey years, particularly for juvenile cockles, as reflected by the relatively high standard errors in Table 2b. Within-year variation is also illustrated by the error bars in Figure 4a and b and should be considered when interpreting differences in average density between years.

Spatial variation in cockle density was also evident across the survey stations (Figure 5a, b), with the highest densities generally occurring towards the centre of The Salty, together with smaller areas of higher density in the southern and western parts of the survey area. Lower cockle densities were generally observed upstream of Shaldon Bridge (Figure 5a, b). This broad spatial distribution pattern was consistent across the survey period, although the extent and intensity of higher-density areas varied between years. In 2024 and 2026, for example, areas of higher cockle density remained concentrated towards the centre of the survey area, despite lower overall mean adult density compared with 2022 (Figure 4a; Figure 5b).

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 2019-2026 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	$Year_{2019}$	$Year_{2020}$	$Year_{2022}$	$Year_{2024}$	$Year_{2026}$	k	LL	σRE	ΔAIC
M_{test}*	0.569 (0.179)	-0.086 (0.067)	0.003 (0.068)	0.310 (0.058)	0.090 (0.063)	-0.317 (0.076)	6	-666.8	1.26	0
M_{null}	0.578 (0.181)	-	-	-	-		2	-686.1	1.28	30.49

(b)

Model	β_0	$Year_{2019}$	$Year_{2020}$	$Year_{2022}$	$Year_{2024}$	$Year_{2026}$	k	LL	σRE	ΔAIC
M_{test}	-0.531 (0.209)	--0.113 (0.183)	0.113 (0.140)	0.607 (0.135)	-0.153 (0.186)	-0.784 (0.236)	6	232.6	1.09	0
M_{null}*	-0.475 (0.218)	-	-	-	-		2	-249.5	1.16	25.90

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
	2026 - 2024	-0.407	0.113	-3.616	0.003*
	2026 - 2022	-0.627	0.108	-5.808	0*
	2026 - 2020	-0.320	0.117	-2.739	0.049*
	2026 - 2019	-0.231	0.116	-1.986	0.273
	2024 - 2022	-0.219	0.093	-2.361	0.126
	2024 - 2020	0.087	0.102	0.852	0.914
	2024 - 2019	0.176	0.103	1.716	0.424
	2022 - 2020	0.307	0.098	3.122	0.015*
	2022 - 2019	0.395	0.097	4.066	0*
	2020 - 2019	0.089	0.108	0.826	0.923
(b)	**contrast**	**Estimate**	**SE**	**z.ratio**	**p.value**
	2026 - 2024	-0.631	0.3498	-1.805	0.371
	2026 - 2022	-1.391	0.3114	-4.468	0*
	2026 - 2020	-1.227	0.3132	-3.917	0.001*
	2026 - 2019	-0.670	0.3488	-1.922	0.305
	2024 - 2022	-0.760	0.2460	-3.088	0.017*
	2024 - 2020	-0.596	0.2524	-2.360	0.126
	2024 - 2019	-0.039	0.2963	-0.131	1.000
	2022 - 2020	0.164	0.1933	0.849	0.915
	2022 - 2019	0.721	0.2407	2.995	0.023*
	2020 - 2019	0.557	0.2466	2.257	0.159

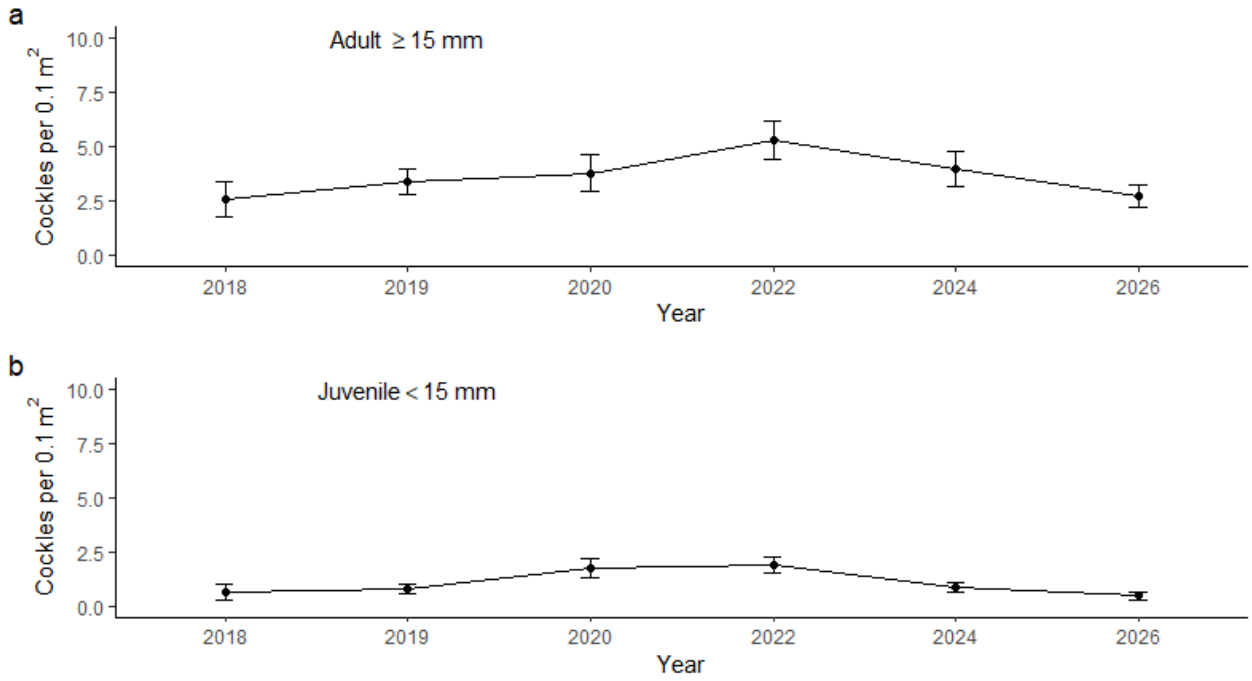


Figure 4 – Mean density (±SE) of (a) adult cockles ≥15 mm and (b) juvenile cockles <15 mm, on the Teign Estuary from 2018–2026.

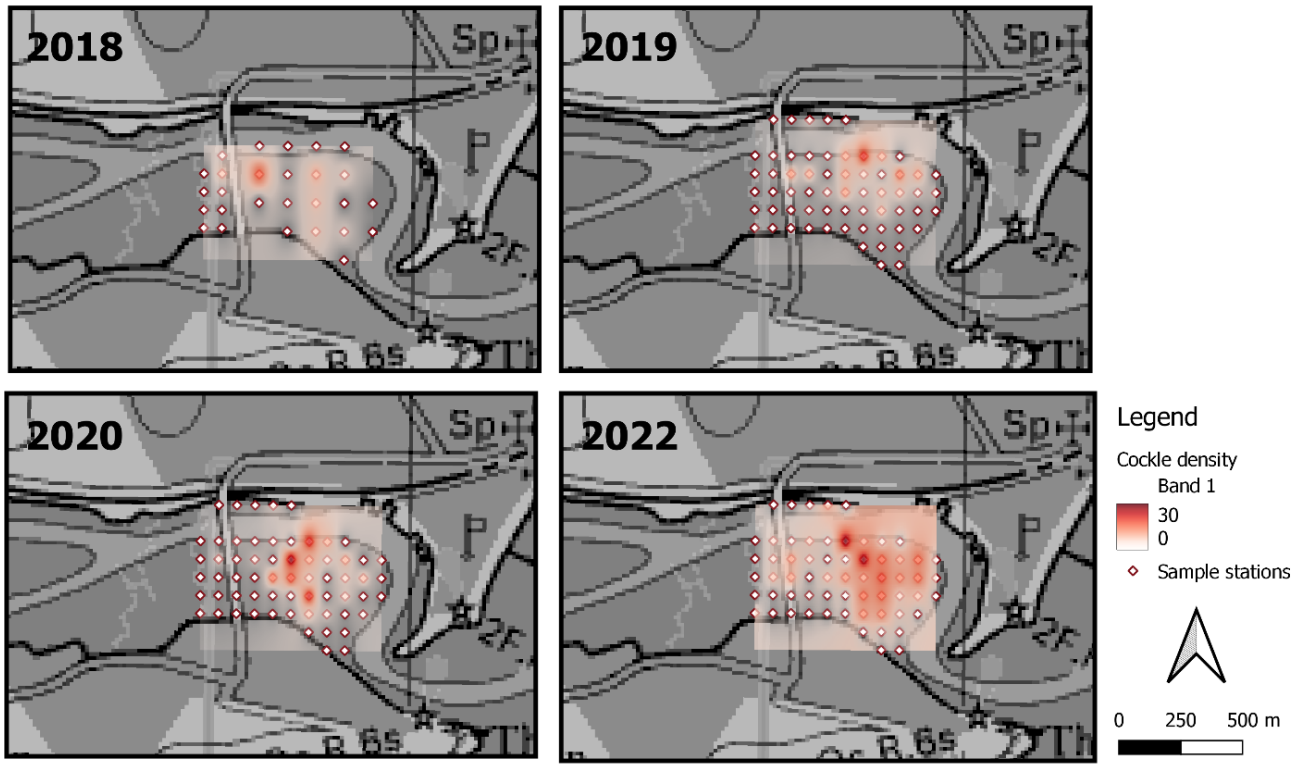


Figure 5a – Cockle density (number of cockles per 0.1m^2 quadrat) on the Teign Estuary in autumn 2018–2022 mapped using Inverse Distance Weighted interpolation on all surveyed stations. * www.ukho.gov.uk/copyright

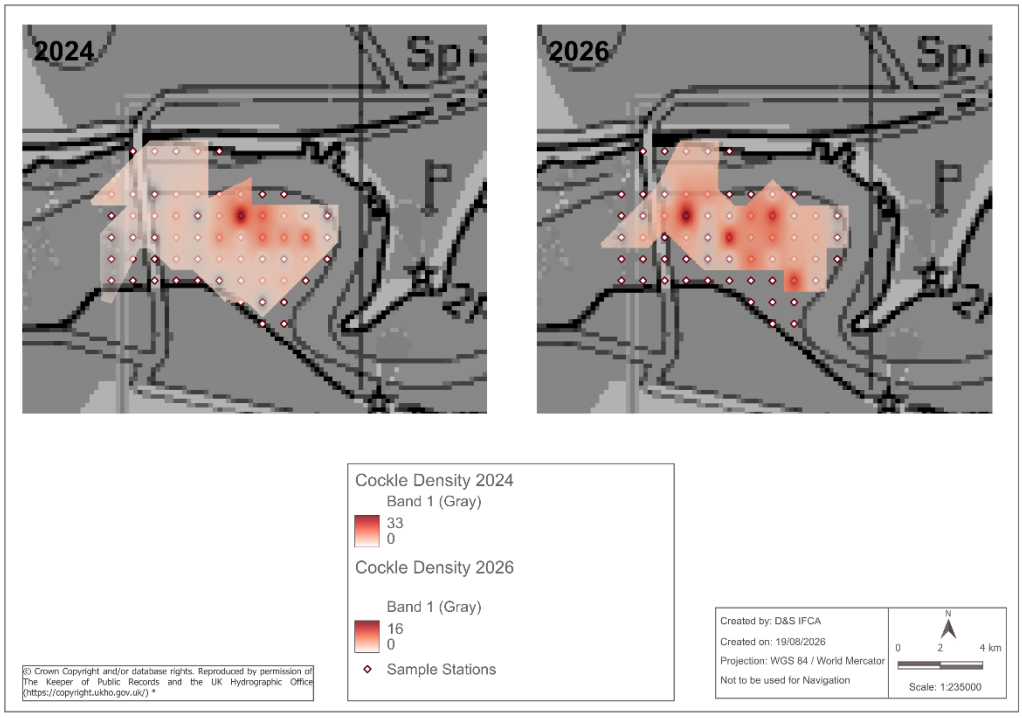


Figure 5b – Cockle density (number of cockles per 0.1m^2 quadrat) on the Teign Estuary in autumn 2024 and 2026. Mapped using Inverse Distance Weighted interpolation based around a buffer of 36.5m on the stations sampled where cockles were present. * www.ukho.gov.uk/copyright

Mean cockle length across the survey stations remained relatively consistent over the survey period, although some variation between years was evident (Figure 6). The boxplots indicate that the median length remained within a relatively narrow range, with 2020 showing the lowest median

length and 2018 the highest. The overall range of lengths varied between years, with particularly wide distributions observed in 2018, 2020 and 2022 (Figure 6).

The frequency distributions of cockle length and width showed variation in shape between survey years (Figures 7 and 8). In 2018, the relatively low number of cockles sampled resulted in broad and poorly defined frequency distributions for both length and width (Figures 7 and 8). In 2019, both length and width distributions were predominantly unimodal, with a single main peak evident in each distribution (Figures 7b and 8b). In 2020 and 2022, the length and width distributions showed evidence of two distinct size groups, particularly for length, resulting in a more bimodal distribution (Figures 7c, d and 8c, d).

In 2024, the length distribution was relatively broad, with no clearly defined single or bimodal peak, while the width distribution showed little evidence of two size groups (Figures 7e and 8e). In 2026, the length and width distributions were broad with no clear peaks (Figures 7f and 9f). Overall, the frequency distributions indicate variation in the size structure of the cockle population between survey years.

The average length of cockles varies between sample locations (Figure). Larger cockles tend to be concentrated towards the centre and eastern side of the site, whereas smaller cockles are more commonly found towards the western and southern areas. This pattern becomes more apparent in the later survey years, with larger cockles increasingly distributed across the central and eastern areas of the site. In 2024, larger cockles were also present towards the western side of the site (Figure 5).

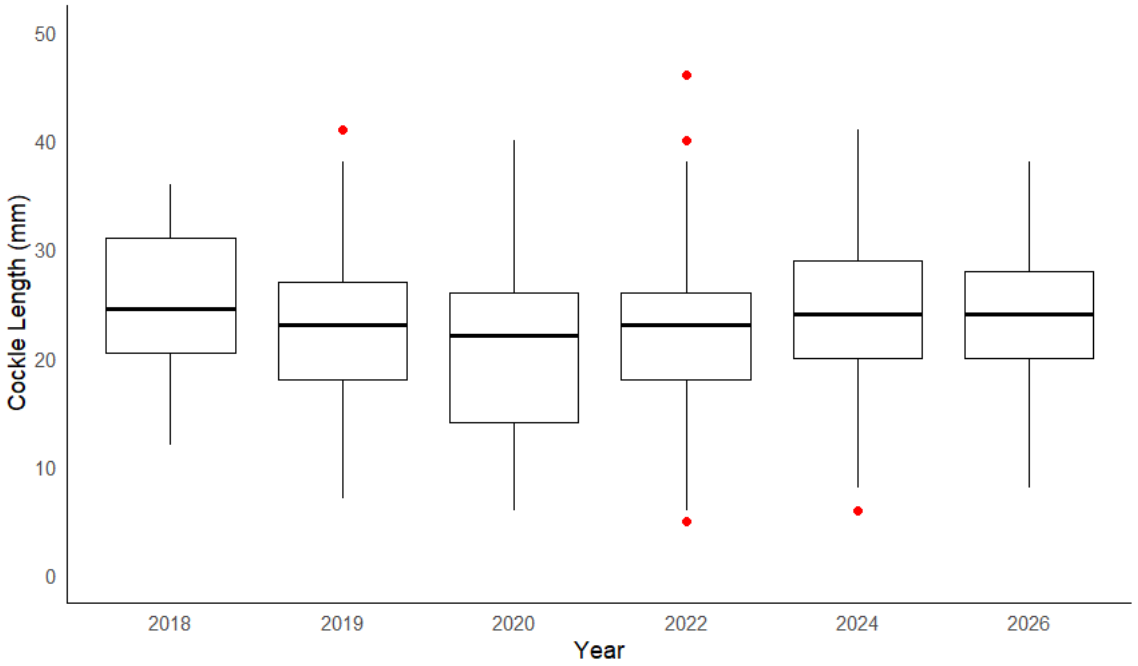


Figure 6 - Length (mm) (median, inter-quartile range, and range) of cockles on the Teign Estuary from 2018–2026.

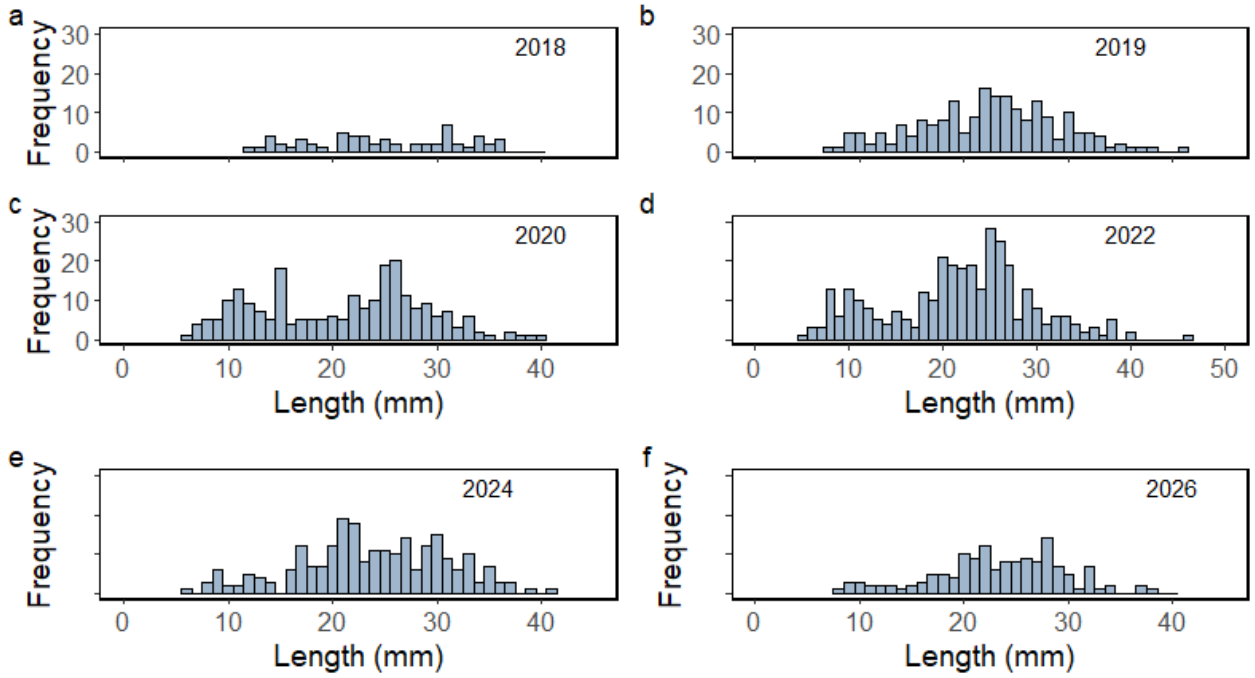


Figure 7– Frequency of cockle lengths (mm) in each survey year on the Teign Estuary.

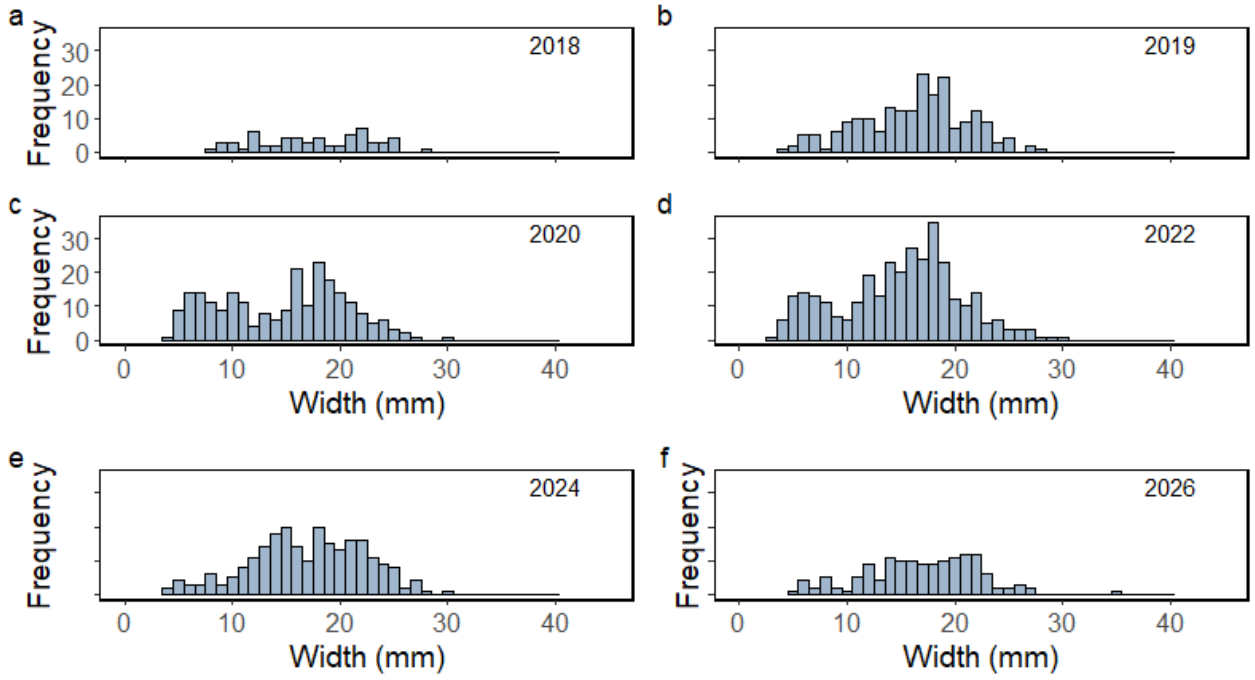


Figure 8– Frequency of cockle widths (mm) in each survey year on the Teign Estuary.



Figure 9 - 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 2026 was estimated at 42 tonnes (Figure 10). This is an apparent decrease of around 34% in estimated total tonnage since the 2024 survey, where total biomass was estimated as 64 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 10. The number of observed cockles in each year class except year 5 has decreased in the 2026 survey compared to the 2024 survey (Figure).

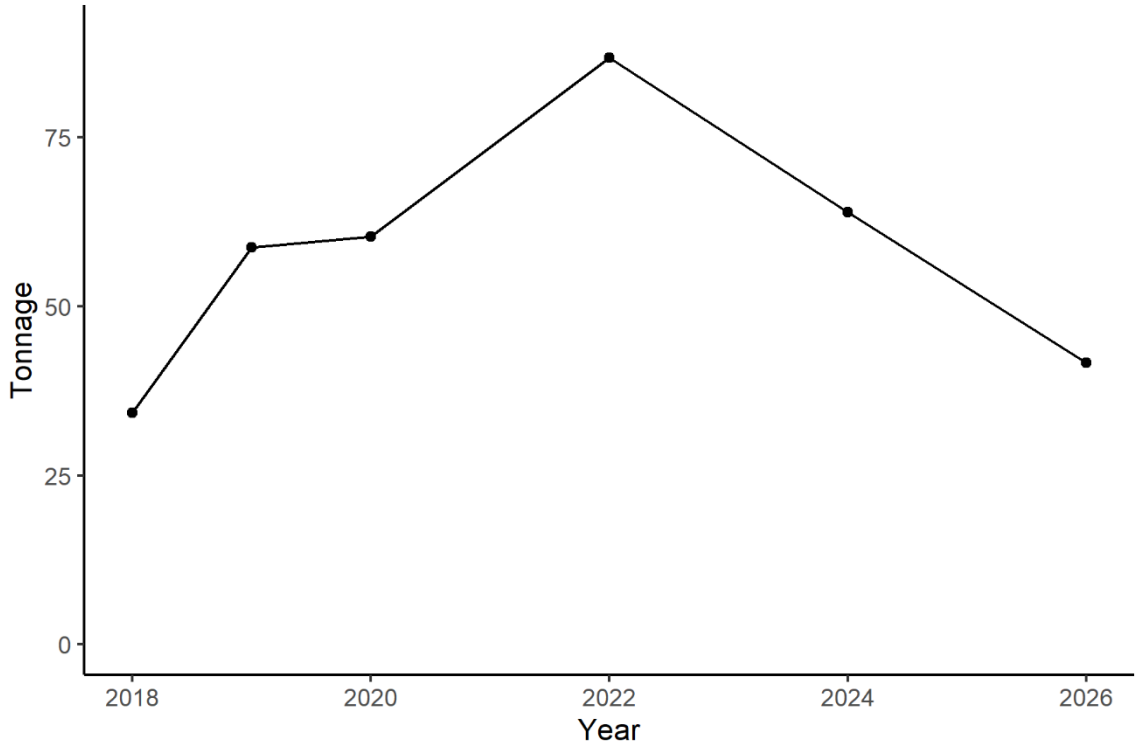


Figure 10 Total estimated tonnage of cockles across the total area of the cockle bed (25.5 ha – excluding Polly Steps) 2018–2026.

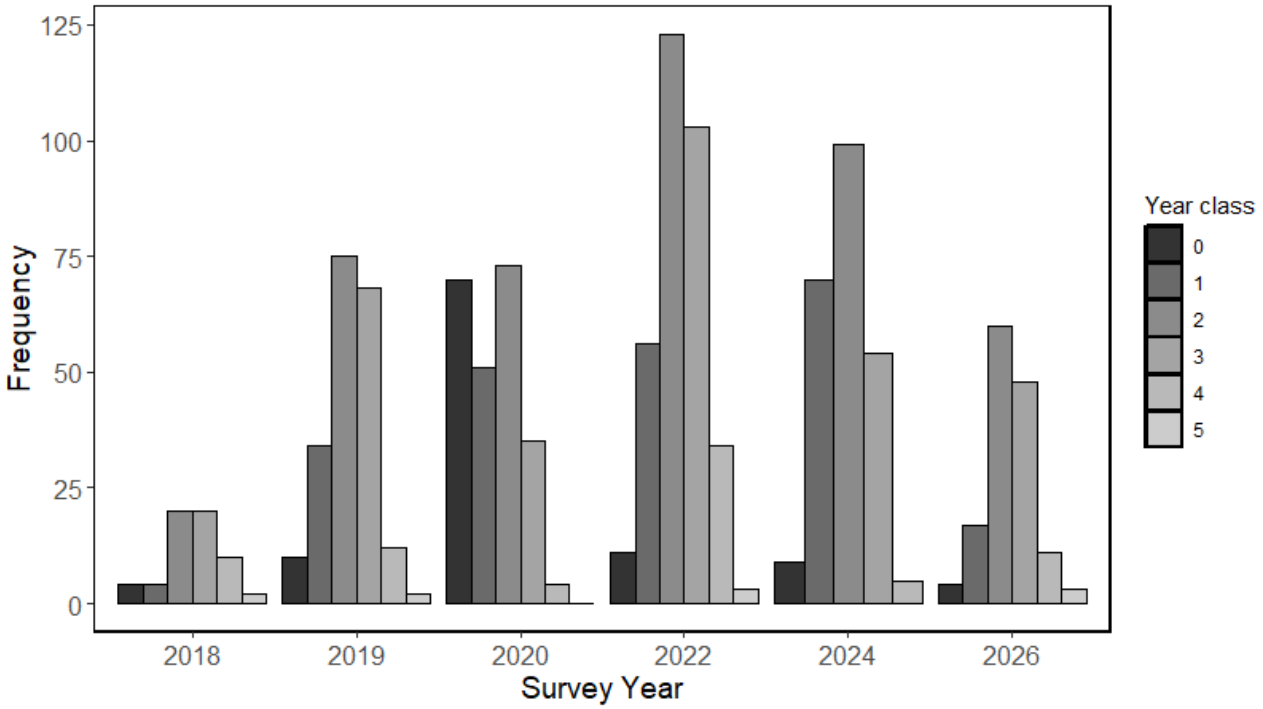


Figure 1– Number of cockles in each year class for each survey year. Year classes are determined by counting the number of growth rings on a cockle's shell (0 rings = year 0, 1 ring = year 1, etc).

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 2026 and discusses the implications for the users of the estuary who gather cockles recreationally.

The results from the surveys conducted between 2018 and 2026 indicate considerable temporal and spatial variation in cockle density within the Teign Estuary, while the overall size of cockles has remained relatively stable. Adult density increased to a maximum in 2022 before appearing to decline in subsequent surveys, with the analysis indicating higher adult density in 2022 and lower density in 2026 relative.

Juvenile density showed a different temporal pattern to adults, with significantly higher densities recorded in 2020 and 2022 relative to the long-term mean. Juvenile density subsequently appeared to decline, with 2026 statistically significantly lower than both 2020 and 2022. However, there was no significant difference in juvenile density between 2024 and 2026. Although juvenile density in 2026 was therefore lower than in the years of highest juvenile abundance, it was broadly comparable with the longer-term mean. The contrasting patterns between juvenile and adult density may reflect differences in recruitment, growth, and mortality between years. The relatively high juvenile densities recorded in 2020 and 2022 may indicate periods of stronger recruitment, while the subsequent reduction in juvenile density could potentially contribute to lower adult abundance in future years if recruitment remains low. However, the surveys represent bi-annual snapshots, and individual cohorts cannot be tracked through time, so a direct relationship between juvenile abundance in a particular year and subsequent adult abundance cannot be confirmed.

The size-frequency distributions provide some additional evidence of variation in population structure between years. The bimodal distributions observed in 2020 and 2022 may indicate the presence of

distinct size groups and could be consistent with stronger recruitment during these years. The presence of an additional smaller size group did not substantially alter the mean cockle size, which remained relatively stable across the monitoring period. This suggests that changes in density have not been accompanied by substantial changes in the average size of cockles within the survey area. The variation in size distributions should, however, be interpreted cautiously, as the number and location of survey stations have varied between years. The increased number of stations surveyed from 2019 onwards also resulted in larger sample sizes than in 2018, meaning that the later surveys are likely to provide a more representative indication of the size structure across the survey area.

In addition to variation in cockle density and size structure, total cockle biomass also varied between survey years, with biomass reaching a peak in 2022 before apparently declining in 2024 and 2026. The high biomass estimate in 2022 coincided with high densities of both adult and juvenile cockles, while the subsequent lower biomass estimate broadly followed the decline in adult density. As mean cockle size remained relatively stable across the monitoring period, the observed changes in biomass are likely to be driven primarily by changes in the observed abundance of cockles rather than substantial changes in individual size. However, the high variability in cockle density between sampling stations and between survey years should be considered when interpreting changes in total biomass, as this variability may affect the detection and interpretation of population change.

Cockle populations are naturally subject to considerable spatial and temporal variation, which is considered a characteristic feature of *Cerastoderma edule* populations. Consequently, long-term monitoring is required to distinguish natural fluctuations from longer-term changes in population dynamics (Jensen, 1992; Whitton et al., 2015). Continued monitoring will be particularly important to determine whether the decline in biomass observed since 2022 represents a short-term fluctuation or a longer-term reduction in the standing stock of cockles within the survey area.

Important caveats

There was substantial variation in both adult and juvenile cockle density between sampling stations. This was reflected in the GLMMs, which included survey station as a random effect and identified considerable station-level variation for both adult and juvenile density. The spatial distribution maps showed that higher cockle densities were generally concentrated towards the centre and north-east of the survey area, with smaller areas of higher density in the southern and western parts of the site, while lower densities were generally observed upstream of Shaldon Bridge. This broad spatial pattern has remained relatively consistent throughout the monitoring period, despite changes in overall abundance. However, comparisons with previous surveys should be interpreted with some caution, as several stations that supported high cockle densities in 2022 could not be surveyed in 2026 due to access restrictions, potentially influencing the density estimates and the apparent spatial distribution of cockles. The persistence of these areas of higher density suggests that local environmental conditions are likely to influence cockle distribution within the estuary.

Differences in hydrology across the survey area may contribute to this spatial variation. Cockles have been reported to favour moderately strong tidal flows, with areas subject to increased submergence and proximity to hydrological features such as channels and tidal pools potentially providing favourable conditions (Tyler-Walters, 2007). Cockles generally occur in stable muddy and sandy intertidal habitats where environmental conditions, including salinity, food availability, temperature and recruitment, are favourable (Boyden and Russell, 1972; Brock, 1979; Guillou and Tartu, 1994; Whitton et al., 2015).

Sediment stability may also contribute to the observed spatial pattern. The central area of the sandbank comprises relatively stable packed sediment, whereas sediments towards the bridge and

seaward extent of the sandbank are potentially subject to greater tidal scour. Increased sediment mobility may reduce the suitability of these areas for cockle settlement and persistence. This provides a possible explanation for the consistently higher densities observed in the central area compared with the margins of the survey site. However, sediment characteristics and hydrodynamic conditions were not directly measured at individual survey stations during the current monitoring period, and their contribution to the observed density patterns therefore remains speculative.

Receational harvesting should potentially be considered when interpreting changes in adult cockle density. D&S IFCA has previously received reports of hand-gathering of cockles within the Teign Estuary, including reports of relatively large quantities being removed. Larger cockles are more likely to be targeted by hand-gatherers, and sustained removal could therefore potentially influence adult density. The reported areas of hand-gathering overlap with some of the survey stations, including areas within the Salty. However, these observations have not been independently verified by D&S IFCA Officers, and no additional analysis of harvesting activity was undertaken as part of the 2026 survey. Furthermore, previous statistical analyses using GLMMs in the 2024 report did not identify evidence that cockle gathering, at the level of effort assessed, was affecting adult cockle density. Consequently, the estimated decline in adult density observed between 2024 and 2026 may not be attributed to cockle gathering on the basis of the current data, and it is important to consider the caveat highlighted above regarding variability in the stations surveyed between years. Further information on the spatial and temporal distribution of harvesting activity would be required to assess whether harvesting contributes to changes in cockle abundance.

The variation in survey timing should also be considered when interpreting changes between years. Surveys have been conducted at different times of year, ranging from July to November. Seasonal differences in recruitment, growth, mortality, and distribution could influence the density and size structure recorded during each survey. This may be particularly important for juvenile cockles, where the timing of the survey relative to recruitment events could influence the number of recently settled individuals recorded. Although the GLMMs demonstrate significant differences between several survey years, some component of the observed variation may therefore be associated with differences in survey timing. Conducting future surveys within a consistent seasonal window would improve comparability between years but is constrained by resource and Officers' availability.

Overall, the monitoring results indicate that cockle density within the Teign Estuary is characterised by strong spatial variation and considerable temporal variation. The persistence of higher-density areas within the central and north-eastern parts of the survey area suggests that local habitat characteristics, including hydrology and sediment stability, may play an important role in determining cockle distribution. The recent apparent decline in adult and juvenile density is also of interest because sustained low recruitment could influence future abundance. Continued monitoring will therefore be important to establish whether the recent changes represent short-term fluctuations or a longer-term change in the cockle population.

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 help inform future development of a potential Hand Working Byelaw.