Teign Estuary
Cockle Stock Assessment 2022

Lauren Henly
Environment Officer
Devon and Severn Inshore Fisheries and Conservation Authority
Research Report
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Contents

Version control history			
Author	**Date**	**Comment**	**Version**
LH	01/03/2023	Draft report	0.1
	08/03/2023	Comments and amendments to draft by J. Stewart	0.2
LH	10/03/2023	Amendments following v0.2	0.3
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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; 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 have 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.

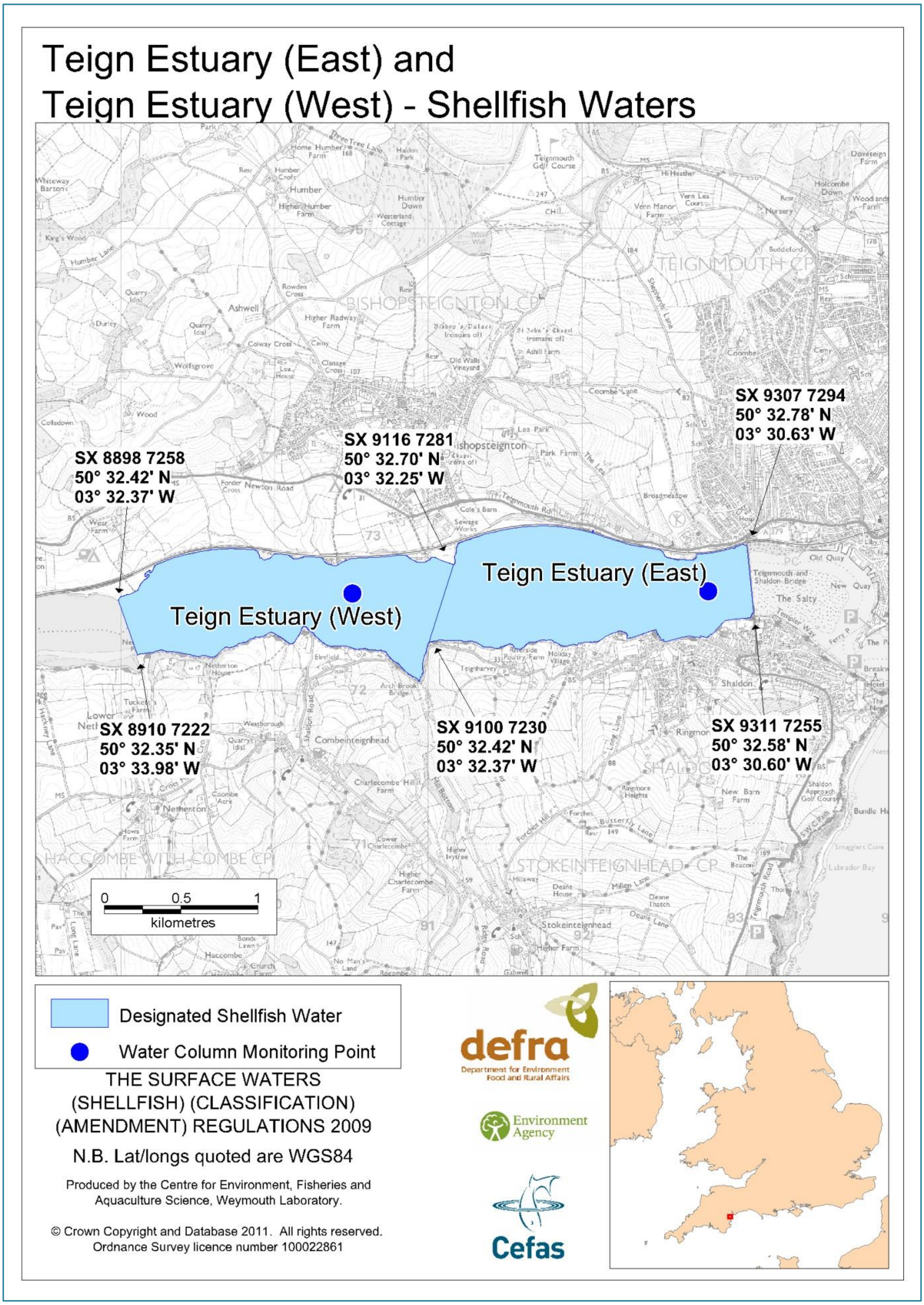
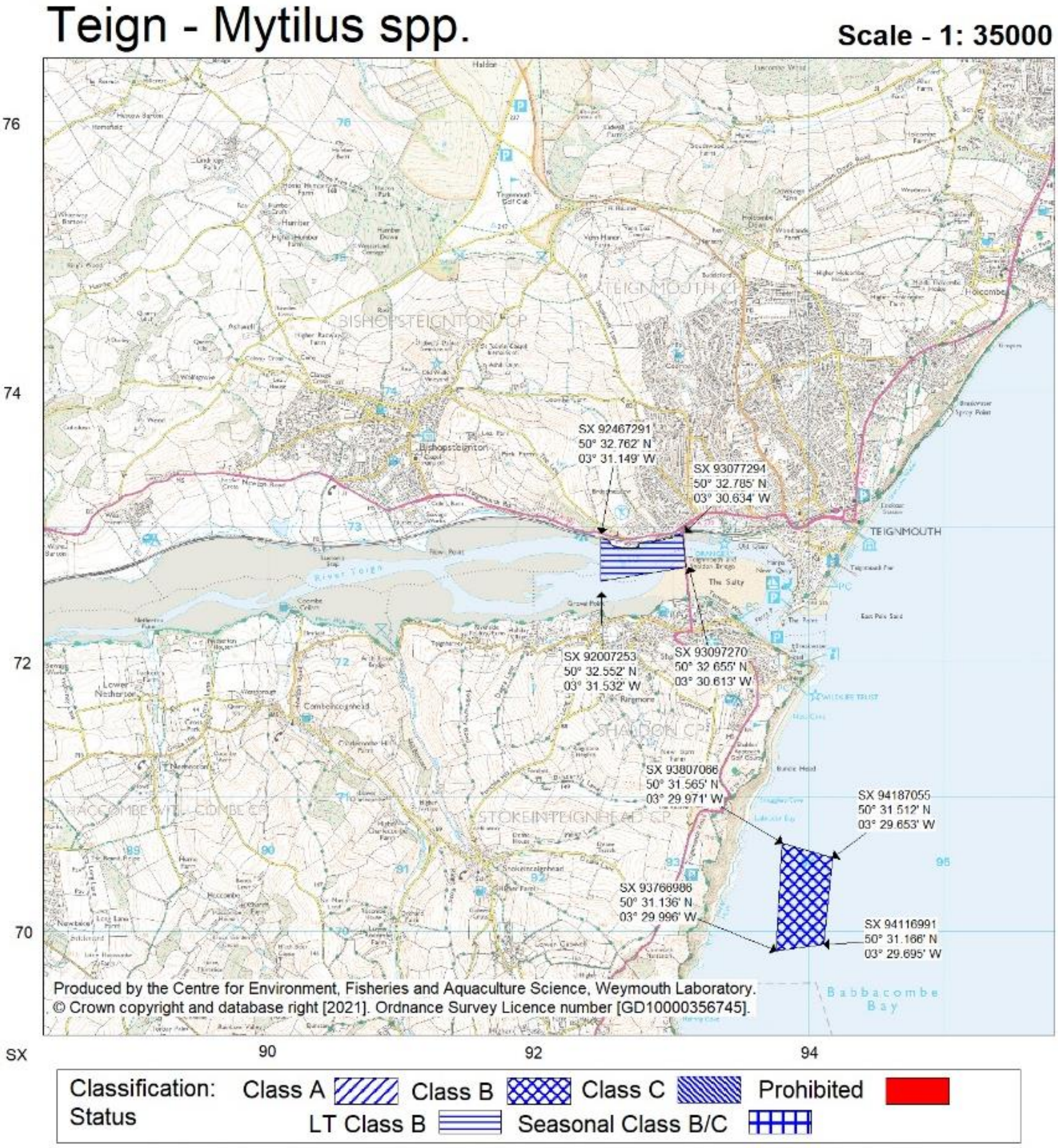


Figure 1 – Shellfish Waters Protected Areas of the Teign Estuary 2016.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2021

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

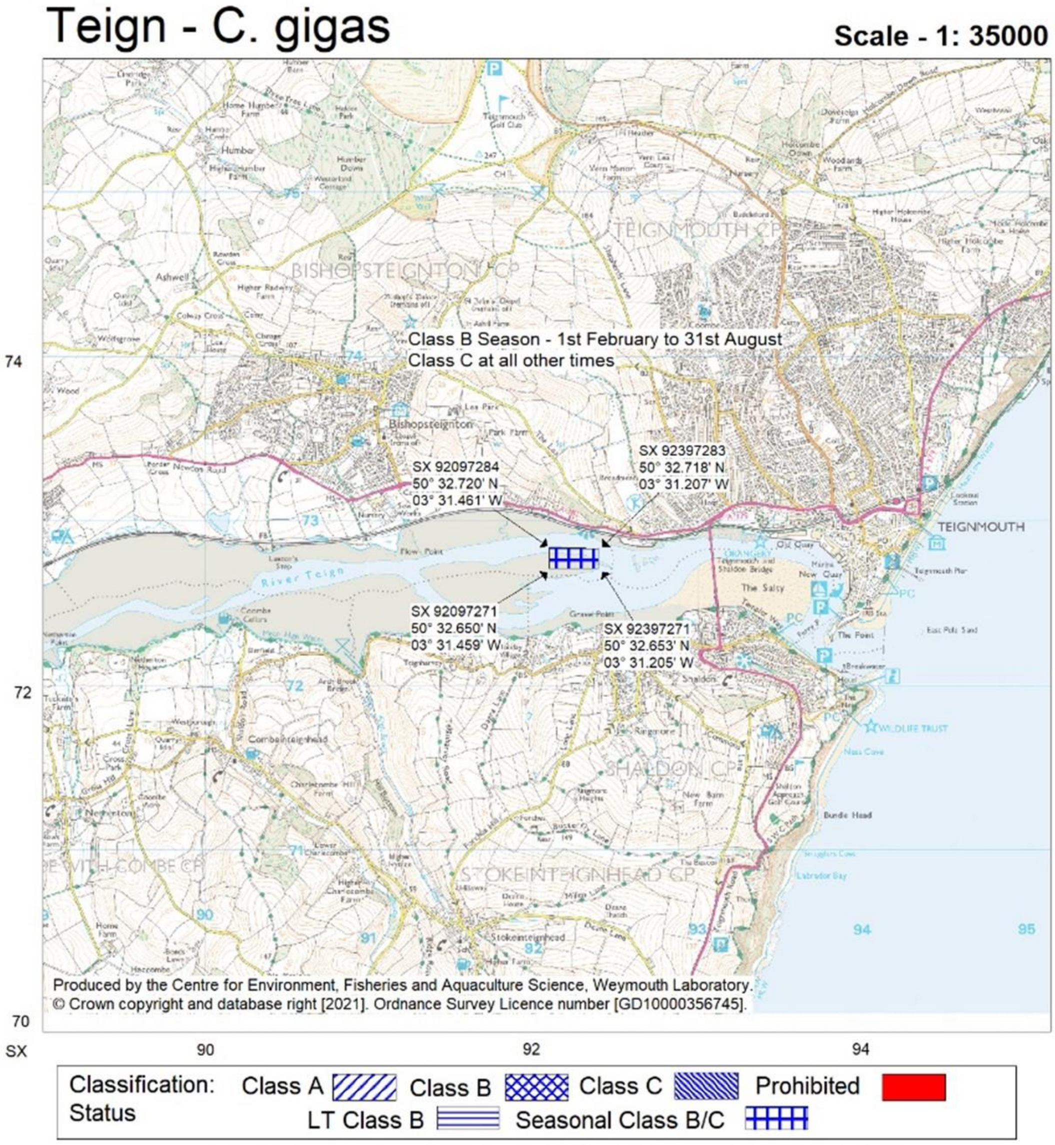
Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

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.

Separate map available for C. gigas at Teign

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, 2021). Up to date classification zone maps are available on the Cefas website.



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N.B. Lat/Longs quoted are WGS84
Separate map available for Mytilus spp. at Teign

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, 2021). 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 occurred in 2018 and 2019 occurred in November and October, respectively, whereas in 2020 and 2022 the surveys were conducted in August. In 2020 the earlier timing of the surveys was due to the uncertainty in timings around the Covid Pandemic, whereas in 2022 August was chosen due to the timings of other molluscan surveys throughout the year. The survey covers the following areas of the Teign estuary: The Salty (east of Shaldon bridge), a small area upstream of Shaldon bridge, and six stations at Polly Steps (at the north end of Shaldon bridge). 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). The six 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 been observed.

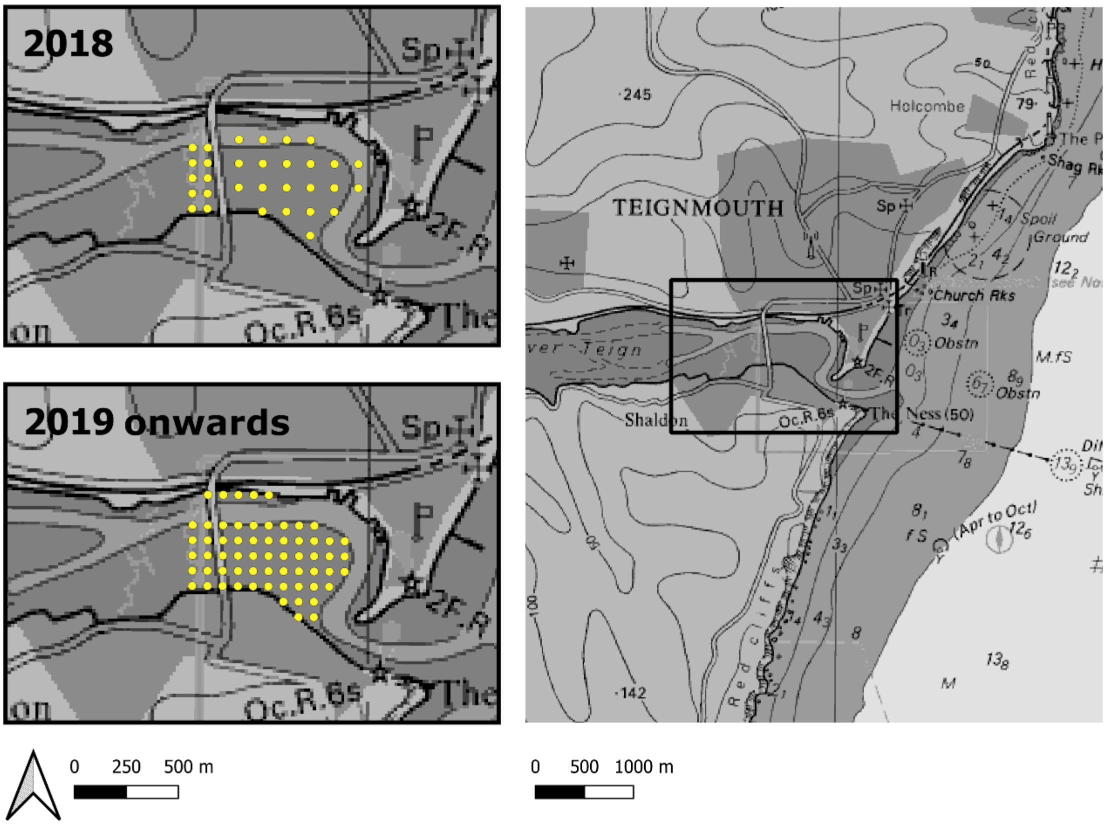

Figure 4 – Teign Estuary cockle survey stations. The sites that are (in)accessible can vary each year.

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).

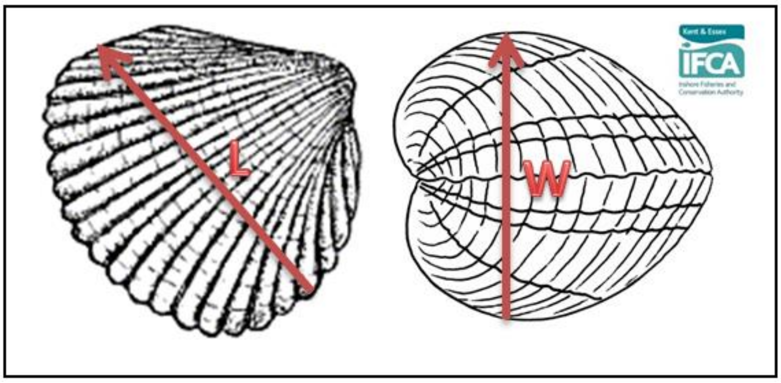

Figure 6 - Cockle length (L) and width (W) measurements.

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. 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 sampled area.

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. The number of stations surveyed and not surveyed was the same in 2019 as 2022, but cockles were present in 6 more stations in 2022 than in 2019 (Table 1).

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 – 2022.

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

The density of adult cockles increased between 2018 and 2022 at an average rate of 12% per year (Table 2a, Figure 7a), whereas juvenile cockle density did not change significantly over this time (Table 2b) despite an apparent numeric increase in the average density across the whole site (Figure 7b). There was high variation in cockle density between survey stations (Figure 8; also shown by the relatively high random effect variance in Table 2a, b) and 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 8).

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). 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 model most parsimonious model, which indicates that adult cockle density increased during the study period (a), but that there was no difference in juvenile cockle density between years (b).

(a)	Model	β_0	Year	k	LL	σRE	ΔAIC
	M_{test}*	-246.3 (0.001)	0.122 (0.000)	3	-436.7	1.33	0
	M_{null}	0.598 (0.001)	–	2	-444.8	1.36	14.24

(b)	Model	β_0	Year	k	LL	σRE	ΔAIC
	M_{test}	360.6 (2.473)	0.178 (0.001)	3	-175.4	1.18	0
	M_{null}*	-0.322 (0.237)	–	2	-178.8	1.23	4.84

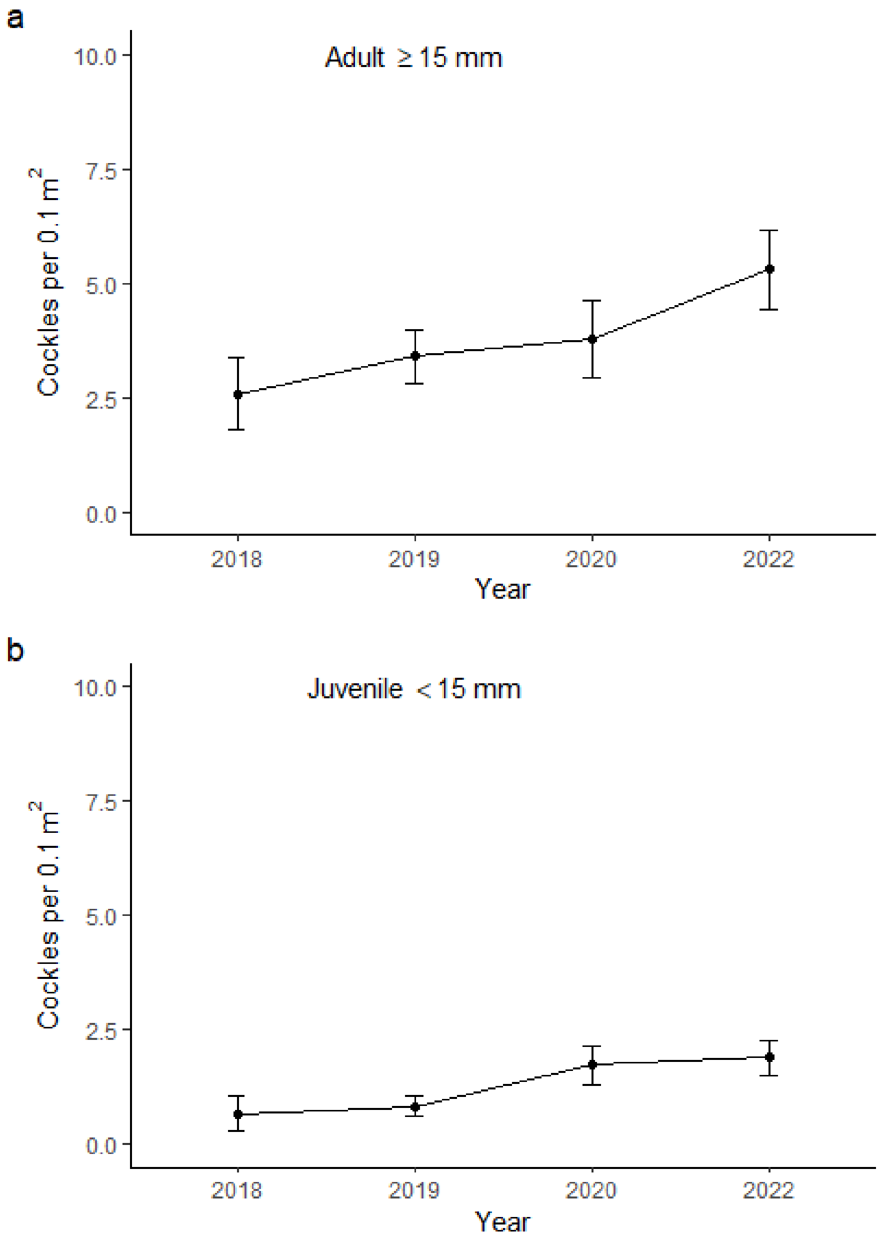

Figure 7 – Mean density (±SE) of (a) adult cockles ≥15 mm and (b) juvenile cockles <15 mm, on the Teign Estuary from 2018–2022.

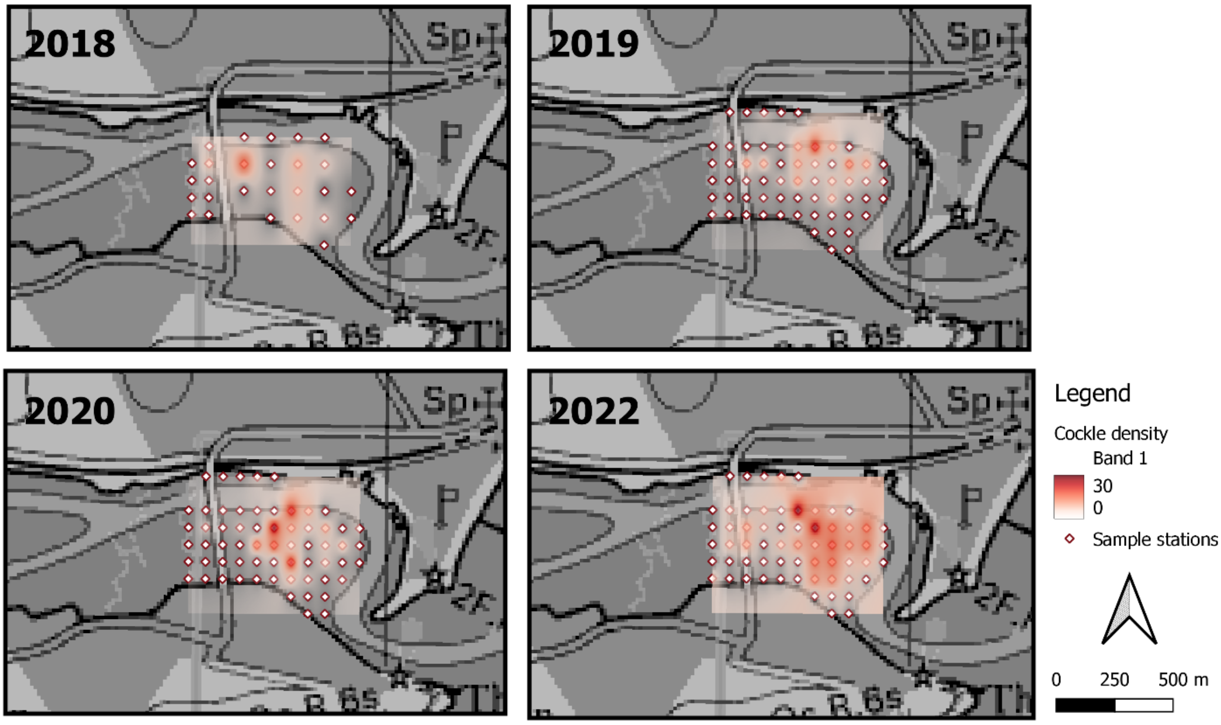

Figure 8 – Cockle density (number of cockles per 0.1m^2 quadrat) on the Teign Estuary in autumn 2018–2022 mapped using Inverse Distance Weighted interpolation.

The average length of cockles across all survey stations has remained stable across the five 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, Figure 11c) appear to have a bimodal distribution (distribution with two clear peaks). The average length of cockles varies between sample locations (Figure 12). In particular, larger cockles tend to be found to the west of the survey site, whereas smaller cockles are found in the centre of the site.

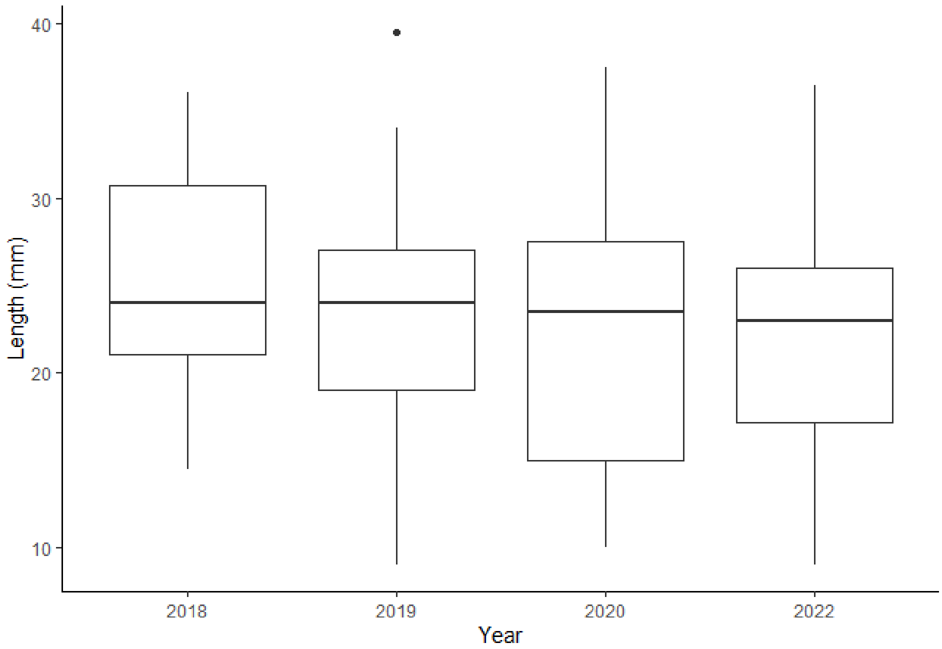

Figure 9 - Length (mm) (median, inter-quartile range and range) of cockles on the Teign Estuary from 2018–2022.

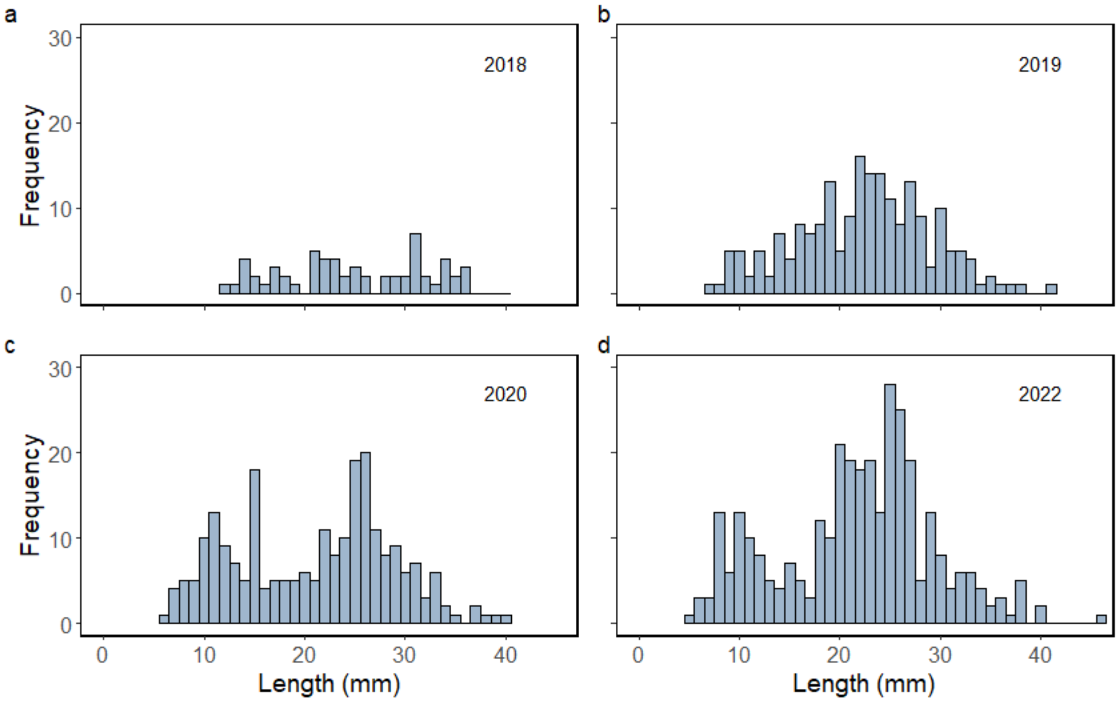

Figure 10 – Frequency of cockle lengths (mm) in each survey year on the Teign Estuary.

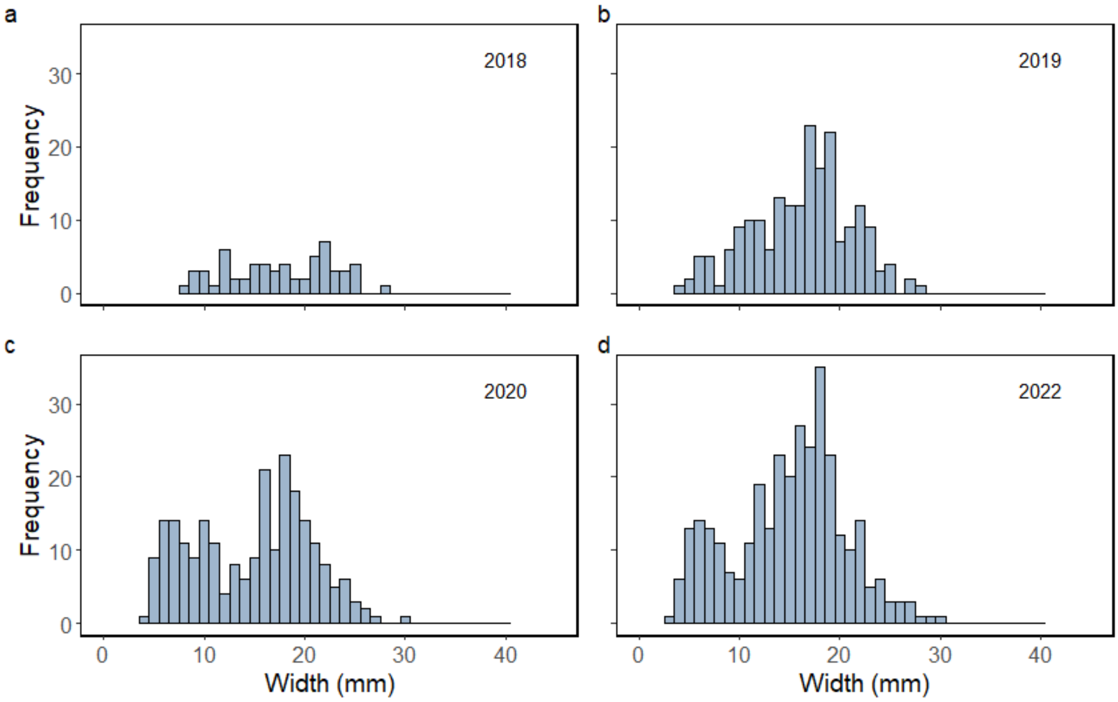

Figure 11 – Frequency of cockle widths (mm) in each survey year on the Teign Estuary.

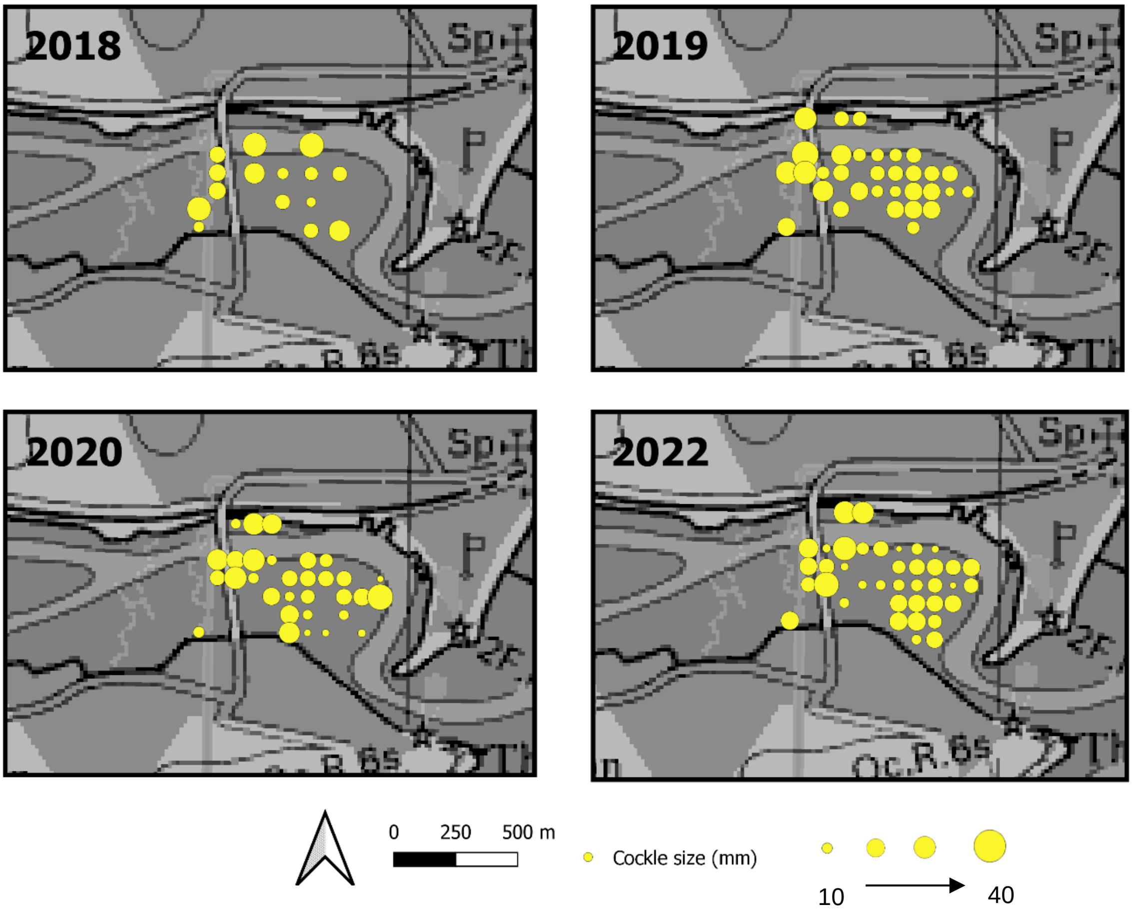

Figure 12 - Median cockle size (mm) at each sampling station on the Teign Estuary in autumn 2018–2020. Sampling sites that were not surveyed or that contained no cockles are not shown on the map.

The total tonnage of cockles across the surveyed area in 2022 was estimated at 79 tonnes (Figure 13). This is an increase in estimated total tonnage since the 2020 survey, where total biomass was estimated as 50.5 tonnes. The number of cockles in each year class except year 0 have increased in the 2022 survey compared to the 2020 survey (Figure 14).

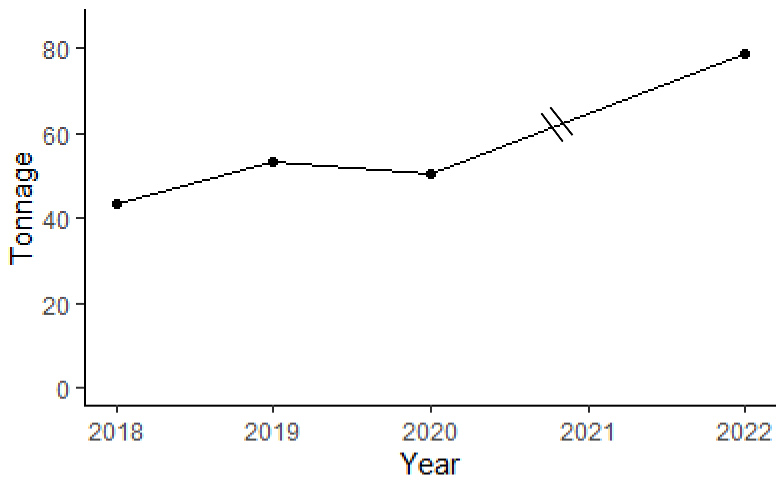

Figure 13 – Total estimated tonnage of cockles across the surveyed area (25.5 ha – excluding Polly Steps) 2018–2022.

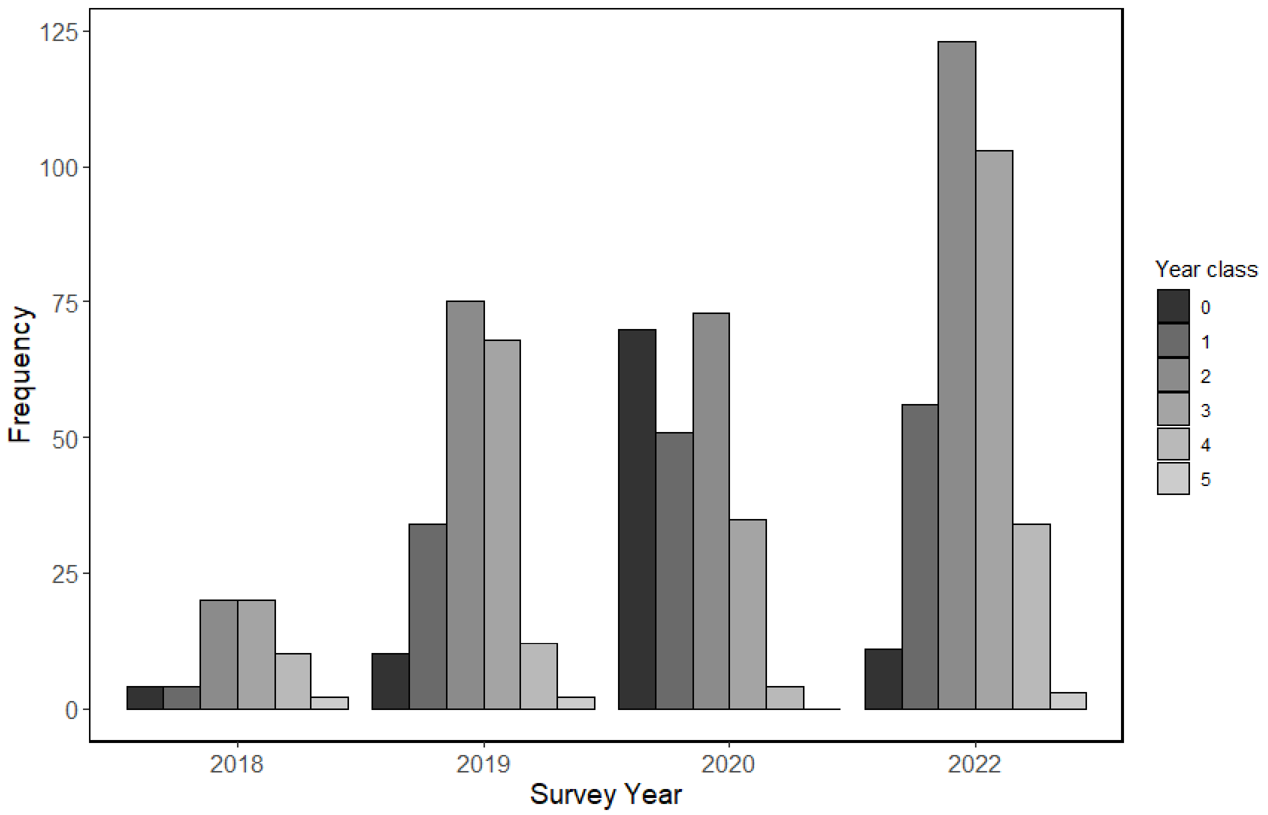

Figure 14 – Number of cockles in each year class for each survey year. Year classes are determined by counting the number of growth rings on a cockle's shell (0 rings = year 0, 1 ring = year 1, etc).

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 2022 and discusses the implications for the users of the estuary who gather cockles recreationally.

The density of adult cockles has increased between 2018–2022 at a rate of approximately 12% per year. This, along with a stable average size of cockles, suggests that the current levels of recreational cockle gathering in the estuary are not having a negative impact on the cockle population in the estuary. Although the values of average juvenile cockle density appear to have increased over the years, the average juvenile cockle density has not changed significantly since 2018. 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. These locations are likely to have higher water flow rates than towards the south-west of the survey site, so could explain the higher densities of cockles as they have been shown to 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).

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 – 2022 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 is 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.

Cockle populations are naturally subject to high levels of variation, which is considered a normal feature of *Cerastoderma edule* populations. Therefore, observing the long-term population trends is therefore vital to understanding the population dynamics of any given cockle population (Jensen, 1992; Whitton *et al.*, 2015). Despite this variation the total biomass of cockles on the bed seems to be increasing, particularly between the 2020–2022 survey years. Although there is currently no commercial fishery for cockles on the Teign Estuary, D&S IFCA will continue the autumn survey every two years to monitor the cockle stocks that are harvested recreationally and to inform future development of a potential Hand Working Byelaw.

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