Experimental relaying trial of the common cockle (Cerastoderma edule) in the Solway Firth

Undertaken as part of the Defra funded FISP Part B Project "Solway Cockle Project", ref: 37318.

April 2025

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Acknowledgements

Many thanks to the students at the University of Glasgow (School of Social & Environmental Sustainability) who contributed to the research through data collection.

1 Introduction

1.1 *Solway Firth Background*

The common cockle (*Cerastoderma edule)* is commercially fished throughout the UK and historically within the Solway Firth (Marine Scotland Science, 2015). Various methods are used to fish cockles commercially including hand-gathering, suction-dredging, and tractor-dredging. The fishing grounds of the Solway Firth closed in 2011 (Stevenson, 2011) due to insufficient stocks and since then have only been surveyed four times in the past twelve years (2013, 2015, 2023 and 2024). Following an eight-year gap since the last survey, a stock assessment was undertaken in 2023, providing key insights into the cockle distribution, stocking densities and age profile across the north Solway Firth. Findings from the 2023 survey revealed the 3rd highest cockle biomass recorded (24,669 tonnes) compared to previous stock surveys (Dickens, *et al*., 2015). The 2023 Solway cockle stock report (Course *et al*., 2023) indicated that approximately 80% of total cockle biomass consisted of 0 to 1 year-old cockles. A reassessment of stocks in 2024 using the same sampling locations as in 2023, found that some banks (North Bank) were almost entirely composed of 0 to 1 year-old cockles and in high densities. It has been documented that high densities of cockles can experience "ridging out," a term used to describe over-abundance (Eastern IFCA, 2019) and mass mortalities often follow. Higher density sites, where 0 to 1 year-olds are present, often result in above average mortality rates and consequently less food for bird populations, and exploitable biomass for fishing. With such a high total biomass composed mainly of juvenile cockles, it can be inferred that a large percentage of the stock fails to make the adult stage at around 1.5 years old (Tyler-Walters, 2007). The 2024 survey (Course *et al*., 2024) confirmed this with a 48% reduction in total biomass dropping from 24,669 to 12,883 tonnes, resulting in a dramatic loss in 0 to 1 year groups. Intraspecific competition may be paying a significant role inflicting higher mortality within the 0 to 1 group cockles, and a strategy of thinning or reseeding in lower densities or in zero-density areas could potentially enhance survival and growth potential through reduced competition and extend the population into areas of current zero density.

1.2 *Previous Research*

Previous studies have demonstrated that high population densities can negatively impact individual growth rates due to increased competition for resources. For instance, research in the Wadden Sea indicated that areas with higher cockle densities exhibited reduced individual growth and overall production (Beukema & Dekker, 2015). This suggests that thinning dense populations could potentially alleviate competition, potentially enhancing growth rates and yield. Attempts at thinning-out or relaying *C. edule* are scarce, although some examples exist. For example, *a* feasibility experiment undertaken at Oosterschelde (Wadden Sea) in 1980 to understand the positive and negative effects of thinning areas of high-density (ridging out) and relaying in lower populated areas (Dijkema *et al*., 1987). In very high densities (>5000 per m^2), cockles touch each other and force the bivalves out of the sediment, leading to prolonged exposure at low tide, higher competition for nutrients and space, ultimately leading to higher mortality rates. In their study, Dijkema *et al*. (1987) found lower cockle densities increased growth rates, although growth success was not entirely down to density-dependence factors with site selection playing a key role. Dikema *et al*. (1987) also suggest that thinning/reseeding cockles could be used as a successful management tool requiring careful site selection.

Large-scale cockle mortalities have been recorded in the Bury Inlet (South Wales, UK) with similar observations of very high-density areas. In their laboratory-based survival experiment using 1-year old cockles, Callaway *et al*. (2013) found that intraspecific competition does play a role in survival, although less significant than physiological weaknesses in specific cohorts as they reach their first year.

There are no recorded controlled studies from the Solway Firth where attempts have been made to assess the impacts of reducing cockle densities on survival and growth, and this study is the first experimental in-situ attempt at thinning at high-density sites and seeding zero density areas. There have been attempts at Neuharlingersieler Nackel (Wadden Sea) using a tagging-recapture approach to assess cockle growth over time (Ramon, 2003). This research used numbered labels glued to individual cockles offering insight into growth trends at this location (Ramon, 2003). This study used cages to contain the species, hence a high recapture rate, however in highly dynamic intertidal zones one challenge with using cages is the potential for sediment accretion leading to cage smothering. The Ramon (2003) study provides useful insight into the possibility of tagging-recapture, however, there remains a lack of studies within the literature investigating the mobility of *C. edule* and if cockles retain a settled position. This is important given that relaying cockles at lower densities, or populating areas with low/zero density, are to retain cockles.

2 Study Aim & Objectives

The central aim of this experimental research is to increase understanding of how cockle populations react to thinning or transplanting as a potential management strategy to promote growth or colonisation potential.

To address the aim, the following objectives have been formulated:

I. Test the survival potential of transplanting cockles in areas identified as zero/low density
II. Evaluate the impact on cockle growth and abundance from thinning high-density sites
III. Assess if planted cockles could be tracked over the survey period

The third objective is important in that tracking individual cockles provides data from which to measure growth potential at both low- and high-density locations, however the challenge of tracking at a small-scale is significant given potentially high natural mortality rates, and a general lack of understanding of *C. edule* mobility under natural conditions. Despite these challenges and limitations, this experimental study aims to provide insights valuable to understanding cockle populations and managing cockle stocks.

3 Methodology

3.1 *General Overview and Site Selection*

The study was partnered with The University of Glasgow who provided advice in experimental design within the confines of the project timescale. The University trained and recruited 5 students to help with efficient and safe sampling on-site, in addition to one member of staff. SeaScope Fisheries Research provided three members of staff with experience in cockle sampling.

Fishing grounds from the 2023 survey were considered for the study to identify suitable high- and low-density locations (Table 3.1). Three locations, Arbigland, Carsethorn, and North Bank were identified as supporting the highest density of 0 to 1-year-old cockles.

Table 3.1 Highest Number of Cockles aged 0 to 1 year old (*C. edule*) found at each bank with unique ID code.

Bank	Strata ID	Individuals (aged 0 to 1) per 0.1 m^2
Arbigland	ARB49_A	786
Auchencairn	AUC05_B	11
Barnhourie	BAR71_C	38
Carsethorn	CAR08_A	680
Fleet Bay	FLE32_A	13
North Bank	NOR48_E	291
Orchardton	ORC03_B	3
Rough Island and Glen Isle	ROU30_B	41
Wigtown Bay	WIG08_B	168

Carsethorn was excluded due to safety concerns caused by the strong tidal currents in this area. In the 2023 survey, Arbigland recorded the highest densities, however there were large disparities between samples stations ranging from 2 to 786 per 0.1 m^2 (Table 3.2). Given significant variation, it was decided to exclude Arbigland from the study.

Table 3.2 Comparison data for site selection: ARB49_A vs ARB49_B and NOR48_E vs NOR37_G

Bank	Strata ID	Individuals (aged 0 to 1) per 0.1 m^2	Latitude	Longitude
Arbigland	ARB49_A	786	54.91948	-3.56126
Arbigland	ARB49_B	2	54.91815	-3.56451
North Bank	NOR48_E	291	54.94398	-3.54914
North Bank	NOR37_G	271	54.9412	-3.51945

North Bank (54°57'32.01"N 3°30'56.26"W) (Figure 3.1) displayed similar densities and was therefore selected. NOR37_G was identified as the most appropriate high-density trial location given NOR48_E is close proximity to the River Nith and could be influenced by flood water and extreme weather events resulting in wash-out of experimental plots.

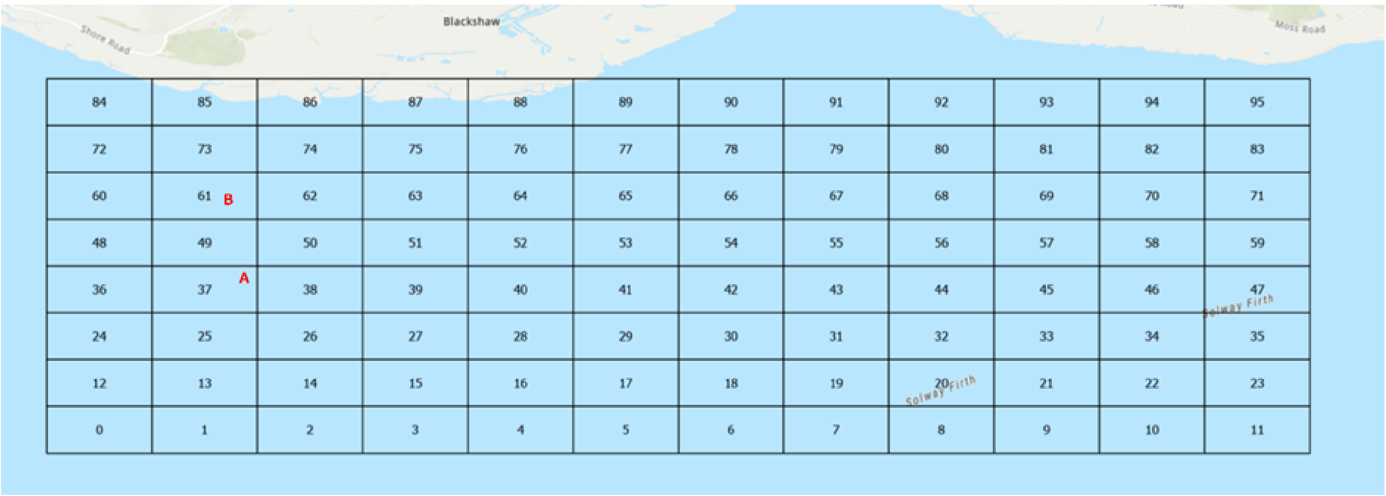


Figure 3.1 Map of North Bank depicting the locations of both sites. (A) NOR37_G (high-density), (B) NOR61_B (low-density).

The zero-density site within North Bank (NOR61_B) was identified from the 2023 survey and approximately 1.3km N-NW from the high-density site (NOR37_G). The zero-density site being in relative proximity to the high-density site means both locations experience similar tidal and weather conditions. This also allows for the rapid and efficient relocation of cockles to cause minimal stress and provide the greatest chance of survival. The location of the high- and zero-density trial locations are shown in Figure 3.2. Please note that the main course of the River Nith has moved further south and west and is no longer on the east side of the NOR61_B experimental site, as shown in Figure 3.2.

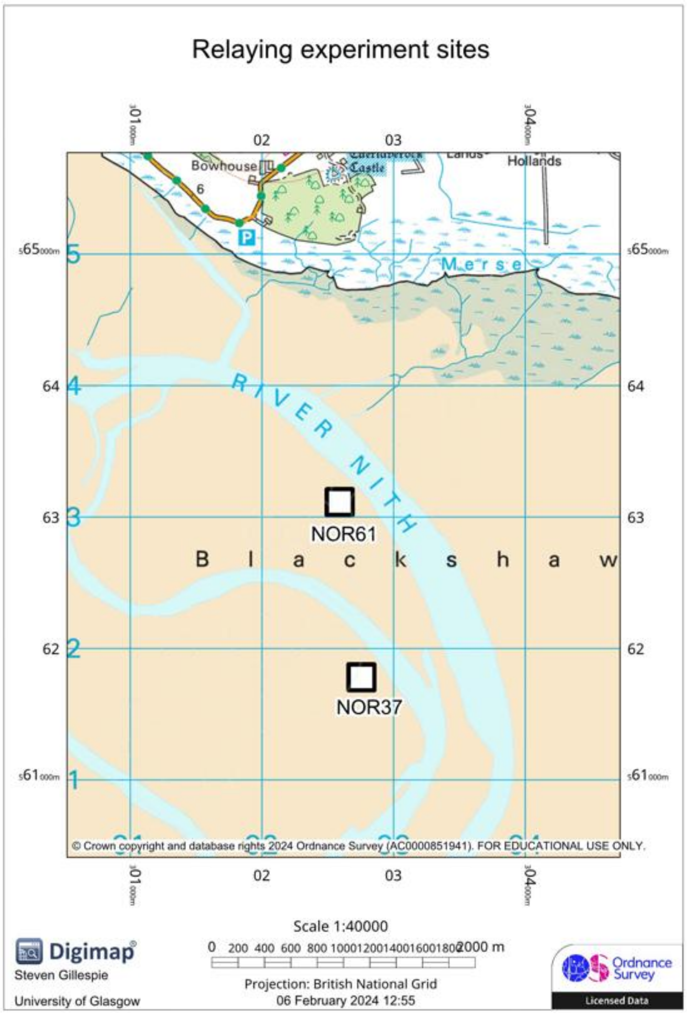
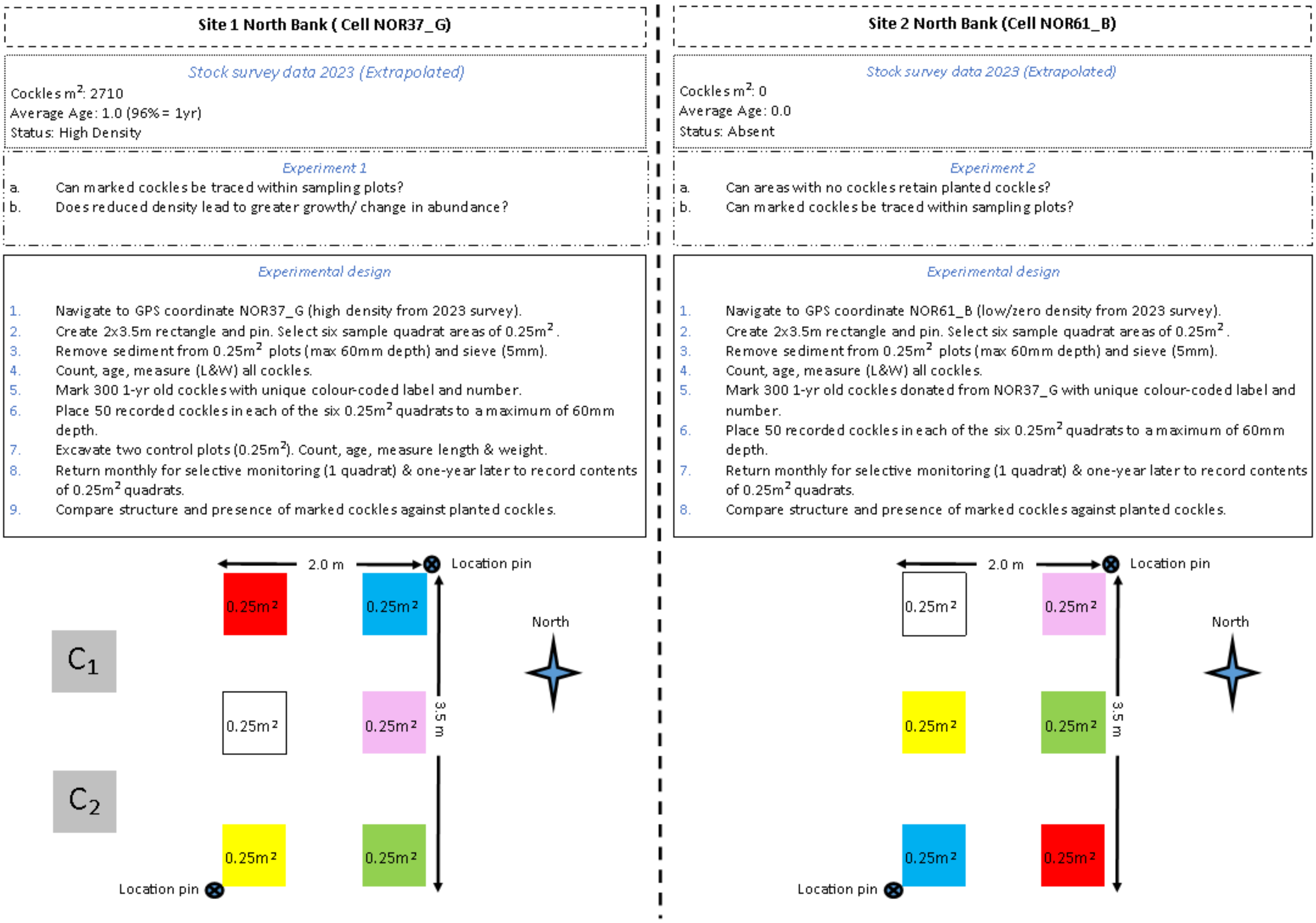


Figure 3.2 High-density (NOR37_G) and zero-density (NOR61_B) trial locations

3.2 Experimental design

3.2.1 *Site Location & Plot Layout*

The experimental design and procedures for both the high-density and low/zero density locations are summarised in Figure 3.3. Coordinates from the 2023 stock assessment were used to navigate to the specific locations using a Garmin eTrex GPS. At each trial location a rectangle (2 x 3.5m) was measured and corners pinned with long heavy-duty marine grade anchor pegs. Given the potential for sediment accretion, the pegs were used to allow for locating the corners of the trial sites on return to each location using a metal detector. Each plot was oriented along the north/south axis and GPS coordinates taken for each corner.



Site 1 North Bank (Cell NOR37_G)

Stock survey data 2023 (Extrapolated)

Cockles m^2: 2710
Average Age: 1.0 (96% = 1yr)
Status: High Density

Experiment 1

a. Can marked cockles be traced within sampling plots?
b. Does reduced density lead to greater growth/ change in abundance?

Experimental design

1. Navigate to GPS coordinate NOR37_G (high density from 2023 survey).
2. Create 2x3.5m rectangle and pin. Select six sample quadrat areas of 0.25m^2.
3. Remove sediment from 0.25m^2 plots (max 60mm depth) and sieve (5mm).
4. Count, age, measure (L&W) all cockles.
5. Mark 300 1-yr old cockles with unique colour-coded label and number.
6. Place 50 recorded cockles in each of the six 0.25m^2 quadrats to a maximum of 60mm depth.
7. Excavate two control plots (0.25m^2). Count, age, measure length & weight.
8. Return monthly for selective monitoring (1 quadrat) & one-year later to record contents of 0.25m^2 quadrats.
9. Compare structure and presence of marked cockles against planted cockles.

Site 2 North Bank (Cell NOR61_B)

Stock survey data 2023 (Extrapolated)

Cockles m^2: 0
Average Age: 0.0
Status: Absent

Experiment 2

a. Can areas with no cockles retain planted cockles?
b. Can marked cockles be traced within sampling plots?

Experimental design

1. Navigate to GPS coordinate NOR61_B (low/zero density from 2023 survey).
2. Create 2x3.5m rectangle and pin. Select six sample quadrat areas of 0.25m^2.
3. Remove sediment from 0.25m^2 plots (max 60mm depth) and sieve (5mm).
4. Count, age, measure (L&W) all cockles.
5. Mark 300 1-yr old cockles donated from NOR37_G with unique colour-coded label and number.
6. Place 50 recorded cockles in each of the six 0.25m^2 quadrats to a maximum of 60mm depth.
7. Return monthly for selective monitoring (1 quadrat) & one-year later to record contents of 0.25m^2 quadrats.
8. Compare structure and presence of marked cockles against planted cockles.

Figure 3.3 Experimental design and procedures at high- and low-density locations

3.2.2 *Quadrat Sampling*

A 0.25 m^2 quadrat was placed in six locations within the rectangle, and two control quadrats established outside the trial plot (Figure 3.3). At both the high and low-density sites, sediment was removed to a depth of 60 mm from each quadrat and sieved using a 5 mm mesh to retain cockles. The number of cockles in each quadrat (density) was recorded along with age, length and weight. Aging was conducted through external concentric annual growth ring analysis (Davies & Blundell, 2019; Henly, 2021, 2023), and although this procedure is known to be difficult due to interannual growth rings and colour-banding (Wheeler *et al.*, 2012), multiple surveyors with experience in aging could confirm the suggested age group. Length of each cockle was measured using Vernier Callipers accurate to 0.01 mm (Figure 3.4). Wet weight of each cockle was measured using calibrated digital balances accurate to 0.01 g. The same procedure was conducted for the control sites.

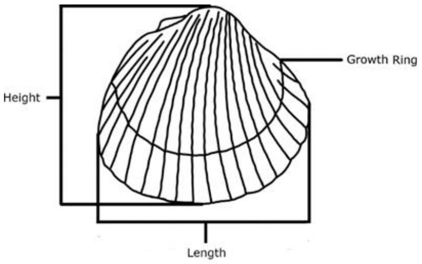


Figure 3.4 Length measurement locations (Source: Mahony *et al.*, 2021)

3.2.3 *Colour-coding Quadrats and Labelling*

At both trial sites, each quadrat location was colour coded (see Figure 3.3) to correspond with coloured labels attached to cockles to be transplanted back into quadrats. The colour differentiation would also allow for tracking of potential cockle movement within each trial site. A total of 600 1-year old cockles were retained from NOR37_G (high-density) for the relaying trial at both the high-density and low-density locations, 50 for each 0.25 m^2 quadrat. Given the low-density location was identified as having zero cockles, the high-density site acted as the donor-site.

Each weighed and measured 1-year old cockle was given a unique number (from 1 to 50) printed on to a coloured waterproof label (approx. 4x4 mm) corresponding with the quadrat colour. The labels were attached to each cockle at the mid-point from hinge to ventral to avoid potential impacts on opening or closing functions. Quick-setting marine and reef-safe cyanoacrylate glue was used to attach each label, then allowed to set. A sample of labelled cockles were then re-weighed to determine the average weight of the glue and label (0.05 g), allowing for accurate growth measurements if recaptured. Full data available in Appendix A.

3.2.4 *Relaying procedure*

In each cleared quadrat, 50 numbered and measured cockles were placed back to a maximum depth of 60mm (Figure 3.5). A light covering of sediment was carefully placed across each quadrat location to reduce exposure from potential bird predation. The relaying density of 50 per m^2 represented a significant decrease in density at NOR37_G under natural conditions (678 per 0.25 m^2 in the 2023 survey), and with less intraspecific competition greater growth potential (de Fouw *et al.*, 2020).

Following completion of the relaying at the high-density site, the researchers moved to the low-density location (NOR61_B) with the 300 remaining measured and labelled cockles. Excavation of the six quadrat plots at the zero-density site confirmed the absence of cockles at this location. Following the same procedure, 50 labelled and measured cockles were transplanted in each 0.25 m^2 quadrat plot. Given the absence of cockles, this marked an increase in density at this site from which to assess potential retention and growth.

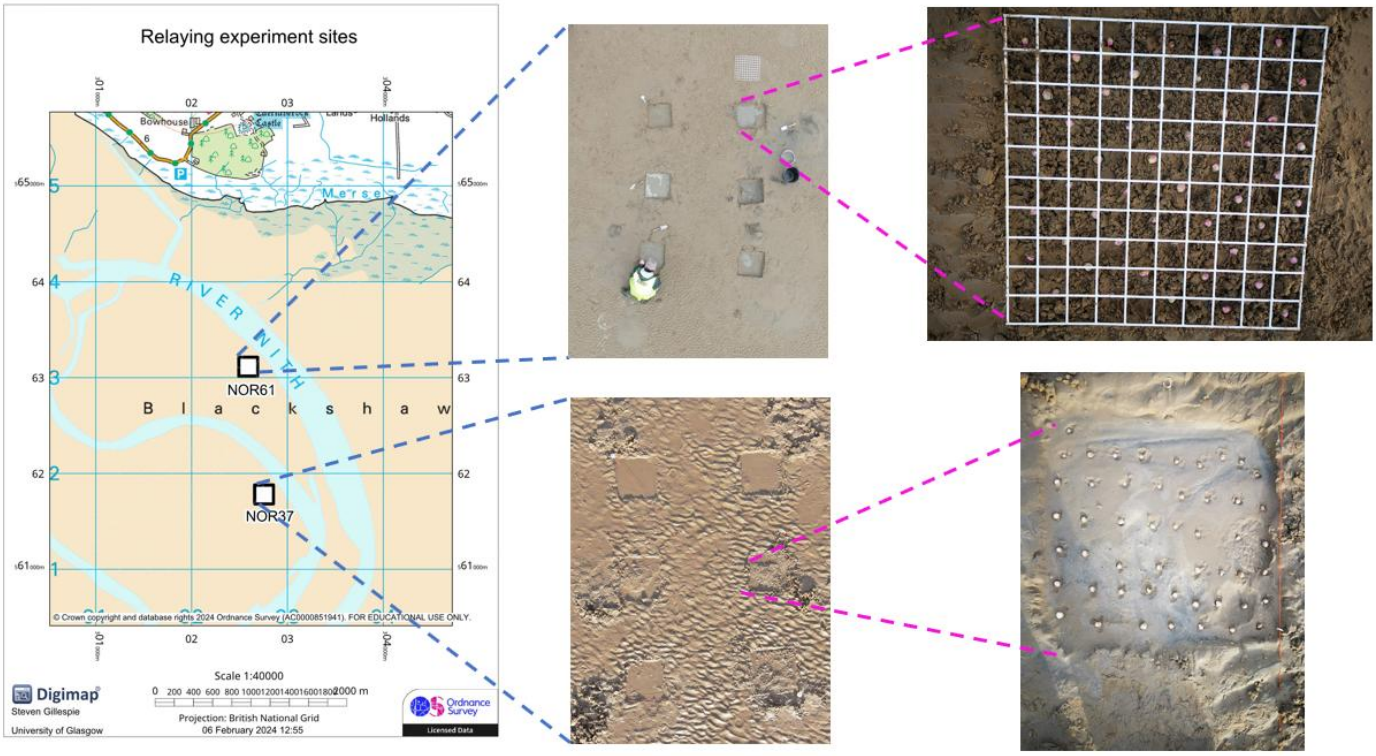


Figure 3.5 Trial plots at each trial location showing six quadrat and relaying of pink labelled cockles

3.2.5 *Monitoring & Return Sampling*

Initial sampling took place on the 20th November 2023 with return visits to both high- and low-density sites on 19th February 2024, 12th May 2024, 9th August 2024 with final sampling taking place on 11th November 2024.

One 0.25 m^2 quadrat at each relaying location (high- and low-density) was monitored from February to August 2024 to assess retention of planted cockles. In addition, control plots were monitored over the same period.

3.3 *Data Management & Analysis*

All data collected were recorded on MS Excel spreadsheets allowing for descriptive statistics to be generated. Inferential statistical analysis of the thinning process was conducted using R version 4.4.2. To ascertain the effect of thinning cockle densities on densities one year later (Nov 2023 – Nov 2024), backwards stepwise regression model selection was used to assess the importance of the variables. The interaction between Year and sample plot was also included and the cockle counts were modelled using a Poisson error distribution and Log link. AIC and log-likelihood ratio test were used to test between models.

4 Trial Results

4.1 *Initial abundance and age at high- and low-density sites*

Prior to replanting, cockles were recorded in each of six plots at both the high-density and low-density trial location on the 20th November 2023. As identified in the 2023 summer stock assessment, the high-density site (NOR37_G) retained a substantial number of cockles across the six 0.25 m^2 quadrats and two control plots (Figure 4.1), although the density of cockles had markedly reduced from an average of 2710 m^2 to 832 m^2. The high-density control plots supported a similar density of cockles to those found within the six quadrats. Variation in numbers across the six quadrats demonstrates the irregularity of cockle abundance and distribution over a small spatial scale.

Excavation of the six 0.25 m^2 quadrats and control at the low-density site (NOR61_B) revealed no cockles present in this location, as identified in the 2023 summer stock assessment.

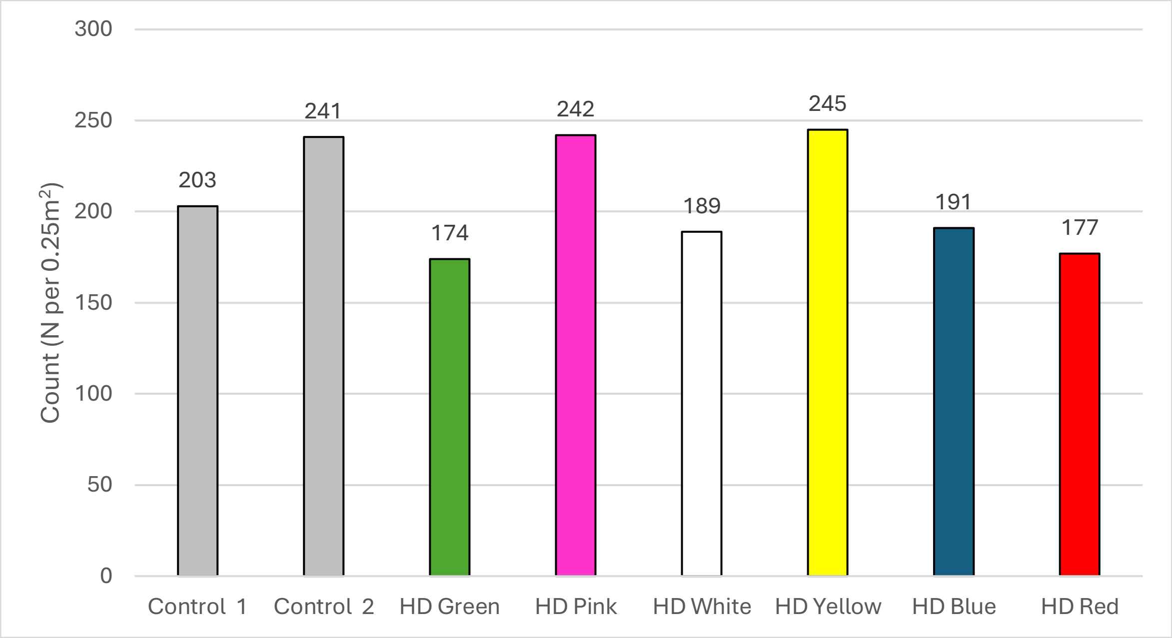


Figure 4.1 Number of cockles in control plots and across the six 0.25 m^2 quadrats at high-density location (NOR37_G) prior to replanting. Colour columns correspond with quadrat location at trial site.

Analysis of age distribution across all six quadrats and the control plots revealed a population entirely composed of 1-year cockles at the high-density, reflecting the 2023 stock survey for NOR37_G (96% 1-year old class).

Following initial assessment, the six quadrats in both high- and low-density sites were cleared and, following recording of age, weight and length, replanted with 50 1-year old cockles.

4.2 *Control monitoring*

Monitoring of cockle numbers in control plots was conducted on a quarterly basis at both the high- and low-density trial locations. The control plots at the low-density site remained zero cockles per m^2 throughout the monitoring period, however significant variation was recorded over time at the high-density location (Figure 4.2). Number of cockles in each control plot (C1 & C2) remained consistent at each time point, however abundance declines significantly in February, May and November 2024.

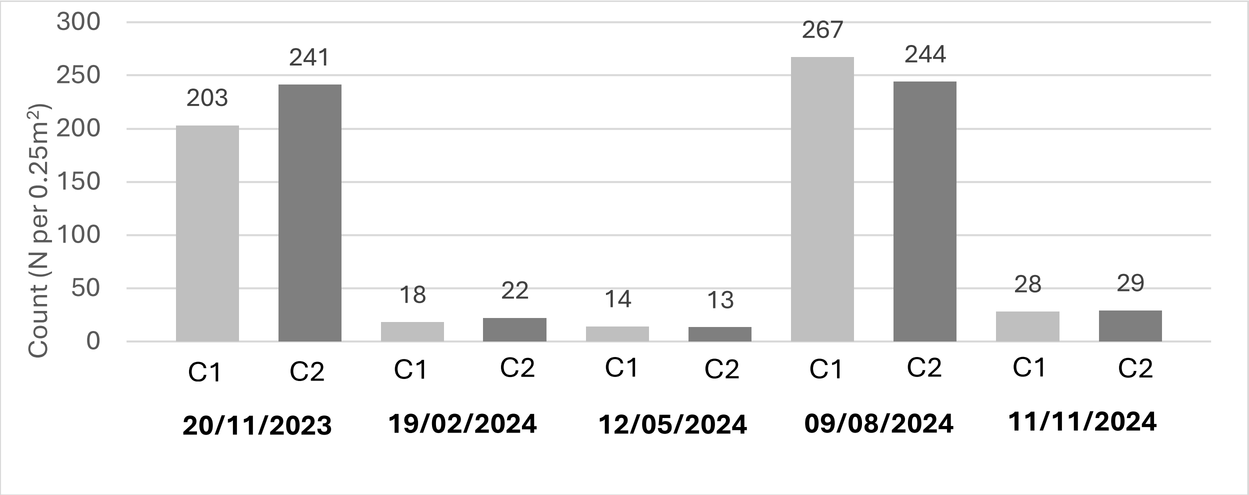


Figure 4.2 Number of cockles in control plots at high-density site over duration of the trial

Analysis of age, length and weight data collected from the control plots reveals the November 2023 plots were entirely composed of 1-year old cockles (Table 4.1), and abundance of this year group dropping by >90% by February. There is no evidence of 2-year old cockles in February 2024 representing the November 2023 cohort after the second winter ring is created. This could be the result of high natural mortality or mobility of cockles moving elsewhere. Abundance remains low in May and dominated by a small number 1-year cockles although two 2-year old cockles are recorded and one spat (0-group cockle). The control plots in August are dominated by spat recruitment with high numbers of 0-group cockles (spatfall possibly occurring in June/July 2024), and increase of 1-year and 2-year cockles compared the May 2024 sampling period. November 2024 control sampling shows a large reduction in 0-group (87-90%) and 1-year age class (94%) from the August survey, although control plot 1 contained a similar number of 2-year old cockles (see Appendix B for full data).

Table 4.1 Number, age, average length and weight of cockles in control plots at high-density site

	Control	Age groups	N	Average Length (mm)	Std. Dev.	Average Weight (g)	Std. Dev.
Nov-23	C1	1	203	16.83	1.71	1.74	0.53
	C2	1	241	16.59	1.71	1.62	0.49
Feb-24	C1	1	18	16.08	1.67	1.48	0.50
	C2	0	1	10.14		0.35	
		1	21	17.05	1.72	1.83	0.59
May-24	C1	0	1	9.52		0.34	
		1	12	16.51	1.28	1.60	0.40
		2	1	20.38		2.84	
	C2	1	12	16.73	1.31	1.60	0.42
		2	1	22.31		3.85	
Aug-24	C1	0	267	12.89	3.53	0.77	1.12
		1	23	17.11	2.82	1.64	1.13
		2	6	26.25	0.88	7.35	0.84
	C2	0	179	8.55	1.77	0.22	0.17
		1	60	18.26	2.56	2.12	0.92
		2	5	25.54	1.07	6.63	1.21
Nov-24	C1	0	24	11.58	1.52	0.56	0.25
		2	5	27.08	0.94	7.33	1.34
	C2	0	23	11.50	1.91	0.55	0.34
		1	5	24.17	2.23	5.85	1.78

4.3 *Cockle tracking following replanting*

At both the high- and low-density locations 50 measured and labelled cockles were placed in each quadrat (Section 3.2.4). Tracking individual cockles has the potential benefit of understanding growth characteristics over time and assessing if cockles remain settled in one location. The red quadrat in the high-density area and white quadrat in the low-density site were selected for replanted cockle monitoring over the duration of the project. All other quadrats remained untouched to avoid disturbance until the final excavation of all plots in November 2024.

The results (Table 4.2) show that over the full duration of the experiment (November 2023 – November 2024), only one cockle out of 300 labelled and planted in each of the high- and low-density sites was found. The solitary individual (HD pink 14) was found in its original pink quadrat at the high-density site, gaining 7.84 mm in length and 4.58 g in weight over the year.

Table 4.2 Individual cockles tracked over trial duration

	Nov-23		Feb-24		May-24		Aug-24		Nov-24	
Location, quadrat & label number	**Length (mm)**	**Weight (g)**	**Length (mm)**	**Weight (g)**	**Length (mm)**	**Weight (g)**	**Length (mm)**	**Weight (g)**	**Length (mm)**	**Weight (g)**
LD White 61	17.26	2.19	17.49	2.31	17.49	2.33				
LD White 64	16.73	1.69	17.05	1.99						
LD White 65	17.3	1.64	17.62	1.81						
LD White 68	17.28	1.61	17.3	1.49						
LD White 88	15.67	1.42	15.67	1.33						
LD White 89	16.5	1.76	16.67	1.73						
LD White 90	17.06	1.77	17.08	1.94						
LD White 91	16.05	1.52	16.06	1.57						
LD White 95	15.89	1.3	15.9	1.41						
LD White 99	15.54	1.53	15.75	1.46						
HD Red 100	15.28	2.18	17.58	2.13						
HD Red 72	17.06	1.42	Found Deceased							
HD Pink 14	17.95	2.28							25.79	6.86

Quarterly monitoring of red (high-density) and white (low-density) quadrats show that tracking cockles was most successful in the low-density area with 10 cockles recovered in the first quarter (Feb 2024) after replanting (Nov 2023). One cockle was found in the low-density May sampling, but thereafter no further cockles were found. The high-density red quadrat retained only one live labelled cockle (HD Red 100) into the Feb 2024 sampling and none thereafter. One dead labelled cockle (Red 72) was found in the high-density red quadrat during the February monitoring.

4.4 *Thinning process and impact on abundance*

Analysis of sample plot content over the experimental period of a year shows variation in abundance, composition, weight and length. At the low-density location (NOR61_B) no cockles were recorded in November 2023, before 50 1-year old labelled cockles were planted in each of the six quadrats. Excavation of plots and controls in November 2024 revealed the location reverted to the original zero-density condition, thus suggesting environmental parameters limit the colonisation and retention of cockles in some areas of the Solway Firth. Given the absence of cockles, no further analysis was possible with the low-density location.

The high-density location (NOR37_G) retained cockles over the year period allowing for analysis to be conducted on the impact of reducing cockle density using backwards stepwise model selection to assess the importance of the variables; 'Year', composed of two levels, one at each sample collection time and 'Sample plot' composed of eight levels, one for each survey sample location including two control plots where no thinning occurred. The interaction between Year and sample plot was also included and the cockle counts were modelled using a Poisson error distribution and Log link. AIC and log-likelihood ratio test were used to test between models.

Model selection showed a significant ($p < 0.001$) effect of both variables, year and sample plot and their interaction, on the density of cockles (Table 4.3). The inclusion of the interaction in the optimal model indicates that density changes recorded at the sample locations were modulated by year and *vice versa*. This indicates that no general trend was observed from one year to the next in any one particular sample plot.

Table 4.3 Model selection table for the cockle count data comparing sample plot locations at the two sample time points.

Model	Explanatory variables	AIC	LRT (p-value)
1	~ Year + Sample_plot +Year:Sample_plot	138.43	-53.213
2	~ Year + Sample_plot	775.34	-378.67 (p< 0.001)

The difference in the density counts at each time point and in the sample plot locations can be seen in Figure 4.3. In general, the trend was for lower densities to be observed in November 2024 than in November 2023, including at the control plots (grey1 – Control plot 1 and grey2 – Control plot 2). However, at three sample plots (Blue, Green and Red) this trend was reversed, and higher cockle density was observed at these plots.

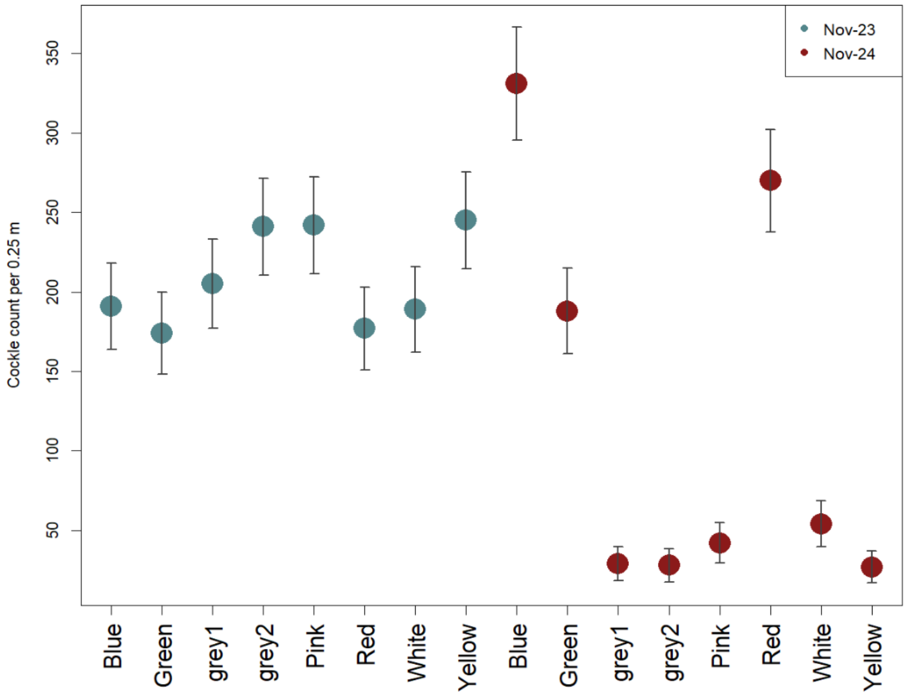


Figure 4.3 Differences in cockle counts at the two sample time points and at each of the subsample sites. Coloured circles show the median model estimate (and the true count). Error bars show 95% confidence intervals of the model estimate.

4.4.1 *Density drivers*

The majority of the differences between the densities recorded in 2023 and 2024 is the result of 0-group (spat) recruitment to the sample plots (Figure 4.4a). The 2021 (2-year old) and' 22 cohorts (1-year old) (Figure 4.4b are present in densities an order of magnitude less than those seen for the 2023 and 2024 cohorts (Figure 4.4c). Additionally, it was hypothesised that cockle density may influence recruitment. High-densities may attract more recruits similar to the effect of noise on oyster recruitment (e.g. McAfee *et al.*, 2023). Alternatively, high densities may adversely affect recently recruited individuals through competition. Figure 4.4c displays the 0-group recruits recorded in November 2024 and any, presumably incoming age-1 cockles. The numbers at the top of the bars display the density of all age groups present at the time of data collection and are indicative of the numbers present during recruitment. Pearson's product moment correlation coefficient comparing the densities of all age groups present (> age 0) with the density of recruits (0-group) was -0.446 (t = -1.22, df = 6, p = 0.268) and indicated no significant correlation between recruitment and the densities of cockles present.

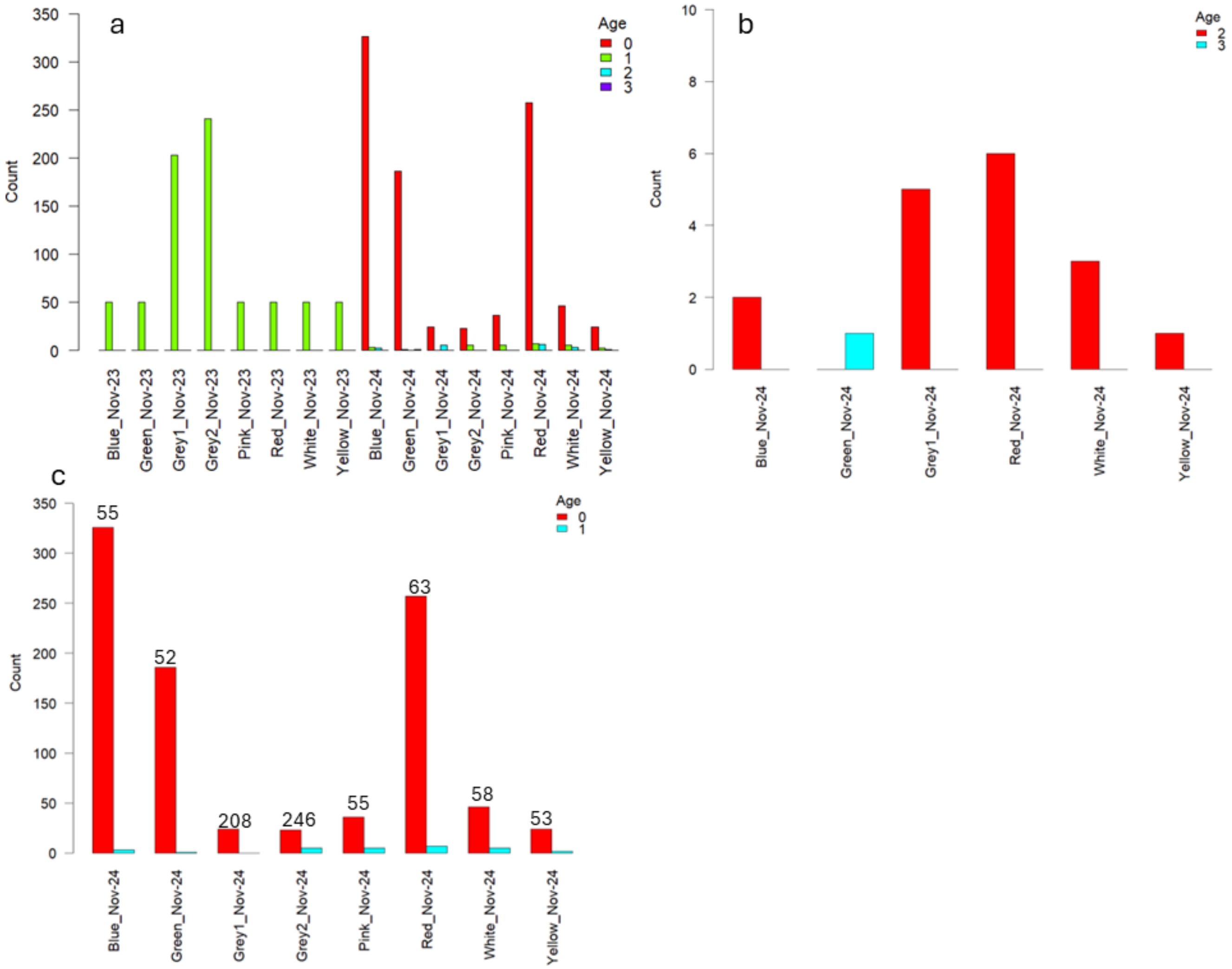


Figure 4.4 Age distribution in cockle samples from each sample plot and at both time points for all age classes (a), counts of the 2021 and 2022 cohorts' sampled in 2024 (b) and the 2023 and 2024 cohorts sampled in 2024 (c). Numbers at the top of bars display the count of cockle density in November 2024 excluding the 0-group.

4.5 *Length and weight comparison*

Analysis of cockle length and weight across the two time points at the high-density location reflects the change in composition of cockles from the planted 1-year old cockles in November 2023 to primarily 0-group spats in November 2024. Both length (Figure 4.5a) and weight (Figure 4.5b) are shorter/ lower across all six sample plots.

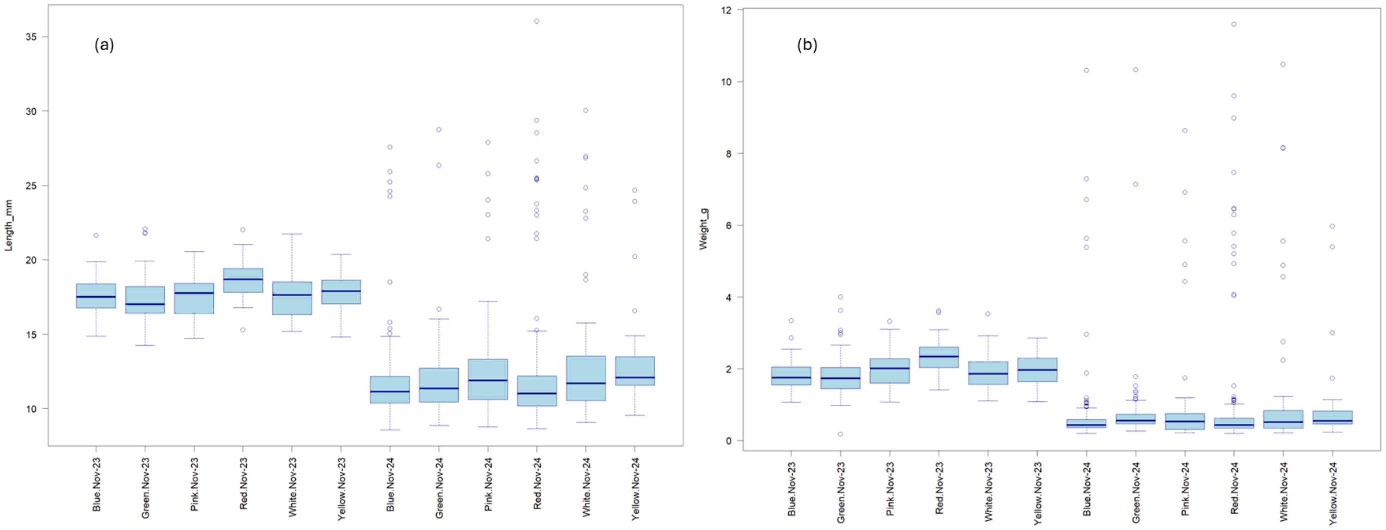


Figure 4.5 Comparison of cockle length and weight in each sample plot from Nov 2023 – Nov 2024

5 Discussion

5.1 *Can zero density locations retain cockles?*

Addressing the key aims of this experimental study in the context of the findings, the research indicates that established areas of low-density (zero cockles) are unlikely to be colonised by cockles even when planting at low densities based on this small-scale experimental trial. While tracking of cockles at the low-density site was more successful (in terms of numbers) into the first quarter-monitoring period following planting, long-term monitoring reveals a return to zero-density (see Section 4.4). Environmental conditions, such as temperature, pollution levels, salinity, oxygen availability, food availability, hydrodynamics and substrate characteristics are known to play an important role in supporting cockle populations (Santos *et al*., 2022). Given the relative proximity to the high-density location, it was unlikely that there was a critical variation in most of these variables. However, work by Darroch (2024) assessing sediment characteristics across high-, low-, and zero-density cockle density locations in the Solway Firth found grain size influenced cockle density (f = 10.95, df =1, P < 0.01) with coarser sediment areas supporting low or zero densities of cockles. In contrast, high-density sites such as NOR37_G were associated with a higher fraction of very fine sand, silt and clay. NOR61_B (low-density) appears to have a drier and coarser substrate compared to the high-density location and therefore may have played a key role in affecting the retention of planted cockles or support any cockle population (Callaway *et al*., 2014). Coarser sediment drains quicker at low tide, especially in elevated tidal flats, thus becomes drier and more susceptible to aeolian mobility (Besnard *et al*., 2022) which may be a further factor in explaining why some areas of the Solway Firth have zero density. Should ecological restoration of cockle populations be a desirable future objective, the data gathered through stock assessments will provide valuable spatial data on where to direct restoration efforts avoiding historical zero density locations. Given the granulometric analysis findings by Darroch (2024), sediment characteristics may also be a useful metric in identifying suitable cockle grounds (assuming all other important variables remain the same).

5.2 *Does reducing densities of cockles in high-density areas lead to greater growth*?

This study remains inconclusive on whether reducing the density of cockles from >174 per 0.25 m^2 to 50 per 0.25 m^2 resulted in greater growth through reduced intraspecific competition. Several factors contribute to this outcome, of which the most fundamental is that tracking individual cockles is problematic and only one cockle could be tracked over the experimental trial start and end dates. While this individual cockle (Pink 14) gained length and weight over the trial (Table 4.2), the absence of a significant number of labelled cockles inhibits extrapolation to the wider population. Furthermore, the population structure and number in all six planted quadrats and controls in the high-density site changed over the trial period from 1-year old planted cockles to a predominance of 0-group cockles (spat) settlement (Figure 4.4a). Very few other year-class cockles were found across all six quadrats at the end of the trial (Figure 4.4b), although half the sample plots maintained a similar number of cockles to the 50 planted (Figure 4.4a). Studies have shown that high densities can promote cockle movement to less competitive locations (Richardson *et al.*, 1993), and given three of the six sample plots supported cockle abundance less than the pre-planting figures and similar to the 50 per 0.25 m^2, competition for space is unlikely to be a key factor explaining the absence of labelled cockles. The difference in population structure is reflected in the length/weight comparison given the 1-year cockles are larger and heavier than 0-group cockles (Figure 4.5a, b). Rather than maintain the planted density of 50 cockles per 0.25 m^2 quadrat, reduced density may have offered space for spat settlement. Comparing recruitment and movement into each of the six high-density plots prior to thinning/planting we find an increase in numbers in three of the six plots and a significant decline in the remaining three and control plots (Figure 4.3). The proximity of all quadrats and control plots point to a highly variable nature and uneven distribution of cockles over short distances with similar environmental conditions (Whitton *et al.*, 2012).

The limitations of this research in understanding the impacts of reducing density on cockle growth include the ability to track cockles effectively given the potential for predation impacts (Sanchez-Salazar *et al.*, 1987), high natural mortality exceeding 60% for 0-group and 1-year olds (Callaway, 2022), natural mobility (Flach, 1996), disease and parasites (Iglesias *et al.*, 2023) and abiotic factors such as temperature, shifting channels and storms. In addition, disturbance to the plots when planting the cockles may have influenced outcomes along with the potential for stress during the counting, measuring and glueing label procedures. All these variables may have impacted on the ability to locate the labelled cockles following planting. However, this research can also note some success in that ten were tracked for four months, one for six months and one was found 12 months later. Therefore, in theory, it is possible to track individuals even using a rudimentary labelling system. One possible solution to enhance potential 'recapture' is to increase the size of the sampling areas (assuming cockles do not migrate a significant distance), and have multiple sites, however this would require a significant increase in human resource to monitor sites within a single tide. Electronic Data Storage Tags (DSTs) also have potential to monitor movement, survival and growth providing insight into population dynamics, however the use of DSTs in the context of shellfish is currently unexplored.

6 Conclusion

Understanding how cockle populations respond to thinning and transplanting is crucial for developing effective management strategies aimed at promoting growth and colonisation. Thinning, or reducing population density, can be deployed to decrease intraspecific competition, potentially enhancing individual growth rates. The relaying trials conducted in the Solway Firth demonstrated the potential benefits and challenges of relocating juvenile cockles from high-density to low-density or zero-density areas. The study confirmed that cockles can be successfully tracked and monitored in experimental plots at least in the short-term (6 months). However long-term (1 year), findings were inconclusive and do not support density management as a tool to enhance growth rates and survival.

Despite the results, such as the survival and growth observed in specific relayed cockles, several challenges were identified. High mortality during the winter months, sedimentation, and environmental variability highlighted the difficulties in ensuring consistent retention and survival of cockles in relayed areas. The retention of individual cockles, particularly in zero-density sites, emphasizes the importance of selecting optimal relaying locations and times to maximize survival and growth.

Future research should focus on refining methodologies, expanding sample sizes, and exploring seasonal effects to build a robust framework for cockle relaying as a sustainable management strategy. These efforts could contribute to enhancing cockle stocks, mitigating mass mortalities, and supporting the economic viability of the Solway Firth fisheries.

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Appendix A Cockles planted in different sample plots

High-density site (NOR37_G)

Green				Pink				White				Yellow				Blue				Red			
Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)
1	17.6	2.09	2.04	1	18.8	2.52	2.47	1	17.28	1.7	1.65	1	17.22	1.71	1.66	1	19.6	2.6	2.55	1	19.77	2.35	2.3
2	18.13	1.8	1.75	2	17.29	1.93	1.88	3	17.2	1.93	1.88	4	19.87	2.8	2.75	2	18.09	2.05	2	3	17.46	1.87	1.82
3	15.65	1.32	1.27	3	17.82	2.04	1.99	4	19.44	2.45	2.4	5	17.15	2.03	1.98	3	18.19	2.23	2.18	5	19.28	2.56	2.51
4	16.6	1.59	1.54	4	16.12	1.13	1.08	6	21.74	3.58	3.53	6	17.64	1.85	1.8	4	17.49	1.79	1.74	6	19.6	2.37	2.32
5	16.37	1.69	1.64	5	17.77	2.13	2.08	8	18.44	1.96	1.91	7	17.92	2.11	2.06	5	16.83	1.41	1.36	7	18.48	2.57	2.52
6	15.01	1.23	1.18	6	15.36	1.46	1.41	9	17.8	2.09	2.04	9	19.29	2.89	2.84	6	18.93	2.18	2.13	8	19.12	2.65	2.6
7	14.26	1.03	0.98	7	18.41	2.35	2.3	10	16.25	1.68	1.63	10	16.01	1.51	1.46	7	17.13	1.77	1.72	9	20.43	3.1	3.05
8	15.87	1.45	1.4	8	19.7	3.15	3.1	11	20.32	2.97	2.92	11	18.67	2.23	2.18	8	17.52	1.72	1.67	12	20.64	3.14	3.09
9	18.16	1.85	1.8	9	20.27	3	2.95	12	16.77	1.57	1.52	12	18.72	2.17	2.12	9	16.35	1.69	1.64	13	18.57	2.45	2.4
10	16.78	1.92	1.87	10	19.27	2.6	2.55	13	16.25	1.72	1.67	13	15.38	1.57	1.52	10	17.9	2.02	1.97	14	18.23	2.42	2.37
12	18.13	2.15	2.1	11	20.55	2.75	2.7	14	17.57	1.73	1.68	14	19.04	2.32	2.27	11	16.94	1.77	1.72	16	18.42	2.31	2.26
13	21.77	3.12	3.07	12	17.88	2.31	2.26	15	15.88	1.54	1.49	15	16.84	1.66	1.61	12	19.33	2.25	2.2	17	19.49	2.75	2.7
14	15.49	1.31	1.26	13	18.05	2.14	2.09	17	16.01	1.4	1.35	16	16.51	1.5	1.45	13	16.05	1.61	1.56	18	17.8	2.32	2.27
15	15.74	1.4	1.35	14	17.95	2.33	2.28	18	18.1	2.33	2.28	17	17.56	1.88	1.83	14	16.41	1.63	1.58	20	20.13	2.93	2.88
16	16.71	1.72	1.67	15	16.78	1.8	1.75	19	18.52	2.25	2.2	18	20.13	2.78	2.73	15	16.43	1.33	1.28	21	18.64	2.39	2.34
17	19.31	2.71	2.66	16	17.78	2.09	2.04	20	19.22	2.66	2.61	19	17.66	1.99	1.94	16	21.62	3.39	3.34	22	19.11	2.58	2.53
18	17.26	1.59	1.54	17	15.49	1.45	1.4	21	19.56	2.45	2.4	20	18.44	2.49	2.44	17	16.51	1.52	1.47	23	20.04	3	2.95
19	15.78	1.3	1.25	18	14.73	1.21	1.16	22	19.54	2.71	2.66	21	18.08	2.47	2.42	18	18.44	2.08	2.03	51	19.07	2.95	2.9
20	16.74	1.4	1.35	19	17.65	2.06	2.01	23	15.67	1.16	1.11	23	20.01	2.67	2.62	19	14.88	1.19	1.14	53	19.43	2.36	2.31
21	18.54	2.6	2.55	20	18.2	2.22	2.17	24	18.72	2.13	2.08	24	15.97	1.53	1.48	20	16.5	1.42	1.37	54	18.78	2.64	2.59
22	16.83	1.63	1.58	21	16.4	1.57	1.52	25	18.15	1.98	1.93	25	17.88	2.06	2.01	21	15.42	1.12	1.07	56	17.8	2.09	2.04
23	19.01	2.08	2.03	22	15.23	1.37	1.32	26	18.48	2.2	2.15	26	18.83	2.45	2.4	22	18.62	2.1	2.05	57	17.96	2.49	2.44
24	17.06	1.64	1.59	23	17.53	2.12	2.07	27	18.13	2.25	2.2	27	17.38	1.97	1.92	23	18.83	2.23	2.18	58	18.51	2.33	2.28
25	16.95	1.8	1.75	24	16.73	2.07	2.02	28	16.32	1.62	1.57	28	18.22	2.25	2.2	24	16.75	1.6	1.55	59	16.79	1.7	1.65
26	21.8	3.68	3.63	25	18.16	2.18	2.13	29	19.19	2.3	2.25	29	17.83	2.01	1.96	25	18.49	2.33	2.28	60	18.12	2.4	2.35
27	18.97	2.23	2.18	26	20.29	3.37	3.32	30	17.7	1.72	1.67	30	18.05	2.16	2.11	26	18.56	2.32	2.27	61	17.42	2.17	2.12

28	17.67	2.01	1.96		27	19.29	2.84	2.79		31	15.79	1.43	1.38		31	18.97	2.44	2.39		27	19.3	2.12	2.07		62	19.13	2.52	2.47
29	16.42	1.52	1.47		28	18.82	2.58	2.53		32	18.64	2.33	2.28		32	18.63	2.38	2.33		28	18.39	1.99	1.94		63	19.41	2.94	2.89
30	19.91	3	2.95		29	18.07	2.02	1.97		34	17.1	1.86	1.81		33	18.37	2.52	2.47		29	16.76	1.22	1.17		64	20.46	2.81	2.76
31	19.45	2.41	2.36		30	18.34	2.29	2.24		35	17.81	2.02	1.97		34	17.22	1.69	1.64		30	17.95	2.02	1.97		65	22.02	3.66	3.61
32	17.53	1.97	1.92		31	16.19	1.73	1.68		36	16.76	1.47	1.42		35	17.03	1.86	1.81		31	17.56	1.96	1.91		67	18.02	2.2	2.15
33	15.58	1.3	1.25		32	18.06	2.08	2.03		37	17.31	1.88	1.83		36	18.84	2.58	2.53		32	16.56	1.45	1.4		68	19.35	2.75	2.7
34	16.23	1.65	1.6		33	15.84	1.62	1.57		38	17.22	2.17	2.12		37	18.44	2.12	2.07		33	17.09	1.74	1.69		69	19.26	2.94	2.89
35	17.44	2.06	2.01		34	17.44	1.9	1.85		39	16.83	1.74	1.69		38	18.53	2.2	2.15		34	17.42	2.36	2.31		70	19.26	2.53	2.48
36	16.72	1.7	1.65		35	17.88	2.09	2.04		40	15.94	1.55	1.5		39	20.36	2.91	2.86		35	17.5	1.75	1.7		71	19.82	2.29	2.24
37	17.02	1.49	1.44		36	16.82	1.96	1.91		41	15.2	1.42	1.37		40	17.31	1.87	1.82		36	17.97	1.95	1.9		72	17.06	1.47	1.42
38	16.3	1.42	1.37		37	16.67	1.55	1.5		42	17.17	1.7	1.65		41	16.47	1.57	1.52		37	16.99	2	1.95		73	19.01	2.23	2.18
39	19.37	3.05	3		38	16.22	1.4	1.35		43	17.7	2	1.95		42	15.79	1.61	1.56		38	18.04	2.06	2.01		74	17.16	1.91	1.86
40	18.29	1.92	1.87		39	20.07	2.81	2.76		44	18.51	2.21	2.16		43	18.42	2.02	1.97		39	15.36	1.35	1.3		75	17.72	1.78	1.73
41	16.69	1.45	1.4		40	19.31	2.25	2.2		45	18.24	1.79	1.74		44	17.58	2.23	2.18		40	17.52	1.56	1.51		76	17.51	1.93	1.88
42	19.37	2.5	2.45		41	17.94	1.96	1.91		47	15.75	1.23	1.18		45	18.28	1.87	1.82		41	18.75	2.16	2.11		77	17.39	1.87	1.82
43	17.5	1.97	1.92		42	17.7	1.9	1.85		48	16.97	1.9	1.85		46	17.94	1.93	1.88		42	17.77	2.06	2.01		78	16.92	1.77	1.72
44	17	2.13	2.08		43	19.14	2.78	2.73		50	16.1	1.46	1.41		47	14.82	1.24	1.19		43	17.89	1.82	1.77		79	16.83	1.66	1.61
45	16.77	1.95	1.9		44	19.45	2.51	2.46		51	18.76	2.64	2.59		51	16.52	1.57	1.52		44	17.69	1.6	1.55		80	18.72	2.41	2.36
46	18.2	1.88	1.83		45	17.29	1.85	1.8		52	19.38	2.7	2.65		52	15.35	1.14	1.09		45	19.87	2.91	2.86		81	17.25	1.99	1.94
47	16.42	1.61	1.56		46	16.85	1.65	1.6		54	16.15	1.35	1.3		53	16.28	1.54	1.49		46	15.81	1.32	1.27		84	18.81	2.05	2
48	17.08	1.57	1.52		47	16.08	1.59	1.54		55	15.47	1.47	1.42		54	18.67	1.9	1.85		47	16.49	1.38	1.33		85	18.02	2.09	2.04
49	16.76	1.78	1.73		48	15.44	1.57	1.52		56	18.94	2.36	2.31		55	16.61	1.64	1.59		48	17.7	1.92	1.87		89	18.55	2.47	2.42
50	16.56	1.2	1.15		49	15.48	1.65	1.6		99	16.33	1.66	1.61		57	18.63	2.35	2.3		49	16.85	1.6	1.55		99	21.03	3.61	3.56
51	22.05	4.05	4		50	15.42	1.19	1.14		100	17.77	2.02	1.97		100	17.08	1.74	1.69		50	17.29	1.69	1.64		100	15.28	2.21	2.16

Low-density site (NOR61_B)

Green				Pink				White				Yellow				Blue				Red			
Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)	Label	L (mm)	W (g)	Adj. W (g)
1	17.6	2.09	2.04	1	18.8	2.52	2.47	1	17.28	1.7	1.65	1	17.22	1.71	1.66	1	19.6	2.6	2.55	1	19.77	2.35	2.3
2	18.13	1.8	1.75	2	17.29	1.93	1.88	3	17.2	1.93	1.88	4	19.87	2.8	2.75	2	18.09	2.05	2	3	17.46	1.87	1.82
3	15.65	1.32	1.27	3	17.82	2.04	1.99	4	19.44	2.45	2.4	5	17.15	2.03	1.98	3	18.19	2.23	2.18	5	19.28	2.56	2.51
4	16.6	1.59	1.54	4	16.12	1.13	1.08	6	21.74	3.58	3.53	6	17.64	1.85	1.8	4	17.49	1.79	1.74	6	19.6	2.37	2.32
5	16.37	1.69	1.64	5	17.77	2.13	2.08	8	18.44	1.96	1.91	7	17.92	2.11	2.06	5	16.83	1.41	1.36	7	18.48	2.57	2.52
6	15.01	1.23	1.18	6	15.36	1.46	1.41	9	17.8	2.09	2.04	9	19.29	2.89	2.84	6	18.93	2.18	2.13	8	19.12	2.65	2.6
7	14.26	1.03	0.98	7	18.41	2.35	2.3	10	16.25	1.68	1.63	10	16.01	1.51	1.46	7	17.13	1.77	1.72	9	20.43	3.1	3.05
8	15.87	1.45	1.4	8	19.7	3.15	3.1	11	20.32	2.97	2.92	11	18.67	2.23	2.18	8	17.52	1.72	1.67	12	20.64	3.14	3.09
9	18.16	1.85	1.8	9	20.27	3	2.95	12	16.77	1.57	1.52	12	18.72	2.17	2.12	9	16.35	1.69	1.64	13	18.57	2.45	2.4
10	16.78	1.92	1.87	10	19.27	2.6	2.55	13	16.25	1.72	1.67	13	15.38	1.57	1.52	10	17.9	2.02	1.97	14	18.23	2.42	2.37
12	18.13	2.15	2.1	11	20.55	2.75	2.7	14	17.57	1.73	1.68	14	19.04	2.32	2.27	11	16.94	1.77	1.72	16	18.42	2.31	2.26
13	21.77	3.12	3.07	12	17.88	2.31	2.26	15	15.88	1.54	1.49	15	16.84	1.66	1.61	12	19.33	2.25	2.2	17	19.49	2.75	2.7
14	15.49	1.31	1.26	13	18.05	2.14	2.09	17	16.01	1.4	1.35	16	16.51	1.5	1.45	13	16.05	1.61	1.56	18	17.8	2.32	2.27
15	15.74	1.4	1.35	14	17.95	2.33	2.28	18	18.1	2.33	2.28	17	17.56	1.88	1.83	14	16.41	1.63	1.58	20	20.13	2.93	2.88
16	16.71	1.72	1.67	15	16.78	1.8	1.75	19	18.52	2.25	2.2	18	20.13	2.78	2.73	15	16.43	1.33	1.28	21	18.64	2.39	2.34
17	19.31	2.71	2.66	16	17.78	2.09	2.04	20	19.22	2.66	2.61	19	17.66	1.99	1.94	16	21.62	3.39	3.34	22	19.11	2.58	2.53
18	17.26	1.59	1.54	17	15.49	1.45	1.4	21	19.56	2.45	2.4	20	18.44	2.49	2.44	17	16.51	1.52	1.47	23	20.04	3	2.95
19	15.78	1.3	1.25	18	14.73	1.21	1.16	22	19.54	2.71	2.66	21	18.08	2.47	2.42	18	18.44	2.08	2.03	51	19.07	2.95	2.9
20	16.74	1.4	1.35	19	17.65	2.06	2.01	23	15.67	1.16	1.11	23	20.01	2.67	2.62	19	14.88	1.19	1.14	53	19.43	2.36	2.31
21	18.54	2.6	2.55	20	18.2	2.22	2.17	24	18.72	2.13	2.08	24	15.97	1.53	1.48	20	16.5	1.42	1.37	54	18.78	2.64	2.59
22	16.83	1.63	1.58	21	16.4	1.57	1.52	25	18.15	1.98	1.93	25	17.88	2.06	2.01	21	15.42	1.12	1.07	56	17.8	2.09	2.04
23	19.01	2.08	2.03	22	15.23	1.37	1.32	26	18.48	2.2	2.15	26	18.83	2.45	2.4	22	18.62	2.1	2.05	57	17.96	2.49	2.44
24	17.06	1.64	1.59	23	17.53	2.12	2.07	27	18.13	2.25	2.2	27	17.38	1.97	1.92	23	18.83	2.23	2.18	58	18.51	2.33	2.28
25	16.95	1.8	1.75	24	16.73	2.07	2.02	28	16.32	1.62	1.57	28	18.22	2.25	2.2	24	16.75	1.6	1.55	59	16.79	1.7	1.65
26	21.8	3.68	3.63	25	18.16	2.18	2.13	29	19.19	2.3	2.25	29	17.83	2.01	1.96	25	18.49	2.33	2.28	60	18.12	2.4	2.35
27	18.97	2.23	2.18	26	20.29	3.37	3.32	30	17.7	1.72	1.67	30	18.05	2.16	2.11	26	18.56	2.32	2.27	61	17.42	2.17	2.12
28	17.67	2.01	1.96	27	19.29	2.84	2.79	31	15.79	1.43	1.38	31	18.97	2.44	2.39	27	19.3	2.12	2.07	62	19.13	2.52	2.47

29	16.42	1.52	1.47		28	18.82	2.58	2.53		32	18.64	2.33	2.28		32	18.63	2.38	2.33		28	18.39	1.99	1.94		63	19.41	2.94	2.89
30	19.91	3	2.95		29	18.07	2.02	1.97		34	17.1	1.86	1.81		33	18.37	2.52	2.47		29	16.76	1.22	1.17		64	20.46	2.81	2.76
31	19.45	2.41	2.36		30	18.34	2.29	2.24		35	17.81	2.02	1.97		34	17.22	1.69	1.64		30	17.95	2.02	1.97		65	22.02	3.66	3.61
32	17.53	1.97	1.92		31	16.19	1.73	1.68		36	16.76	1.47	1.42		35	17.03	1.86	1.81		31	17.56	1.96	1.91		67	18.02	2.2	2.15
33	15.58	1.3	1.25		32	18.06	2.08	2.03		37	17.31	1.88	1.83		36	18.84	2.58	2.53		32	16.56	1.45	1.4		68	19.35	2.75	2.7
34	16.23	1.65	1.6		33	15.84	1.62	1.57		38	17.22	2.17	2.12		37	18.44	2.12	2.07		33	17.09	1.74	1.69		69	19.26	2.94	2.89
35	17.44	2.06	2.01		34	17.44	1.9	1.85		39	16.83	1.74	1.69		38	18.53	2.2	2.15		34	17.42	2.36	2.31		70	19.26	2.53	2.48
36	16.72	1.7	1.65		35	17.88	2.09	2.04		40	15.94	1.55	1.5		39	20.36	2.91	2.86		35	17.5	1.75	1.7		71	19.82	2.29	2.24
37	17.02	1.49	1.44		36	16.82	1.96	1.91		41	15.2	1.42	1.37		40	17.31	1.87	1.82		36	17.97	1.95	1.9		72	17.06	1.47	1.42
38	16.3	1.42	1.37		37	16.67	1.55	1.5		42	17.17	1.7	1.65		41	16.47	1.57	1.52		37	16.99	2	1.95		73	19.01	2.23	2.18
39	19.37	3.05	3		38	16.22	1.4	1.35		43	17.7	2	1.95		42	15.79	1.61	1.56		38	18.04	2.06	2.01		74	17.16	1.91	1.86
40	18.29	1.92	1.87		39	20.07	2.81	2.76		44	18.51	2.21	2.16		43	18.42	2.02	1.97		39	15.36	1.35	1.3		75	17.72	1.78	1.73
41	16.69	1.45	1.4		40	19.31	2.25	2.2		45	18.24	1.79	1.74		44	17.58	2.23	2.18		40	17.52	1.56	1.51		76	17.51	1.93	1.88
42	19.37	2.5	2.45		41	17.94	1.96	1.91		47	15.75	1.23	1.18		45	18.28	1.87	1.82		41	18.75	2.16	2.11		77	17.39	1.87	1.82
43	17.5	1.97	1.92		42	17.7	1.9	1.85		48	16.97	1.9	1.85		46	17.94	1.93	1.88		42	17.77	2.06	2.01		78	16.92	1.77	1.72
44	17	2.13	2.08		43	19.14	2.78	2.73		50	16.1	1.46	1.41		47	14.82	1.24	1.19		43	17.89	1.82	1.77		79	16.83	1.66	1.61
45	16.77	1.95	1.9		44	19.45	2.51	2.46		51	18.76	2.64	2.59		51	16.52	1.57	1.52		44	17.69	1.6	1.55		80	18.72	2.41	2.36
46	18.2	1.88	1.83		45	17.29	1.85	1.8		52	19.38	2.7	2.65		52	15.35	1.14	1.09		45	19.87	2.91	2.86		81	17.25	1.99	1.94
47	16.42	1.61	1.56		46	16.85	1.65	1.6		54	16.15	1.35	1.3		53	16.28	1.54	1.49		46	15.81	1.32	1.27		84	18.81	2.05	2
48	17.08	1.57	1.52		47	16.08	1.59	1.54		55	15.47	1.47	1.42		54	18.67	1.9	1.85		47	16.49	1.38	1.33		85	18.02	2.09	2.04
49	16.76	1.78	1.73		48	15.44	1.57	1.52		56	18.94	2.36	2.31		55	16.61	1.64	1.59		48	17.7	1.92	1.87		89	18.55	2.47	2.42
50	16.56	1.2	1.15		49	15.48	1.65	1.6		99	16.33	1.66	1.61		57	18.63	2.35	2.3		49	16.85	1.6	1.55		99	21.03	3.61	3.56
51	22.05	4.05	4		50	15.42	1.19	1.14		100	17.77	2.02	1.97		100	17.08	1.74	1.69		50	17.29	1.69	1.64		100	15.28	2.21	2.16

Appendix B Control data

High-density Controls Nov 2023 (0.25m^2)				High-density Controls Feb 2024 (0.25m^2)				High-density Controls May 2024 (0.25m^2)				High-density Controls Aug 2024 (0.25m^2)				High-density Controls Nov 2024 (0.25m^2)			
C	L (mm)	W (g)	A (y)	C	L (mm)	W (g)	A (y)	C	L (mm)	W (g)	A (y)	C	L (mm)	W (g)	A (y)	C	L (mm)	W (g)	A (y)
1	18.7	2.4	1	1	17.07	1.68	1	1	9.52	0.34	0	1	6.17	0.1	0	1	28.5	9.22	2
1	22.99	4.13	1	1	17.62	1.92	1	1	16.72	1.34	1	1	6.44	0.08	0	1	27.38	6.52	2
1	19.05	2.24	1	1	17.05	1.51	1	1	16.1	1.42	1	1	6.48	0.09	0	1	26.18	6.52	2
1	21.66	3.99	1	1	15.3	1.1	1	1	15.83	1.33	1	1	6.5	0.08	0	1	27.08	8.25	2
1	18.62	2.39	1	1	17.94	2.14	1	1	16.95	1.77	1	1	6.54	0.08	0	1	26.28	6.14	2
1	19.52	2.16	1	1	18.04	1.97	1	1	18.94	2.4	1	1	6.58	0.08	0	1	14.04	1.08	0
1	15.79	1.22	1	1	17.69	1.96	1	1	14.96	1.18	1	1	6.62	0.07	0	1	13.12	0.76	0
1	19.25	2.53	1	1	15	1.31	1	1	16.91	1.73	1	1	6.64	0.09	0	1	13.63	0.85	0
1	19.75	2.78	1	1	15.38	1.17	1	1	16.02	1.43	1	1	6.66	0.08	0	1	12.34	0.62	0
1	18.25	2.3	1	1	16.11	1.44	1	1	17.45	1.91	1	1	6.73	0.09	0	1	13.79	0.9	0
1	18.8	2.38	1	1	15.35	1.32	1	1	14.2	1.04	1	1	6.8	0.1	0	1	13.01	0.7	0
1	19.52	2.46	1	1	18.97	2.63	1	1	16.09	1.51	1	1	6.85	0.09	0	1	14.19	1.16	0
1	16.35	1.52	1	1	13.86	0.88	1	1	17.97	2.12	1	1	7.02	0.1	0	1	12.05	0.52	0
1	18.34	2.1	1	1	14.56	1	1	1	20.38	2.84	2	1	7.05	0.11	0	1	11.53	0.53	0
1	16.1	1.61	1	1	16.74	1.5	1	2	22.31	3.85	2	1	7.12	0.12	0	1	10.3	0.4	0
1	18.92	2.4	1	1	13.57	0.85	1	2	19.13	2.34	1	1	7.2	0.11	0	1	13.44	0.88	0
1	17.48	1.95	1	1	13.28	0.74	1	2	16.68	1.68	1	1	7.21	0.1	0	1	11.66	0.53	0
1	18.5	2.15	1	1	15.95	1.46	1	2	18.2	1.98	1	1	7.25	0.13	0	1	11.03	0.42	0
1	17.33	1.78	1	2	18.28	2.26	1	2	16.32	1.47	1	1	7.29	0.12	0	1	11.62	0.53	0
1	17.89	2.12	1	2	18.32	2.03	1	2	17.48	1.92	1	1	7.31	0.13	0	1	10.39	0.35	0
1	17.57	1.86	1	2	16.34	1.57	1	2	18.01	1.95	1	1	7.33	0.11	0	1	10.06	0.37	0
1	19.37	2.6	1	2	19.2	2.68	1	2	15.83	1.29	1	1	7.33	0.13	0	1	10.72	0.4	0
1	16.97	1.85	1	2	20.26	2.99	1	2	16.59	1.7	1	1	7.39	0.12	0	1	9.72	0.34	0
1	19	2.41	1	2	16.78	1.69	1	2	15.78	1.17	1	1	7.44	0.12	0	1	11.13	0.4	0
1	18.88	2.31	1	2	14.83	1.33	1	2	14.28	0.87	1	1	7.44	0.13	0	1	10.01	0.29	0
1	19.39	2.42	1	2	17.3	1.63	1	2	16.65	1.67	1	1	7.49	0.12	0	1	10.19	0.29	0
1	15.66	1.4	1	2	17.6	2.04	1	2	15.83	1.19	1	1	7.54	0.14	0	1	10.64	0.42	0
1	17.55	2.06	1	2	15.86	1.17	1					1	7.56	0.14	0	1	9.73	0.44	0
1	16.26	1.4	1	2	18.51	2.36	1					1	7.59	0.12	0	1	9.68	0.28	0
1	18.23	2.32	1	2	19.65	2.58	1					1	7.6	0.14	0	2	26.57	8.14	1
1	18.4	2.07	1	2	19.64	2.88	1					1	7.67	0.13	0	2	26.13	7.1	1
1	17.02	1.97	1	2	16.56	1.67	1					1	7.7	0.13	0	2	21.09	3.78	1
1	17.84	2.17	1	2	15.66	1.34	1					1	7.71	0.13	0	2	23.41	4.62	1
1	18.39	2.18	1	2	15.04	1.15	1					1	7.72	0.13	0	2	23.67	5.59	1
1	14.81	1.27	1	2	15.56	1.53	1					1	7.87	0.13	0	2	13.84	1.06	0
1	17.67	1.87	1	2	15.26	1.3	1					1	7.9	0.13	0	2	12.78	0.7	0
1	16.1	1.38	1	2	16.7	1.75	1					1	7.98	0.15	0	2	13.85	0.89	0
1	16.64	1.77	1	2	16.02	1.39	1					1	8	0.16	0	2	14.88	1.41	0
1	16.02	1.5	1	2	14.68	1.09	1					1	8.01	0.17	0	2	13.86	0.94	0
1	19.33	2.72	1	2	10.14	0.35	0					1	8.08	0.14	0	2	13.68	0.84	0

1	14.56	1.28	1												1	8.11	0.18	0		2	10.58	0.38	0
1	17.22	1.71	1												1	8.19	0.16	0		2	15.01	1.17	0
1	16.54	1.62	1												1	8.19	0.15	0		2	11.38	0.49	0
1	18.99	2.56	1												1	8.27	0.17	0		2	10.25	0.13	0
1	17.63	1.77	1												1	8.32	0.17	0		2	10.08	0.37	0
1	19.71	2.69	1												1	8.39	0.18	0		2	10.01	0.31	0
1	17.22	1.55	1												1	8.41	0.16	0		2	11.39	0.46	0
1	16.97	1.59	1												1	8.43	0.18	0		2	10.2	0.33	0
1	19.27	2.34	1												1	8.61	0.19	0		2	9.69	0.29	0
1	15.69	1.53	1												1	8.77	0.22	0		2	11.61	0.54	0
1	18.45	2.08	1												1	9.12	0.22	0		2	8.59	0.24	0
1	14.51	1.17	1												1	9.27	0.23	0		2	10.92	0.44	0
1	17.17	1.66	1												1	9.87	0.29	0		2	12.37	0.57	0
1	16.28	1.37	1												1	12.46	0.46	0		2	9.7	0.33	0
1	17.45	2.06	1												1	12.46	0.51	0		2	11.14	0.43	0
1	15.88	1.45	1												1	12.47	0.47	0		2	9.58	0.24	0
1	17.13	1.64	1												1	12.47	0.42	0		2	9.13	0.17	0
1	15.83	1.47	1												1	12.49	0.46	0					
1	16.68	1.75	1												1	12.62	0.61	0					
1	15.31	1.14	1												1	12.62	0.62	0					
1	17.81	1.85	1												1	12.63	0.56	0					
1	15.02	1.04	1												1	12.63	0.59	0					
1	17.77	2.24	1												1	12.64	0.53	0					
1	17.17	1.73	1												1	12.64	0.53	0					
1	17.17	1.85	1												1	12.65	0.50	0					
1	15.02	1.35	1												1	12.66	0.56	0					
1	16.93	1.74	1												1	12.66	0.59	0					
1	16.3	1.56	1												1	12.68	0.51	0					
1	18.06	2.11	1												1	12.69	0.51	0					
1	15.97	1.65	1												1	12.69	0.51	0					
1	17.25	1.73	1												1	12.70	0.44	0					
1	17.5	1.93	1												1	12.70	0.59	0					
1	18.72	2.01	1												1	12.71	0.46	0					
1	17.08	1.64	1												1	12.71	0.58	0					
1	18.96	2.09	1												1	12.73	0.54	0					
1	21.56	3.72	1												1	12.73	0.46	0					
1	17.12	1.62	1												1	12.74	0.56	0					
1	19.69	2.82	1												1	12.74	0.66	0					
1	16.89	1.79	1												1	12.74	0.54	0					
1	15.92	1.45	1												1	12.75	0.59	0					
1	16.76	1.81	1												1	12.77	0.52	0					
1	18.01	2.04	1												1	12.77	0.48	0					
1	19.65	2.71	1												1	12.78	0.51	0					
1	14.96	1.4	1												1	12.79	0.55	0					
1	19.81	2.64	1												1	12.79	0.53	0					
1	18.5	2.34	1												1	12.80	0.49	0					

1	16.97	1.44	1												1	12.83	0.52	0					
1	15.24	1.29	1												1	12.84	0.52	0					
1	15.52	1.43	1												1	12.85	0.52	0					
1	15.86	1.44	1												1	12.85	0.57	0					
1	16.14	1.37	1												1	12.86	0.62	0					
1	16.23	1.62	1												1	12.87	0.58	0					
1	14.99	1.17	1												1	12.88	0.51	0					
1	17.89	1.91	1												1	12.89	0.51	0					
1	16.88	1.64	1												1	12.92	0.56	0					
1	16.79	1.55	1												1	12.92	0.52	0					
1	16.69	1.75	1												1	12.93	0.49	0					
1	17.37	1.75	1												1	12.93	0.26	0					
1	16.69	1.75	1												1	12.94	0.56	0					
1	16.26	1.89	1												1	12.94	0.53	0					
1	17.75	1.9	1												1	12.94	0.53	0					
1	17.06	1.93	1												1	12.95	0.64	0					
1	14.15	1.04	1												1	12.96	0.64	0					
1	18.65	2.17	1												1	13.10	0.61	0					
1	15.64	1.39	1												1	13.11	0.58	0					
1	16.91	1.79	1												1	13.12	0.54	0					
1	16.92	1.89	1												1	13.12	0.61	0					
1	17.39	1.69	1												1	13.13	0.66	0					
1	17.34	2.11	1												1	13.13	0.52	0					
1	17.03	1.99	1												1	13.14	0.62	0					
1	18.29	2.04	1												1	13.14	0.64	0					
1	16.78	1.53	1												1	13.15	0.61	0					
1	17.02	1.77	1												1	13.15	0.57	0					
1	19.05	2.13	1												1	13.15	0.51	0					
1	14.88	1.24	1												1	13.19	0.55	0					
1	17.54	1.88	1												1	13.19	0.66	0					
1	15.07	1.26	1												1	13.22	0.66	0					
1	19.66	2.48	1												1	13.23	0.61	0					
1	14.13	1.06	1												1	13.24	0.62	0					
1	17.83	1.89	1												1	13.24	0.65	0					
1	15.07	1.19	1												1	13.24	0.53	0					
1	16.39	1.8	1												1	13.26	0.56	0					
1	15.91	1.43	1												1	13.26	0.53	0					
1	17.82	2.02	1												1	13.26	0.72	0					
1	17.9	2.13	1												1	13.27	0.57	0					
1	16.1	1.78	1												1	13.27	0.58	0					
1	16.73	1.72	1												1	13.27	0.60	0					
1	16.12	1.43	1												1	13.27	0.61	0					
1	17.02	1.82	1												1	13.28	0.66	0					
1	16.13	1.38	1												1	13.28	0.68	0					
1	18.21	2.28	1												1	13.28	0.65	0					
1	14.12	0.95	1												1	13.29	0.62	0					
1	17.23	1.84	1												1	13.29	0.57	0					

1	15.95	1.52	1												1	13.30	0.65	0					
1	17.02	1.63	1												1	13.31	0.61	0					
1	13	0.84	1												1	13.31	0.52	0					
1	16.68	1.68	1												1	13.32	0.61	0					
1	15.99	1.36	1												1	13.32	0.72	0					
1	17.18	1.89	1												1	13.33	0.55	0					
1	15.34	1.24	1												1	13.34	0.70	0					
1	18.09	2.1	1												1	13.35	0.52	0					
1	14.37	1	1												1	13.36	0.52	0					
1	17.89	2.23	1												1	13.37	0.68	0					
1	15.77	1.23	1												1	13.38	0.53	0					
1	18.72	2.33	1												1	13.39	0.57	0					
1	15.76	1.57	1												1	13.39	0.62	0					
1	14.69	1.2	1												1	13.40	0.67	0					
1	17.67	1.82	1												1	13.41	0.63	0					
1	14.55	1.08	1												1	13.41	0.63	0					
1	14.5	1.11	1												1	13.42	0.62	0					
1	19.14	2.41	1												1	13.44	0.59	0					
1	16.84	1.81	1												1	13.44	0.62	0					
1	19.45	2.36	1												1	13.45	0.59	0					
1	17.32	1.72	1												1	13.45	0.60	0					
1	16.06	1.39	1												1	13.46	0.74	0					
1	16.1	1.53	1												1	13.46	0.68	0					
1	15.49	1.16	1												1	13.46	0.59	0					
1	17.87	1.72	1												1	13.47	0.60	0					
1	15.76	1.31	1												1	13.48	0.70	0					
1	15.54	1.21	1												1	13.48	0.77	0					
1	15.68	1.43	1												1	13.49	0.70	0					
1	17.34	1.8	1												1	13.50	0.61	0					
1	16.44	1.52	1												1	13.50	0.73	0					
1	15.86	1.45	1												1	13.51	0.68	0					
1	17.88	1.79	1												1	13.54	0.61	0					
1	15.4	1.38	1												1	13.55	0.83	0					
1	15.36	1.27	1												1	13.56	0.72	0					
1	16.6	1.27	1												1	13.57	0.63	0					
1	14.41	1.22	1												1	13.57	0.66	0					
1	17.99	2.18	1												1	13.57	0.59	0					
1	15.14	1.11	1												1	13.60	0.58	0					
1	14.72	1.2	1												1	13.61	0.68	0					
1	16.03	1.46	1												1	13.61	0.65	0					
1	16.81	1.62	1												1	13.62	0.77	0					
1	15.81	1.4	1												1	13.64	0.75	0					
1	13.35	0.72	1												1	13.70	0.54	0					
1	15.74	1.35	1												1	13.71	0.66	0					
1	15.54	1.54	1												1	13.71	0.70	0					
1	15.25	1.35	1												1	13.71	0.59	0					
1	16.27	1.32	1												1	13.71	0.60	0					

1	16.91	1.92	1												1	13.72	0.68	0					
1	15.4	1.36	1												1	13.74	0.72	0					
1	16.38	1.67	1												1	13.74	0.64	0					
1	13.88	0.9	1												1	13.75	0.68	0					
1	15.17	1.27	1												1	13.76	0.59	0					
1	14.36	1	1												1	13.76	0.72	0					
1	15.3	1.12	1												1	13.77	0.75	0					
1	13.81	1.01	1												1	13.77	0.71	0					
1	15.87	1.39	1												1	13.78	0.67	0					
1	14.33	1.06	1												1	13.79	0.68	0					
1	14.94	1.11	1												1	13.84	0.60	0					
1	13.14	0.84	1												1	13.86	0.66	0					
1	15.17	1.3	1												1	13.89	0.72	0					
1	13.81	0.92	1												1	13.91	0.70	0					
1	12.87	0.64	1												1	13.93	0.66	0					
1	11.45	0.49	1												1	13.94	0.75	0					
1	17.29	1.73	1												1	13.95	0.68	0					
1	16.68	1.61	1												1	13.95	0.70	0					
1	17.77	1.81	1												1	13.95	0.76	0					
1	17.59	1.78	1												1	13.96	0.69	0					
1	18.25	2.3	1												1	13.97	0.63	0					
1	15.63	1.48	1												1	13.97	0.86	0					
1	19.36	2.66	1												1	14.04	0.82	0					
2	20.53	3.4	1												1	14.06	0.70	0					
2	16.43	1.33	1												1	14.10	0.75	0					
2	16.64	1.66	1												1	14.12	0.70	0					
2	17.88	1.68	1												1	14.13	0.71	0					
2	18.75	2.44	1												1	14.14	0.76	0					
2	16.58	1.59	1												1	14.14	0.73	0					
2	18.94	2.36	1												1	14.18	0.75	0					
2	17.97	2.15	1												1	14.19	0.92	0					
2	17.79	1.97	1												1	14.19	0.81	0					
2	18.52	2.32	1												1	14.21	0.67	0					
2	17.82	1.88	1												1	14.22	0.84	0					
2	19.44	2.63	1												1	14.22	0.77	0					
2	19.13	2.35	1												1	14.23	0.60	0					
2	18.35	2.18	1												1	14.23	0.78	0					
2	17.53	1.95	1												1	14.25	0.81	0					
2	16.82	1.4	1												1	14.27	0.86	0					
2	18.31	1.92	1												1	14.28	0.74	0					
2	20.56	2.53	1												1	14.30	0.75	0					
2	18.09	2.05	1												1	14.30	0.76	0					
2	18.26	2.02	1												1	14.33	0.78	0					
2	17.2	1.56	1												1	14.35	0.73	0					
2	18.1	2.12	1												1	14.41	0.90	0					
2	17.78	1.93	1												1	14.42	0.84	0					
2	17.06	1.69	1												1	14.43	0.72	0					

2	18.43	2.23	1												1	14.47	0.73	0					
2	17.99	1.99	1												1	14.53	0.69	0					
2	17.88	2.34	1												1	14.54	0.64	0					
2	17.37	1.84	1												1	14.56	0.71	0					
2	17.69	1.93	1												1	14.57	0.77	0					
2	18.62	2	1												1	14.71	0.85	0					
2	17.84	1.73	1												1	14.73	0.83	0					
2	20.42	2.72	1												1	14.73	0.83	0					
2	15.74	1.4	1												1	14.90	0.81	0					
2	18.79	2.33	1												1	14.91	0.76	0					
2	16.81	1.93	1												1	14.94	0.95	0					
2	18.33	2.21	1												1	14.66	0.93	1					
2	18.35	2.33	1												1	14.70	0.84	1					
2	14.88	1.23	1												1	14.72	0.82	1					
2	18.33	2.29	1												1	14.73	0.87	1					
2	16.1	1.5	1												1	14.73	0.80	1					
2	17.45	1.83	1												1	14.73	0.96	1					
2	18	1.75	1												1	14.74	0.95	1					
2	16.92	1.66	1												1	15.77	0.84	1					
2	18.27	2.19	1												1	15.80	1.11	1					
2	17	1.73	1												1	15.84	1.11	1					
2	16.24	1.41	1												1	15.97	1.01	1					
2	18.22	1.81	1												1	16.06	1.11	1					
2	16.04	1.43	1												1	16.10	1.00	1					
2	18.61	2.18	1												1	16.24	1.15	1					
2	19.88	2.84	1												1	16.27	1.10	1					
2	19.1	2.54	1												1	16.38	1.07	1					
2	16.81	1.51	1												1	16.43	1.25	1					
2	18.73	1.62	1												1	20.52	2.73	1					
2	17.48	2.04	1												1	21.22	3.24	1					
2	17.13	1.81	1												1	21.66	3.56	1					
2	17.06	1.86	1												1	21.79	3.81	1					
2	16.9	1.82	1												1	21.89	3.5	1					
2	15.06	1.25	1												1	22.58	3.95	1					
2	16.95	1.67	1												1	24.73	6.1	2					
2	20.45	2.82	1												1	25.99	7.98	2					
2	17.05	2.04	1												1	26.24	6.49	2					
2	17.06	1.96	1												1	26.38	7.86	2					
2	16.16	1.39	1												1	26.86	7.53	2					
2	18.5	2.12	1												1	27.29	8.11	2					
2	17.15	2.03	1												2	5.48	0.06	0					
2	18.17	2.14	1												2	5.92	0.08	0					
2	17.22	1.9	1												2	6.17	0.08	0					
2	16.23	1.41	1												2	6.28	0.09	0					
2	15.09	1.01	1												2	6.32	0.12	0					
2	17.32	1.76	1												2	6.32	0.07	0					
2	15.99	1.44	1												2	6.4	0.09	0					

2	15.02	1.08	1												2	6.45	0.1	0					
2	16.03	1.35	1												2	6.47	0.09	0					
2	14.47	1.09	1												2	6.48	0.09	0					
2	20.07	2.64	1												2	6.5	0.08	0					
2	20.89	3.11	1												2	6.51	0.08	0					
2	16.31	1.67	1												2	6.55	0.09	0					
2	16.63	1.68	1												2	6.61	0.11	0					
2	17.59	2.1	1												2	6.61	0.09	0					
2	17.31	1.56	1												2	6.63	0.08	0					
2	17.61	1.94	1												2	6.64	0.09	0					
2	16.65	1.54	1												2	6.64	0.08	0					
2	18.85	2.21	1												2	6.65	0.1	0					
2	16.12	1.21	1												2	6.66	0.08	0					
2	15.4	1.37	1												2	6.7	0.08	0					
2	16.22	1.72	1												2	6.74	0.09	0					
2	18.02	2.1	1												2	6.79	0.06	0					
2	15.03	1.21	1												2	6.80	0.10	0					
2	16.46	1.55	1												2	6.8	0.08	0					
2	14.95	1.34	1												2	6.81	0.09	0					
2	16.58	1.54	1												2	6.85	0.09	0					
2	15.48	1.26	1												2	6.86	0.10	0					
2	14.72	1.12	1												2	6.88	0.09	0					
2	14.61	0.95	1												2	6.88	0.1	0					
2	15.74	1.61	1												2	6.90	0.14	0					
2	15.66	1.16	1												2	6.92	0.1	0					
2	18.16	2.13	1												2	6.92	0.11	0					
2	18.52	2.24	1												2	6.94	0.1	0					
2	18.17	2.07	1												2	6.94	0.1	0					
2	18.17	1.88	1												2	6.94	0.09	0					
2	16.47	1.53	1												2	7.02	0.11	0					
2	17.42	1.81	1												2	7.02	0.1	0					
2	16.71	1.59	1												2	7.04	0.09	0					
2	18.19	2.12	1												2	7.04	0.1	0					
2	16.43	1.62	1												2	7.05	0.1	0					
2	16.15	1.53	1												2	7.07	0.1	0					
2	17.19	1.72	1												2	7.07	0.1	0					
2	15.9	1.39	1												2	7.09	0.1	0					
2	17.69	1.94	1												2	7.16	0.11	0					
2	12.92	0.72	1												2	7.16	0.11	0					
2	16.37	1.62	1												2	7.17	0.12	0					
2	15.25	1.15	1												2	7.23	0.12	0					
2	15.46	1.41	1												2	7.27	0.12	0					
2	15.98	1.35	1												2	7.3	0.13	0					
2	14.47	1.06	1												2	7.32	0.1	0					
2	18.06	1.97	1												2	7.32	0.11	0					
2	17.33	1.92	1												2	7.41	0.1	0					
2	15.88	1.31	1												2	7.44	0.12	0					

2	16.01	1.69	1												2	7.48	0.14	0					
2	18.45	2.04	1												2	7.51	0.12	0					
2	17.5	1.83	1												2	7.57	0.14	0					
2	16.91	1.52	1												2	7.63	0.14	0					
2	17.36	1.74	1												2	7.64	0.10	0					
2	18.81	2.27	1												2	7.66	0.14	0					
2	16.08	1.47	1												2	7.66	0.13	0					
2	15.7	1.43	1												2	7.68	0.17	0					
2	14.39	0.98	1												2	7.68	0.13	0					
2	17.49	1.81	1												2	7.68	0.13	0					
2	17.33	1.89	1												2	7.71	0.13	0					
2	16.69	1.57	1												2	7.71	0.13	0					
2	16.28	1.38	1												2	7.72	0.16	0					
2	17.18	1.68	1												2	7.72	0.16	0					
2	15.84	1.4	1												2	7.73	0.17	0					
2	16.41	1.27	1												2	7.74	0.14	0					
2	14.9	1.22	1												2	7.78	0.17	0					
2	15.42	1.25	1												2	7.78	0.15	0					
2	15.87	1.33	1												2	7.80	0.16	0					
2	17.65	1.78	1												2	7.81	0.14	0					
2	12.54	0.89	1												2	7.82	0.16	0					
2	16.4	1.57	1												2	7.86	0.12	0					
2	15.5	1.24	1												2	7.90	0.16	0					
2	16.13	1.39	1												2	7.91	0.16	0					
2	18.27	1.98	1												2	7.91	0.16	0					
2	18.13	1.87	1												2	7.94	0.14	0					
2	15.4	1.19	1												2	7.95	0.20	0					
2	16.77	1.83	1												2	7.96	0.11	0					
2	18.71	2.18	1												2	7.96	0.17	0					
2	17.42	1.67	1												2	8.01	0.14	0					
2	17.22	1.7	1												2	8.04	0.19	0					
2	15.17	1.08	1												2	8.09	0.17	0					
2	17.89	2.14	1												2	8.13	0.17	0					
2	18.33	1.88	1												2	8.15	0.19	0					
2	19.73	2.41	1												2	8.18	0.16	0					
2	13.87	0.72	1												2	8.22	0.18	0					
2	18.74	2.17	1												2	8.24	0.15	0					
2	15.8	1.5	1												2	8.26	0.18	0					
2	18.11	1.97	1												2	8.26	0.16	0					
2	15.52	1.19	1												2	8.27	0.18	0					
2	17.22	1.96	1												2	8.30	0.15	0					
2	16.1	1.59	1												2	8.30	0.17	0					
2	15.5	1.22	1												2	8.31	0.19	0					
2	16.41	1.44	1												2	8.32	0.19	0					
2	15.92	1.19	1												2	8.33	0.17	0					
2	16.07	1.22	1												2	8.34	0.16	0					
2	16.29	1.55	1												2	8.35	0.75	0					

2	16.28	1.36	1												2	8.36	0.20	0					
2	17.09	1.96	1												2	8.38	0.23	0					
2	16.99	1.68	1												2	8.38	0.16	0					
2	17.63	1.87	1												2	8.39	0.17	0					
2	15.28	1.16	1												2	8.40	0.17	0					
2	15.3	1.31	1												2	8.43	0.21	0					
2	15.41	1.3	1												2	8.46	0.23	0					
2	17.35	1.74	1												2	8.51	0.16	0					
2	14.85	1.21	1												2	8.53	0.21	0					
2	14.2	0.93	1												2	8.54	0.17	0					
2	15.75	1.51	1												2	8.55	0.24	0					
2	16.96	1.69	1												2	8.58	0.19	0					
2	14.57	1.18	1												2	8.59	0.20	0					
2	17.44	1.68	1												2	8.60	0.21	0					
2	15.78	1.45	1												2	8.63	0.18	0					
2	13.74	0.94	1												2	8.63	0.18	0					
2	16.21	1.66	1												2	8.73	0.24	0					
2	17.07	1.47	1												2	8.73	0.20	0					
2	17.56	1.92	1												2	8.74	0.23	0					
2	17.4	1.78	1												2	8.79	0.20	0					
2	17.37	1.83	1												2	8.83	0.23	0					
2	17.54	1.68	1												2	8.93	0.17	0					
2	15	1.24	1												2	8.96	0.24	0					
2	12.92	0.68	1												2	8.98	0.26	0					
2	11.48	0.43	1												2	8.98	0.25	0					
2	14.17	0.89	1												2	8.99	0.22	0					
2	15.77	1.45	1												2	9.02	0.19	0					
2	17.98	2.08	1												2	9.03	0.15	0					
2	16.82	1.74	1												2	9.08	0.31	0					
2	15.21	1.26	1												2	9.17	0.18	0					
2	15.83	1.41	1												2	9.20	0.21	0					
2	15.18	1.39	1												2	9.32	0.14	0					
2	15.87	1.45	1												2	9.97	0.31	0					
2	15.17	1.19	1												2	9.97	0.18	0					
2	12.87	0.78	1												2	9.99	0.29	0					
2	15.14	1.29	1												2	10.00	0.28	0					
2	16.28	1.51	1												2	10.00	0.31	0					
2	15.99	1.52	1												2	10.04	0.41	0					
2	14.81	1.34	1												2	10.06	0.36	0					
2	14.74	0.83	1												2	10.09	0.34	0					
2	20.41	3.06	1												2	10.16	0.26	0					
2	14.54	1.13	1												2	10.17	0.36	0					
2	14.77	1.16	1												2	10.19	0.35	0					
2	15.02	1.32	1												2	10.25	0.32	0					
2	15.85	1.3	1												2	10.36	0.35	0					
2	18.37	2.03	1												2	10.40	0.30	0					
2	14.6	1.16	1												2	10.48	0.30	0					

2	14.41	1.01	1												2	10.54	0.34	0					
2	14.64	1.11	1												2	10.56	0.49	0					
2	13.58	0.84	1												2	10.56	0.43	0					
2	15.08	1.24	1												2	10.64	0.36	0					
2	14.65	0.96	1												2	10.69	0.36	0					
2	15.5	1.27	1												2	10.69	0.38	0					
2	13.2	0.75	1												2	10.69	0.35	0					
2	13.8	0.86	1												2	10.72	0.36	0					
2	15.8	1.25	1												2	10.77	0.32	0					
2	14.51	0.9	1												2	10.90	0.37	0					
2	13.65	0.98	1												2	10.94	0.34	0					
2	13.66	0.99	1												2	11.02	0.37	0					
2	16	1.31	1												2	11.06	0.44	0					
2	14.33	1	1												2	11.11	0.41	0					
2	18.63	2.21	1												2	11.15	0.28	0					
2	12.48	0.75	1												2	11.34	0.36	0					
2	17.89	1.82	1												2	11.40	0.40	0					
2	16.77	1.7	1												2	11.48	0.52	0					
2	13.66	0.86	1												2	11.64	0.59	0					
2	15.81	1.46	1												2	11.65	0.51	0					
2	14.36	0.96	1												2	11.68	0.45	0					
2	14.07	0.96	1												2	11.79	0.52	0					
2	12.51	0.46	1												2	11.91	0.52	0					
2	13.67	0.79	1												2	12.01	0.74	0					
2	18.29	2.01	1												2	12.06	0.47	0					
2	17.32	1.55	1												2	12.33	0.49	0					
2	13.29	0.8	1												2	12.49	0.57	0					
2	19.17	2.36	1												2	13.46	0.66	0					
2	17.65	2.17	1												2	13.86	0.86	0					
															2	13.88	0.93	0					
															2	13.96	0.97	1					
															2	14.41	0.99	1					
															2	14.54	1.13	0					
															2	14.84	1.20	1					
															2	15.01	1.13	1					
															2	15.19	1.30	1					
															2	15.46	1.18	1					
															2	15.46	1.24	1					
															2	15.46	1.07	1					
															2	15.53	1.57	1					
															2	15.76	1.27	1					
															2	16.09	1.64	1					
															2	16.30	1.34	1					
															2	16.30	1.49	1					
															2	16.31	1.37	1					
															2	16.32	1.36	1					
															2	16.37	1.48	1					

															2	16.49	1.54	1					
															2	16.50	1.58	1					
															2	16.59	1.72	1					
															2	16.62	1.55	1					
															2	16.65	1.54	1					
															2	16.67	1.57	1					
															2	16.97	1.53	1					
															2	16.98	1.74	1					
															2	17.10	1.56	1					
															2	17.17	1.70	1					
															2	17.57	1.64	1					
															2	17.61	1.82	1					
															2	17.73	1.90	1					
															2	18.00	2.11	1					
															2	18.05	1.94	1					
															2	18.13	2.12	1					
															2	18.13	2.11	1					
															2	18.17	1.81	1					
															2	18.18	1.92	1					
															2	18.28	1.90	1					
															2	18.33	1.84	1					
															2	18.86	2.10	1					
															2	18.91	2.24	1					
															2	19.05	2.29	1					
															2	19.06	2.34	1					
															2	19.23	2.42	1					
															2	19.33	2.49	1					
															2	19.37	2.21	1					
															2	19.40	2.14	1					
															2	19.59	2.36	1					
															2	20.00	2.49	1					
															2	20.12	2.53	1					
															2	20.40	3.13	1					
															2	20.76	3.06	1					
															2	20.92	2.82	1					
															2	21.20	2.89	1					
															2	21.49	3.68	1					
															2	21.91	3.62	1					
															2	22.12	3.88	1					
															2	22.50	3.42	1					
															2	23.38	3.63	1					
															2	23.64	4.29	1					
															2	24.14	4.29	1					
															2	24.28	4.78	2					
															2	24.92	6.02	2					
															2	25.25	5.21	1					
															2	25.3	7.65	2					

															2	26.19	7.36	2					
															2	26.99	7.36	2					