Eastern IFCA
Inshore Fisheries and Conservation Authority

RESEARCH REPORT
2014

MUSSEL REGENERATION PROJECT

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CONTENTS

Introduction

The inter-tidal mussel stocks in The Wash have traditionally provided a valuable resource for the local fishing industry; either being harvested directly for market or relayed from poor-growing beds within the regulated fishery to leased lay ground within the several fishery. These stocks also provide an important habitat for invertebrate communities and an essential food resource for the internationally important communities of birds that reside or over-winter in the Wash. Due to their importance, management measures have been developed over the years both to protect the sustainability of the fishery and to achieve Conservation Objective targets for the site. For the mussel stocks these Conservation Objective targets include maintaining a total mussel stock biomass above 13,000 tonnes and an adult mussel stock biomass above 7,000 tonnes.

Since these Conservation Objective targets were introduced, management decisions for the mussel fisheries have focused heavily on achieving these target thresholds rather than developing the fishery. Barring the occasional die-off, these policies have helped to stabilise the overall mussel biomass, but by continually harvesting the stocks down to their minimum thresholds, the beds have not had an opportunity to develop beyond these levels. This has produced a situation in which several of the beds appear to be in terminal decline, while the fishery has become ever more dependent on those few beds that are still in a healthy condition.

Healthy mussel beds with a good coverage and high mussel density create a raised matrix of live mussels and dead shell bound together with byssus threads. This is an important habitat for attracting fresh settlements of seed which find shelter from weather and protection from predators among the crevices. Over the years the combination of fishery and natural mortalities on some of the beds has exceeded recruitment, resulting in declining stocks. On those beds where this situation has been sustained for several years, the decline has resulted in mussel densities declining below the critical thresholds required to create raised matrices. With their potential to attract seed thus reduced further, these beds can no longer attract sufficient recruitment to reverse their decline. This in turn places more pressure on the remaining healthy beds to deliver the fishery’s needs, endangering their sustainability too.

While fishery closures will help those beds that still have sufficient densities to recover, they will not help those beds that have already fallen below those thresholds. To halt their decline and facilitate their recovery, additional measures will be needed. Relaying partially grown mussel seed from elsewhere is the most effective way of facilitating an immediate recovery on a mussel bed. The cost of seed is prohibitive for large-scale rejuvenation projects, however, and could not be sustained long-term as a viable management option. Instead a cheaper alternative solution for attracting seed is required that can be used as a management tool for facilitating recovery on beds where and when required.

A culch of shell has long been recognised as an important substrate for growing bivalve molluscs. Observations made during the annual inter-tidal mussel surveys have highlighted that mussel shells alone appear to be a poor medium for recruitment. Dense patches of mussel shell often remain in the ground following fisheries or natural mortality, but these areas frequently take many years to recover. Seed has often been observed to have settled in gullies containing either ridged out cockles or cockle shells, however. The reason for this difference may be in the disposition for mussel shells to lay flat on the ground and become buried, while cockle shells being more rounded, tend to remain raised, providing a matrix for attachment. As there is an abundance of relatively cheap cockle shells that are a by-product of the cockle fishery, a study was proposed to test their suitability as culch for attracting seed.

The timing of this type of study is important because the cockle shells need to be in place before the settlement occurs. Following spawning the mussel larvae drift and disperse in the water column as swimming zooplankton. Once they reach about 0.25mm in length metamorphosis occurs and the larvae begin to settle. With mussels, this occurs in two stages. Primary settlement occurs sub-tidally, during which the larvae attach briefly to filamentous materials such as certain algae, hydroid colonies and fibrous rope. They remain attached to these materials until they have grown to about 0.5 - 1.5mm in length, after which they detach and become planktonic again. Secondary settlement can occur inter-tidally or sub-tidally, with the larvae usually settling on hard or creviced surfaces. It is during the secondary settlement phase that recruitment to inter-tidal mussel beds occurs, and which this project will be aiming to attract. Primary spat are usually abundant in the water between May-July, following the spring spawning. Shells deposited during this period should be ready to attract the subsequent secondary settlement.

Method

The trial was initially proposed to take place within the Gat mussel bed. Since the mid-1990s the Gat had supported the largest extent of wild mussels in the Wash, but heavy mortalities between 2011 and 2014 had caused the stocks to decline, leaving large bare patches within the bed. Although it made sense to assist the recovery of this bed, the cause of the mortalities had not been determined and there was concern over the lack of recent mussel recruitment on the Gat. Because this trial was to determine whether a culch of cockle shells could be used to attract mussel seed, it was important to conduct the experiment in an area conducive for settlement. For this, a bed was preferred that had attracted regular recent settlements. The Trial Bank mussel bed on the Inner Westmark Knock sand was believed suitable for this purpose because not only had it attracted regular spatfalls in recent years, it also contained a large bare area that had resulted from heavy fishing in 2012. Although spat had settled within existing patches of mussels in this bed during 2013, there had been negligible settlement within these bare patches.

Six experimental 20m x 20m plots were marked out with wooden stakes on April 1st 2014. These plots were situated within an area of the mussel bed that had formally supported mussels but which had not recovered following fishing. The sites were chosen in areas that supported no mussels, had similar sandy silt sediments to each other and had sufficient space between them so that there would be no interaction between treatment areas and control sites. Three of these plots were to be used for depositing the cockle shell culch and the other three were left bare as control sites. Buoys were attached to the stakes at each corner of the three plots that were assigned to have the shells deposited in them to act a visual reference for the vessels laying the shells. Table 1 shows the coordinates of the central position of each plot while figure 1 shows the position of the plots within the Trial Bank mussel bed.

Table 1 – Position of each of the experimental plots

Site	Treatment	Latitude	Longitude
1	Shell	52 50'.394N	00 14'.892E
2	Shell	52 50'.366N	00 14'.966E
3	Shell	52 50'.341N	00 14'.906E
4	Control	52 50'.329N	00 14'.960E
5	Control	52 50'.404N	00 14'.982E
6	Control	52 50'.368N	00 14'.900E

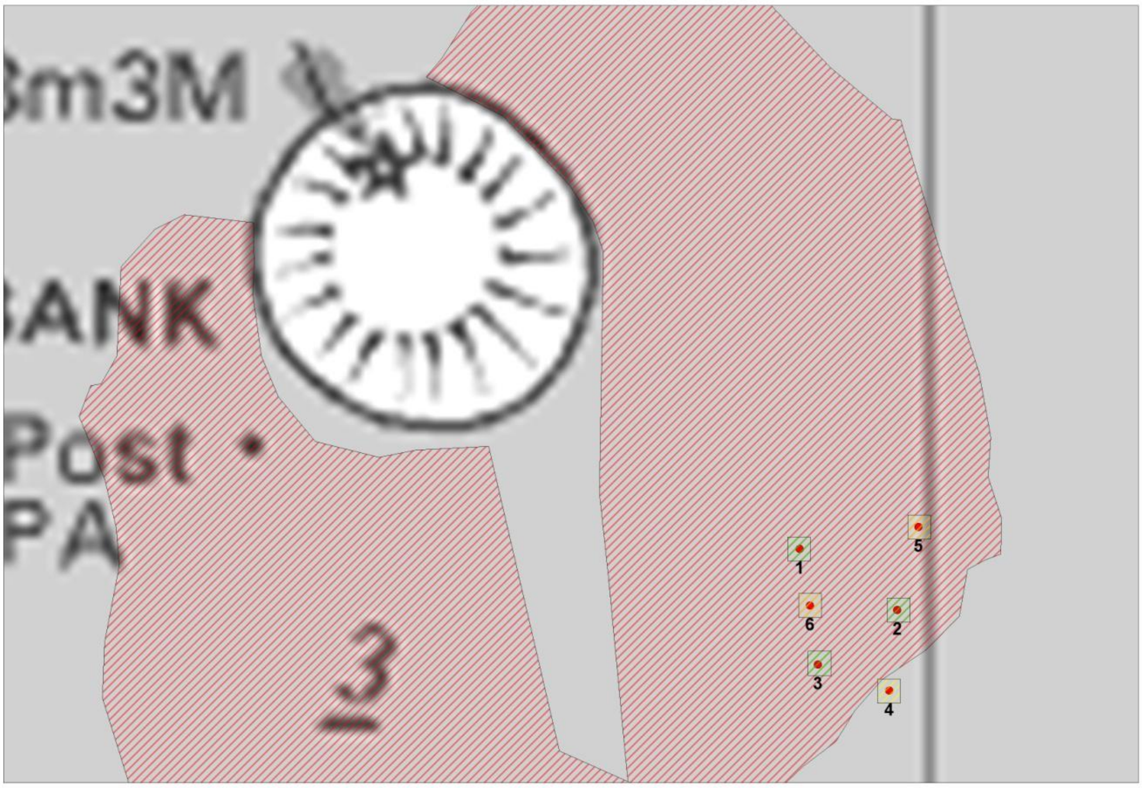


Figure 1 – Position of the six experimental plots within the Trial Bank mussel bed

The intention was to cover the three treatment plots with cockle shell to a depth of 15cm. This was thought to be sufficient to create a raised matrix that would be suitable for attracting seed and also to prevent burial as sediment accreted onto the site during the course of the study. This would require 180m^3 of shells, equating to approximately 90 bulk bags or 72 tonnes. The three control sites were left bare.

The shells were purchased from DANI Foods, a shellfish processor based in Boston, while two Boston based fishing vessels successfully tendered for the role of transporting the shells to the mussel bed and depositing them within the experimental plots. Because depositing shells technically falls under the definition of "disposal at sea", such activities usually require an MMO disposal licence. Because of the small scale of this activity, an exemption was granted from the MMO prior to the activity occurring.

Laying of the shells was conducted on May 30th, 31st and June 1st, with each vessel carrying 15 tonnes of shell on each of the trips. These were carried loose in the holds of the vessels, having been filled from 1-tonne bags on the quay. Once on station the shells were washed out of the holds through pipes usually used for relaying mussels (see figures 2 and 3). On each of the low water periods following deposition, the shells were spread evenly within the plots. Where shells had drifted out of the plots, they were raked or shovelled into baskets and carried into the plots (see figures 4-6). At plot 2, where insufficient compensation had been given for the tide on the first day, it was necessary to move the plot slightly, rather than attempt to move large quantities of shell. On the third day the stakes marking this plot were moved approximately 10m northwards and their new coordinates noted.

Figure 2 – Cockle shells being washed from vessel's hold

Figure 3 – Vessel laying cockle shells within experimental plot

Figure 4 – Spreading shells in Plot 3. May 30th.

Figure 5 - Spreading shells in Plot 1. Plot 2 is visible in top right. June 1st.

Figure 6 – Plot 3 following shell spreading. June 1st.

Site monitoring

The experimental sites were monitored each month between July and October. During these visits photographs were taken of each plot in order to build a time series of images showing any changes that might have occurred between visits. These images are included in Appendix 1.

The presence of any mussel settlement was checked visually within each plot prior to three random samples being collected from each. Samples were collected by throwing an 11cm diameter corer ring into the plot and collecting the sample from where it landed. This size of sampler is quite small, but this size was chosen because past experience of mussel settlements had indicated that mussel numbers can be high when settlements occur. With hindsight, using a standard $0.1m^2$ quadrat would have been more appropriate because the settlement during the monitoring period turned out to be only light.

All of the samples were sieved in situ using a 0.5mm sieve to remove the sediment from the samples. The samples were then placed in labelled bags for analysis ashore. Analysis involved measuring the length and weight of all mussels found, the age, width and weight of all cockles and the number and combined weight of Macoma in each sample.

Results

Durability of the shelly substrate

The experimental plots were visited four times during 2014 after the shells had been deposited. These sampling occasions were on July 16th, August 8th, September 9th and October 24th. The photographic evidence in appendix 1 shows that during this period the height of the raised mounds of shell gradually declined until they were flush with the ground. No evidence was found that the shells were washing out of the plots and the clear edges of the shells within the plot boundaries in the later photographs suggests they hadn't. Instead, the shells seemed to have sunk into the sediment and become buried. That they were flush with the ground indicated they had sunk rather than acting as sediment traps and accumulating sufficient sediment to bury themselves.

Mussels

Visual observations made at the time of sampling found that both the bare control sites and the experimental shell plots had failed to attract high quantities of mussel spat during the course of the study. The plots containing shell were found to have accumulated low densities of mussels, however, whereas the control sites did not. Table 2 shows the numbers of mussels collected in the samples taken from each plot during the course of the study.

Table 2 – The number of mussels found in the samples collected from each plot

	Control plots				Experimental shell plots			
Date	**4**	**5**	**6**	**Total**	**1**	**2**	**3**	**Total**
July 16	1	0	0	1	0	0	1	1
August 8	0	0	0	0	0	0	0	0
September 9	0	0	0	0	3	1	1	5
October 24	0	0	0	0	6	0	3	9
Total	**1**	**0**	**0**	**1**	**9**	**1**	**5**	**15**

From table 2 it can be seen that during the course of the study period more mussels were found in the samples collected from the experimental shell areas (15 mussels) than from the bare control sites (1 mussel). Figure 7 shows the total numbers of mussels collected from these areas each month. Statistical analysis using Anova-single factor tests on individual plots, found that when looking at the whole study period from July to October this difference was significant at a 95% confidence level ($p=0.04$). As more mussels began to accumulate on the shells towards the latter half of the experiment, the difference become more significant ($p=0.02$ for the period September/October).

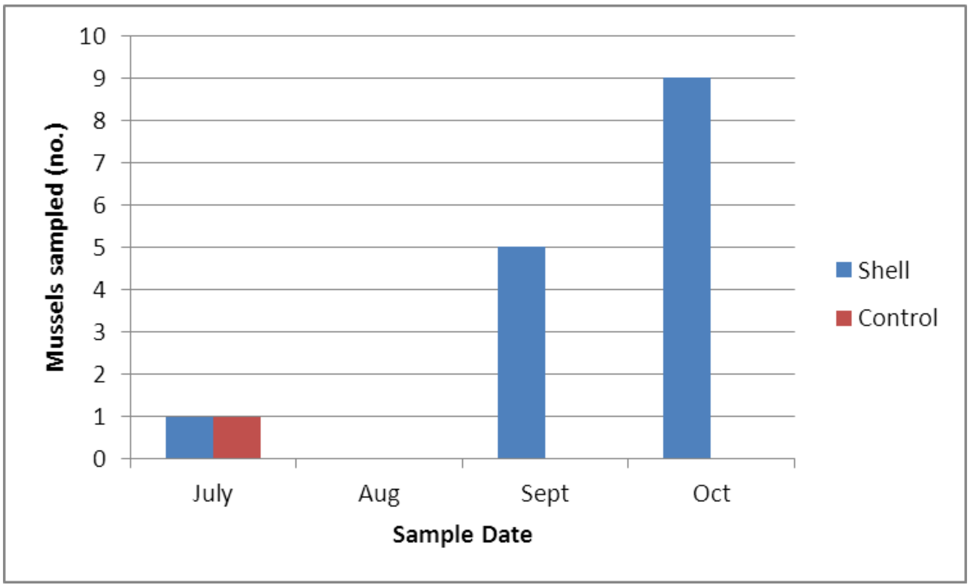


Figure 7 – The number of mussels collected from the experimental shell plots and from the bare control plots during the study period.

Figure 8 shows the size frequency of the mussels found in the samples collected during the study period. These ranged in size from 7mm length to 45mm. These data support visual observations made at the time of the sampling, that the mussels accumulating in the experimental plots were not all recent settlements of seed but included older mussels, too. Within the study period, from when the shells were deposited at the end of May until the final sampling in October, it is unlikely new seed would have grown to a size exceeding 20mm length. At least half of the mussels found in the samples, therefore, must have migrated into the plots after the shells had been deposited, rather than settling in them as seed. Observations made during sampling found the highest density of mussels were occurring along the northern edges of the three plots treated with shell. It is believed these mussels had originated from elsewhere within the mussel bed and had attached to the shells while being washed over them. No correlation was found between the size of the mussels found and the date of sampling.

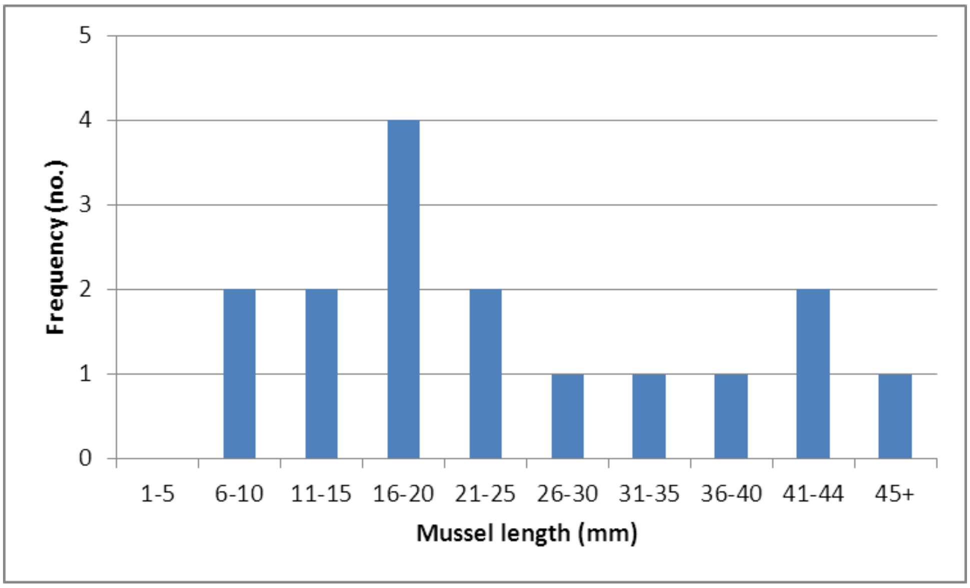


Figure 8 – Size frequency of mussels found in the samples

36.01g of mussels were found in the samples collected on the final occasion in October. Scaled up, this represented an estimated mussel biomass over the three shelly plots of 560kg.

Cockles

In addition to supporting mussels, the experimental area has also traditionally supported cockle stocks. Visual observations made throughout the experimental period found cockles to be present in both the control plots and those that had shells deposited in them. Table 3 shows the number of Year-1 and older cockles that were found in the samples taken from each plot during the sampling period. Analysis of these data was conducted to determine whether depositing the shells had had an impact on the cockles that occupied those plots.

Table 3 – The number of Yr-1 and older cockles found in the samples collected from each plot

	Control plots				Experimental shell plots			
Date	**4**	**5**	**6**	**Total**	**1**	**2**	**3**	**Total**
July 16	13	11	30	54	19	9	38	66
August 8	21	22	25	68	9	13	26	48
September 9	15	21	24	60	26	4	8	38
October 24	8	20	9	37	13	1	4	18
Total	**57**	**74**	**88**	**219**	**67**	**27**	**76**	**170**

More cockles were found in samples taken from the control plots (219 cockles) than from the shelly plots (170 cockles), but overall, this difference was not found to be statistically significant at a 95% confidence limit (p=0.39).

The total number of cockles collected between July and October from each plot varied from 27 cockles in the experimental shell plot 2 and 88 in the control plot 6. At a 95% level of confidence, significant differences were found in the number of cockles taken from experimental shell plot 2 and both the control plots 5 (p=0.02) and control plot 8 (p=0.03). No other significant differences were found between the other plots.

During the October sampling, the numbers of cockles found in the samples collected from both the control and experimental sites were lower than they had been in the preceding months but this was not significant at a 95% level of confidence (p=0.34 in control sites, p=0.39 in experimental shell plots).

A settlement of juvenile cockles occurred in the area after the shells had been deposited. Analysis was conducted to determine whether depositing the shells had impacted on settlement/survival of these juveniles. Table 4 shows the number of year-0 cockles found in the samples taken from each of the plots during the study period.

Table 4 – The number of Yr-0 juvenile cockles found in the samples collected from each plot

	Control plots				Experimental shell plots			
Date	**4**	**5**	**6**	**Total**	**1**	**2**	**3**	**Total**
July 16	3	2	5	10	0	2	1	3
August 8	10	7	6	23	4	0	0	4
September 9	14	14	10	38	0	3	1	4
October 24	6	9	12	27	1	2	4	7
Total	**33**	**32**	**33**	**98**	**5**	**7**	**6**	**18**

During the study period 98 Year-0 cockles were found in samples taken from the control plots compared to 18 from the experimental plots containing shell. This is a significant difference (p= 1.98E-05).

<u>Macoma balthica</u>

All of the sites were found to support the bivalve mollusc, *Macoma balthica*. Table 5 shows the number of these found in the samples taken from each site during the study period.

Table 5 – The number of Macoma balthica found in the samples collected from each plot

	Control plots				Experimental shell plots			
Date	**4**	**5**	**6**	**Total**	**1**	**2**	**3**	**Total**
July 16	12	2	3	17	1	5	9	15
August 8	10	4	1	15	1	5	5	11
September 9	9	3	3	15	2	1	2	5
October 24	1	3	0	4	2	1	1	4
Total	**32**	**12**	**7**	**51**	**6**	**12**	**17**	**35**

Although fewer Macoma were found in the samples taken from the experimental shelly areas (35) than from the control areas (51), this difference was not found to be significantly different at a 95% level of confidence (p=0.33).

Although there were no significant differences between the number of Macoma found in the control sites and the experimental shell sites, there were large variations between the individual sites that were significant (p=0.04). This indicated there was greater variation in the spatial distribution of macoma between sites than any impact depositing the shells may have had.

<u>Other observations</u>

Other species than those described above were also observed to be present in the six plots. Because their numbers tended to be lower than could be accurately measured during sampling, or because they were too mobile to be captured in the samples, their numbers were not estimated during this study. Observations made during sampling found that juvenile shore crabs (*Carcinus maenas*), common periwinkle (*Littorina littorea*) and gastropods of the *Hydrobia* genus were present in both the control and experimental plots. The frequency of the crabs appeared to be much higher in the experimental shelly areas throughout the monitoring period. As the shells began to sink, shallow pools developed within the shelly plots. These were found to support populations of brown shrimp (*Crangon crangon*) and gobies (*Pomatoschistus spp*). Because these shallow pools were more frequent within the shelly plots, the abundance of these latter species was found to be greater in the shelly areas than within the control plots.

Discussion

The objective of the trial was primarily to determine whether a culch of cockle shells could successfully be used as a viable means of attracting mussel seed into mussel beds. The experiment tested the suitability of cockle shells as a medium for attracting seed by comparing the levels of mussel that was found within experimental shelly plots compared to untreated control plots. During the study period the shelly plots did aggregate a significantly higher abundance of mussels than the control sites. This was not found to be entirely due to their success at attracting seed, however. At least half of the mussels found to have aggregated within these areas were too old to have settled within the shells as seed. Instead, these were assumed to have migrated into the experimental plots subsequent to the shells being deposited. More than likely, these had become unattached from elsewhere in the mussel bed and then attached to the shells after being washed over them. By the time of the last sampling occasion in October, the three experimental sites containing shell were estimated to support 560kg of mussels. Although this is significantly more than aggregated within the control plots, it represented only a sparse coverage (see figure 9). Considering 72 tonnes of shell were deposited to attract this number of mussels, the viability of this method could be questioned. The inter-tidal mussel surveys conducted in the Wash by the Authority during September and October, however, found that mussel recruitment had been poor on all of the regulated beds during 2014. It is difficult to determine, therefore, how successful the shells would have been at attracting seed had recruitment in the Wash been better. It is proposed that the study is continued during 2015 to provide another opportunity to see if the shells are successful when there is better recruitment.

Figure 9 – Photograph showing the level of coverage of mussels that had aggregated within one of the experimental shelly plots by October.

Cockles are an important commercial and ecological species to the site. Because they frequently co-habit sites with mussels, the impact of depositing shells on them was also monitored. Year-1 and older cockles would already have been present within the sites when the shells were deposited. Because they are an infaunal species, depositing shells to a depth of 15-20 cm could smother them. The results from the study indicate that while there were lower numbers of cockles found within the shelly plots compared to the control sites, this difference was not statistically significant. High numbers of cockles certainly managed to survive being covered by the shells. The same was found of another infaunal bivalve, *Macoma balthica*. The shells did appear to have a negative impact on the settlement of cockle seed, however, evidenced by significantly fewer Year-0 cockles being found within the shelly plots than the control sites. This inhibition of cockle settlement is something that would require serious consideration should the method be used on a widespread scale to rejuvenate mussel beds.

During the monitoring period the shells were found to have sunk into the sediment at a relatively rapid rate. Because the aim is to create a raised matrix for attracting seed, this is an important consideration if large-scale rejuvenations are planned. The timing of their deposition will be important so they are still raised at the time of secondary settlement. It also means their function will only be effective short-term rather than long-term, as shells deposited one year are unlikely to still be effective the following year. The sediment in the area in which the experiment was conducted was relatively soft. On firmer ground it can be supposed that shells probably won't sink as fast, but on such ground they will probably face an increased risk of being washed away.

As the shells sank into the sediment, their original uneven topography allowed shallow pools to develop. These were found to support populations of brown shrimps and gobies that were not present in the control sites. Both of these species are important prey species, in addition to the brown shrimps being an important commercial species. Large numbers of small shore crabs were also observed to be living in the shelly plots. In terms of these three species, the shells appeared to have increased the biodiversity of the site. However, until core samples are analysed to study the impact on a much wider range of species, it cannot be determined precisely what impact the shells have had on the overall biodiversity. It is planned to conduct the analysis of some core samples in conjunction with the 2015 study.

It is recommended that in conjunction with further trials, a number of spat collectors are set at strategic locations around the Wash to gain a greater understanding of where and when mussel spat are settling. It would also be beneficial to gain a better understanding of the dynamics involved in the primary settlement stage.

Appendix 1 – Photographs of study plots during the July-October 2014 monitoring period


Shell Plot 1 – July 16th


Shell Plot 1 – July 16th

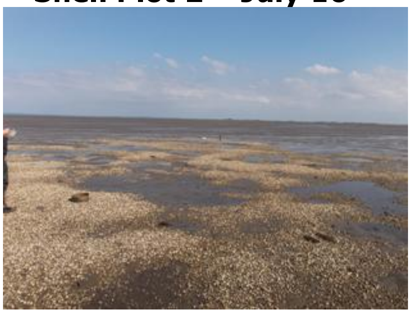

Shell Plot 1 – July 16th


Shell Plot 1 – July 16th


Shell Plot 2 – July 16th


Shell Plot 2 – July 16th

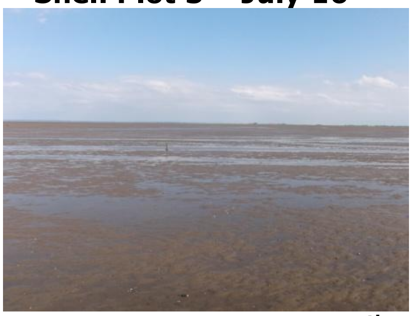

Shell Plot 2 – July 16th


Shell Plot 2 – July 16th


Shell Plot 3 – July 16th


Shell Plot 3 – July 16th


Shell Plot 3 – July 16th


Control Plot 4 – July 16th


Control Plot 4 – July 16th


Control Plot 4 – July 16th


Control Plot 4 – July 16th


Control Plot 5 – July 16th


Control Plot 5 – July 16th


Control Plot 5 – July 16th


Control Plot 6 – July 16th


Control Plot 6 – July 16th


Control Plot 6 – July 16th


Shell Plot 1 – August 8th


Shell Plot 1 – August 8th


Shell Plot 1 – August 8th


Shell Plot 2 – August 8th


Shell Plot 2 – August 8th


Shell Plot 2 – August 8th


Shell Plot 1 – August 8th


Shell Plot 1 – August 8th


Shell Plot 1 – August 8th


Control Plot 4 – Aug 8th


Control Plot 4 – Aug 8th


Control Plot 4 – Aug 8th


Control Plot 5 – Aug 8th


Control Plot 5 – Aug 8th


Control Plot 5 – Aug 8th


Control Plot 6 – Aug 8th


Control Plot 6 – Aug 8th


Shell Plot 1 – Sept 9th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