Eastern IFCA

Inshore Fisheries and Conservation Authority

RESEARCH REPORT 2014

WFO MUSSEL STOCK ASSESSMENT

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WFO MUSSEL SURVEY

CONTENTS

Introduction

The intertidal 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. Because of their importance as both a fishery and conservation resource, these beds are protected by strict management measures and policies. In order to inform the Authority's management decisions, these beds are monitored annually each autumn.

The historic data record is fragmented but shows the abundance of mussels on the regulated beds has been variable during last century, with at least four major fluctuations having occurred. The stocks were at a recorded peak in the early 1920s with a biomass of 30,000 tonnes. Since then there have been further peaks but the magnitude of each one appears to have successively declined. In the 1940s a peak of 25,000 tonnes was recorded, while in 1981 it reached only 18,000 tonnes and 12,000 tonnes in 1988. Between each of these peaks there have been periods of low stock abundance when the biomass of mussels declined to approximately 7,000 tonnes. In the late 1980s the stocks declined even lower following a period of heavy fishing activity that coincided with poor recruitment. Following this decline draconian fishery management measures were introduced but recovery was slow until an exceptional spatfall in 2001 rejuvenated several of the beds and helped new ones to develop. This successful recruitment enabled the stocks to recover to a recent peak of 15,188 tonnes in 2009.

Such widespread settlements as occurred in 2001 are uncommon in the Wash. Annual monitoring of the beds has revealed that the majority of the recruitment in the Wash tends to occur within the existing established beds rather than on ground outside of the beds. This is likely due to the physical matrix of living and dead shells bound by byssus threads found within a healthy mussel bed providing favourable conditions for attracting settlement and affording protection for seed. When spat has occasionally settled outside of existing mussel beds, this has generally been on a culch of cockles and/or cockle shells that could be providing a similar matrix.

Following the recovery of the stocks from their crash in the 1990s, and an increasing awareness of the mussel beds as an important environmental resource, a comprehensive review of the management measures for shellfish in the Wash was conducted. This review resulted in a set of shellfish management policies being agreed in 2008. These policies were designed to ensure that the management of the fisheries in the Wash do not inhibit the Conservation Objectives for the Wash and North Norfolk Coast European Sites being achieved. Following their introduction Natural England were able to upgrade the conservation status of many parts of the Wash Site of Special Scientific Interest (SSSI) from unfavourable declining to unfavourable recovering. Among other measures, these policies recognise the important role that existing beds have in attracting new settlements of seed, limiting exploitation on individual beds to levels those beds can sustain.

Unfortunately, the criteria determining good environmental status are not the same as the industry would use to judge a bed's commercial value, and satisfying the preferred requirements for both groups is difficult. For instance, whereas the industry's preference would be for a mono-culture of similar aged and sized mussels, from a conservation perspective, mixed-aged beds provide far greater biodiversity and long-term stability. Because the management measures are designed to meet SSSI Conservation Objective targets and provide long-term stability by maintaining the integrity of individual beds, most of the beds now support mussel populations of mixed ages and size. As many of the older mussels have become heavily encrusted with barnacles, they are of poor commercial value and of little use to the industry. This has led fishermen to raise concerns about the state of the intertidal beds and forward suggestions that the beds should be entirely fished out in order to promote new settlement. Such an approach should be viewed with extreme caution as irreparable damage could easily be caused. Principles such as these were tested during the 2003 and 2004 fisheries, during which some areas of beds were allowed to be totally removed during the course of the fishery. To date, most of those areas have not resettled and remain bare of mussels.

Although managing the fishery in a manner that will achieve Conservation Objective target thresholds has helped to stabilise the overall mussel biomass, by regularly harvesting the stocks down to their minimum thresholds, the beds have

not had an opportunity to develop beyond these levels. On some beds, where their density has fallen below the level in which they can support the raised matrices of mussel, shell and byssus threads, they no longer attract sufficient seed to offset natural mortality. Such beds are currently in a state of continued decline and are in danger of being lost. As a consequence, the fishery has become reliant on those beds that are still currently in better condition. Continued pressure on these beds, however, will eventually reduce their densities below critical levels, too, leading to their declines.

Fishery disturbance is not the only pressure impacting the beds. In recent years high numbers of 2 and 3 year-old mussels have died. These mortalities have resulted in significant losses on some of the beds. These were most noticeable between 2009 and 2010 when the mussel stocks crashed from 15,188 tonnes to 9,600 tonnes, but have continued to a lesser extent on some of the beds since then. The original die-off was attributed to high infestation rates of the copepod parasite, *Mytilicola intestinalis*, which had been found in high numbers in the mussels. Although this parasite is still present in the mussel stocks, its numbers appear much lower than those recorded in 2010, so perhaps do not explain recent mortality events.

Method

The intertidal mussel surveys in the Wash are conducted during the daytime low periods of spring tides. These tides allow vessel access the higher beds while allowing lower beds to become fully exposed. For most of the surveys, the beds are accessed by drying the research vessel out close to the bed, taking care to use safe anchor sites selected prior to the survey.

To determine the biomass of mussels within a bed, the area of the bed is multiplied by the mean biomass of the mussels within the bed. Because the mussels in the Wash tend to have patchy distributions, the mean biomass is determined by multiplying the mean mussel density within the patches with the mean percentage coverage of the patches.

To determine the area of the bed, one member of the survey team walks around the perimeter of the bed, close to the edge of the mussels, entering waypoints into a handheld GPS at each change of direction. Determining the edge of the bed can be subjective at times as not all beds have clearly defined edges. In such cases, experience is required to maintain consistency in what is included within the bed perimeter. The waypoints gained from the survey are transferred to a Geographic Information System (GIS), MapInfo, from which the perimeter of the bed can be plotted and its area determined.

To measure the mean density and coverage of the mussels within the bed, the Authority uses a procedure demonstrated by the Dutch marine consultants, MarinX, during the 2004 mussel surveys (van Stralen & Bol, 2004). The survey is conducted in transects that zig-zag across the bed, taking care that the transect lines offer equal bias to all parts of the bed. On small beds this can be determined by eye at the time of the survey, but for larger beds this can be difficult. For larger beds gridded charts taken from the previous year's survey are used to assign an even coverage of transect lines (see figure 1).

As the survey team walk along the transect lines, the coverage of mussels is determined using an 11cm ring attached to a pole. Every three paces the ring is placed on the ground and the presence ("hit") or absence ("miss") of mussels within the ring recorded. Randomisation is achieved by placing the ring down to one side, outside of the field of vision of the user. In order to calculate patch

density, samples of mussels are taken from within some of the rings that were determined to be "hits". Prior to commencing the survey it is determined how many of the "hits" will be taken as samples. This is a compromise between accuracy and how many mussels can be carried/measured. Depending on the size of the bed, how good the coverage looks and how many small mussels appear to be in the bed, sampling may occur as often as 1 sample from 2 hits to 1 sample from 7 hits. For most of the beds in the Wash samples are collected from either 1 in 4 or 1 in 5 hits.

When a sample is collected it is taken from within the ring that produced the "hit" determination using a corer of the same diameter as the sampling ring. This is gently twisted into the ground to a depth of approximately 8cm (it is important to twist the corer rather than pushing it into the ground, as any mussels that are partially in/out will then tip either in or out of the corer rather than just being pushed down into the mud). All the mussels within the corer are then placed into a 5 litre container, enabling numerous small random samples to be collected from throughout the bed.

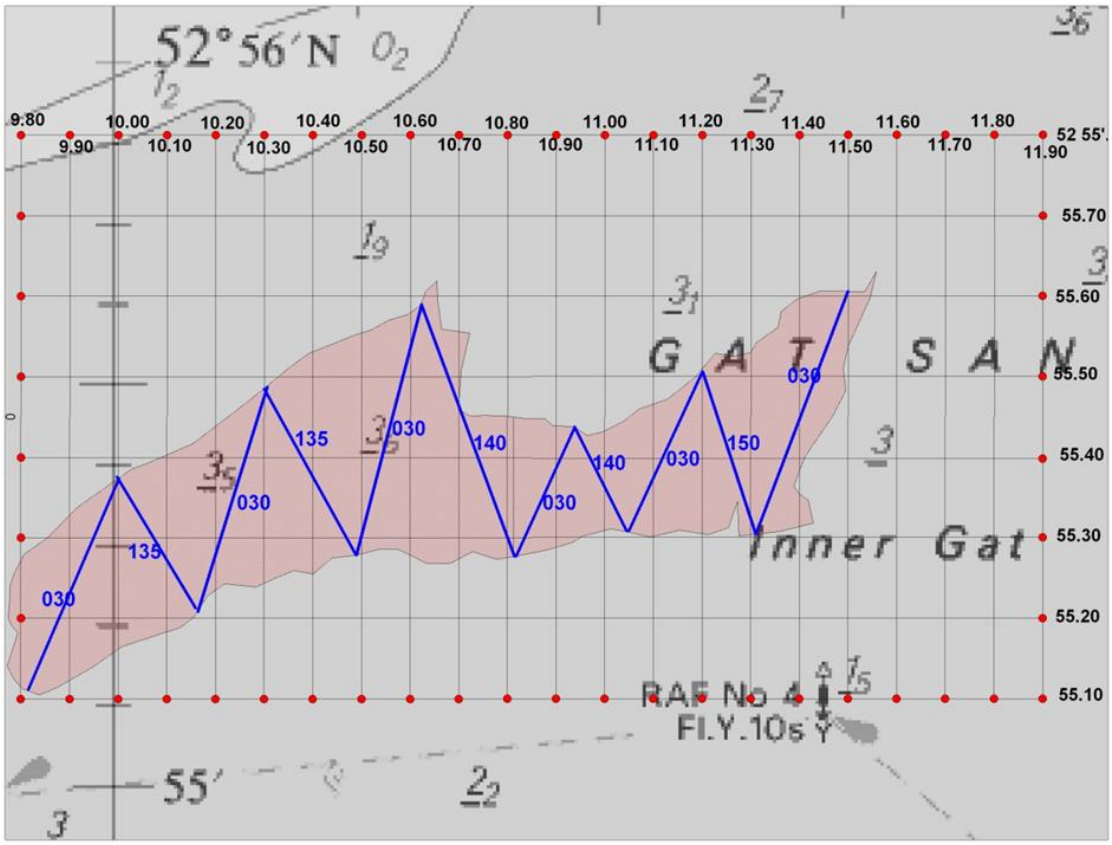

Figure 1 – Chart showing the area of a mussel bed, the transect lines to be surveyed, their bearings and an overlaid grid showing the lat/long positions

For the surveys in the Wash, samples are divided into groups that have been collected from transects that are 150 hit/miss determinations in length. These are washed using a 0.5mm sieve and placed in labelled bags. On returning to the research vessel the live mussels are separated from the debris in each sample. The length of each mussel is determined, and the samples divided into those mussels that are of marketable size (≥45mm) and those that are smaller. The weights of these samples are then recorded (during the 2012 surveys, the number and weight of mussels ≥25mm length were also recorded as this size range is favoured by oystercatchers).

In addition to determining the biomass of mussels within the bed, the size distribution of the population is obtained from the length measurements of mussels in the retained samples.

Results

The 2014 surveys commenced on September 21st and were completed on October 27th. During this period 20 areas of mussel bed, plus the Welland Bank, were surveyed. This included two new areas of bed between Mare Tail and Herring Hill that had not previously been surveyed. The distribution of the surveyed the beds are shown in figure 2.

Table 1 summarises the stocks found on the beds at the time of the survey and compares them to the previous year's level. From this table it can be seen that even with the inclusion of two new beds, the total mussel biomass had declined during that period from 12,100 tonnes to 10,127 tonnes. This decline was widespread. Excluding the two new beds, the results indicate that all but five of the beds had suffered declines. Of those five, three were either very small (Shellridge) or difficult to survey and prone to surveying errors (Main End, which lies partially submerged, and Pandora, which is covered by large expanses of shell). Of the larger beds, by 2014 only the North Mare Tail and Toft beds were found to support more than 1,000 tonnes, compared to five beds the previous year. While fishing activity can account for some of the losses seen on the Mare Tail, Holbeach, Herring Hill and Breast beds, all of which were opened to the 2013/2014 seed fishery, the majority of the losses cannot be attributed to this 400 tonne fishery. During recent years high mortalities have been witnessed among the Year-3 mussel cohorts, causing declines of healthy-looking beds and limiting the number of mussels that attain harvestable size. During the same period, new recruitment has been at best average, and in most years, poor.

Figure 3 highlights the changing stock levels between the 2013 and 2014 surveys.

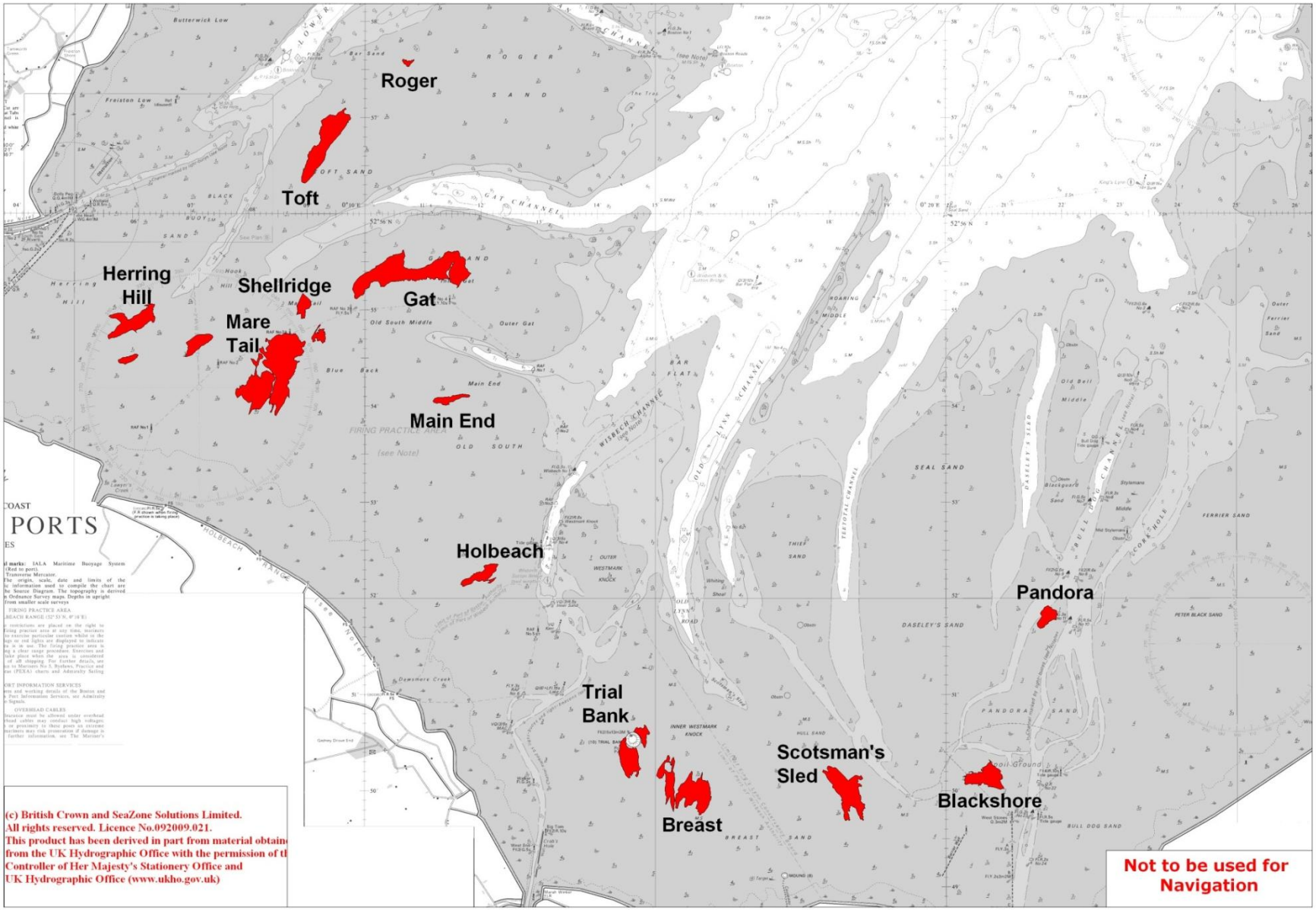

Figure 2 - Distribution of intertidal mussel beds surveyed during 2014

Table 1 – Summary of the mussel stocks on individual beds at the time of the 2014 surveys

	2014							2013	
BED	**AREA**	**COVERAGE**	**DENSITY**	**TOTAL STOCK**	**STOCK >45MM**	**% >45MM**	**Tonnes/ha**	**TOTAL STOCK**	**% CHANGE**
Mare Tail North	66.7	41	0.9	2437	991	40.7	36.5	2398	1.6
Mare Tail South	35.5	28	0.78	782	214	27.4	22.0	890	-12.1
Mare Tail East	4.7	26	0.41	51	6	11.8	10.9	54	-5.6
Mare Tail West	11.4	37	0.8	342	48	14.0	30.0	na	na
Shellridge	7.6	11	0.31	26	16	61.5	3.4	6	333.3
Toft	43.1	31	1.24	1638	1346	82.2	38.0	2005	-18.3
Roger	1.6	25	0.69	28	18	64.3	17.5	64	-56.3
Gat, West	43	30	0.54	699	401	57.4	16.3	1110	-37.0
Gat, Mid	24.1	13	0.58	186	142	76.3	7.7	388	-52.1
Gat, East	16.5	31	0.71	361	309	85.6	21.9	337	7.1
Main End	6.6	29	0.74	141	111	78.7	21.4	95	48.4
Holbeach	12.4	37	0.66	303	102	33.7	24.4	502	-39.6
Herring Hill	25.1	36	0.79	710	96	13.5	28.3	881	-19.4
East Herring Hill	3.9	38	0.49	71	15	21.1	18.2	na	na
Trial Bank	24.9	33	0.85	686	137	20.0	27.6	1014	-32.3
Breast, West	15.4	12	0.91	162	55	34.0	10.5	316	-48.7
Breast, East	31.7	26	1.08	893	247	27.7	28.2	1154	-22.6
Scotsman's Sled, East	36.9	24	0.33	291	78	26.8	7.9	365	-20.3
Blackshore	21.6	17	0.46	171	104	60.8	7.9	386	-55.7
Pandora	9.5	21	0.74	149	139	93.3	15.7	135	10.4
TOTAL	**442.23**			**10127**	**4575**	**45.2**	**22.9**	**12100**	-16.3
Welland Bank	1.6	72	1.87	210	127	60.5	264.2	328	-36.0

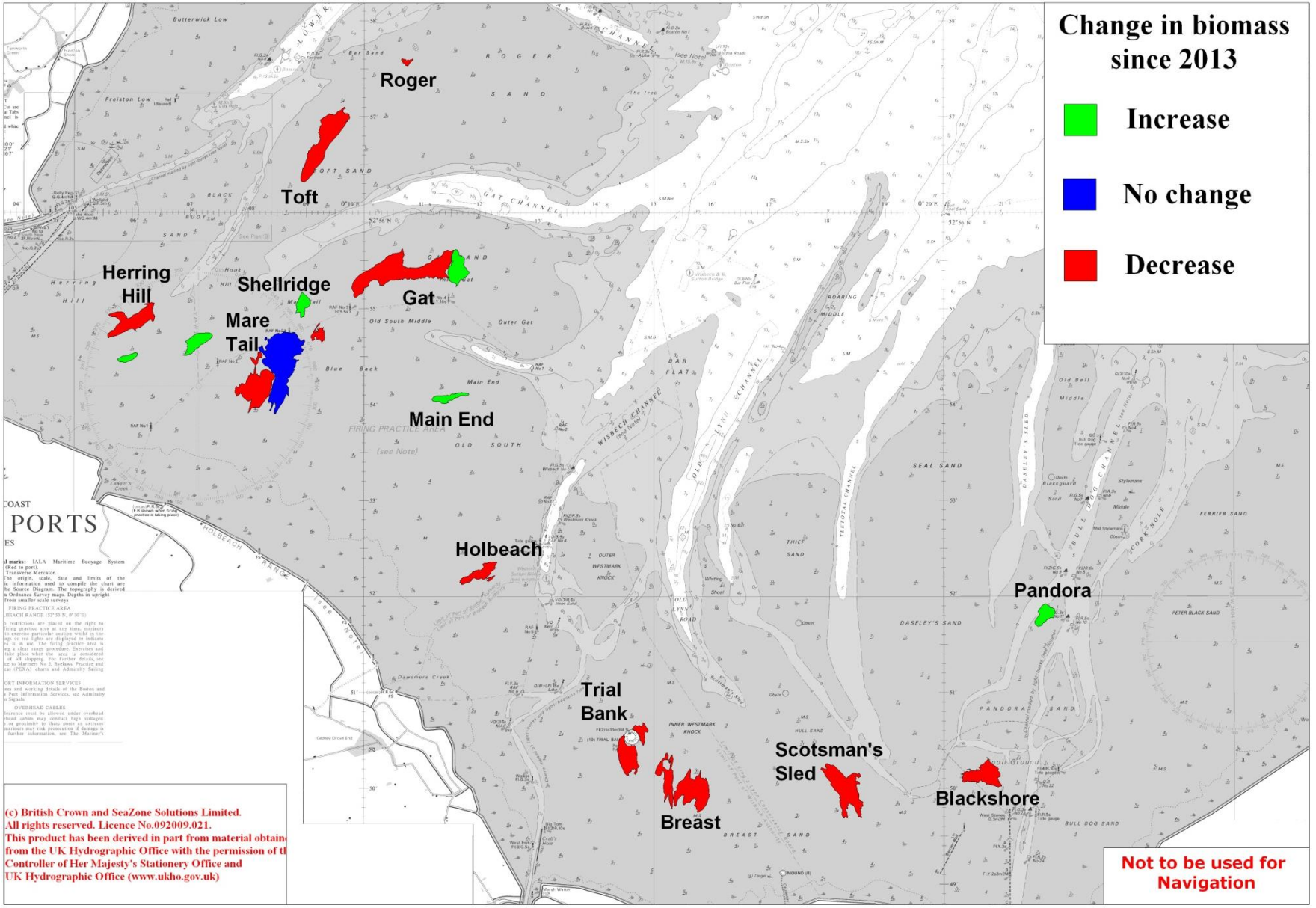

Figure 3 – Chart highlighting the changes in mussel biomass to individual beds between the 2013 and 2014 surveys

The following section describes the individual beds at the time of the 2014 survey.

Mare Tail Beds

Mare Tail supports a conglomeration of mussel beds that are either short distances apart or separated by creeks. For survey purposes, these beds are monitored as individual entities and include the North, South and East Mare Tail beds, plus the nearby Shellridge. Until 2004 the area supported a fifth bed near the RAF No.2 beacon, but following heavy exploitation during the 2004/2005 fishery this bed disappeared and has shown little sign of subsequent resettlement. The 2014 survey did find that there had been a recent settlement to the west of this, creating a new bed termed the West Mare Tail. Figure 4 shows the distribution of these five beds

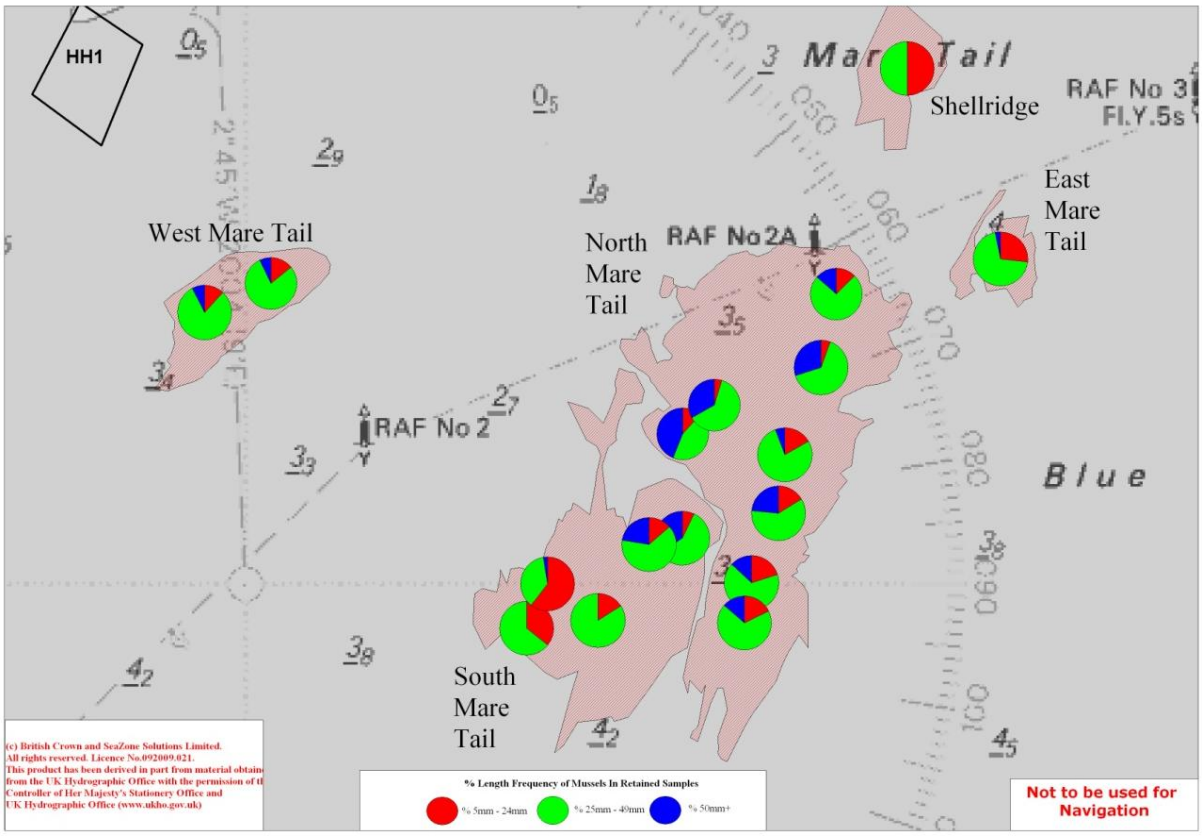

Figure 4 - Mussel size distributions on the Mare Tail mussel beds – October 2014

The individual beds on the Mare Tail are described as follows.

North Mare Tail

- Area: 66.7 hectares
- Coverage: 41%
- Mean Density: 0.90 kg/0.1m^2
- Total Stock: 2,437 tonnes
- Stock ≥ 45mm: 991 tonnes

The North Mare Tail bed was surveyed on October 12th, during which samples were collected from every sixth "hit", producing 82 samples from eight transects. Figure 5 shows the mussel size frequency within the population taken from these samples.

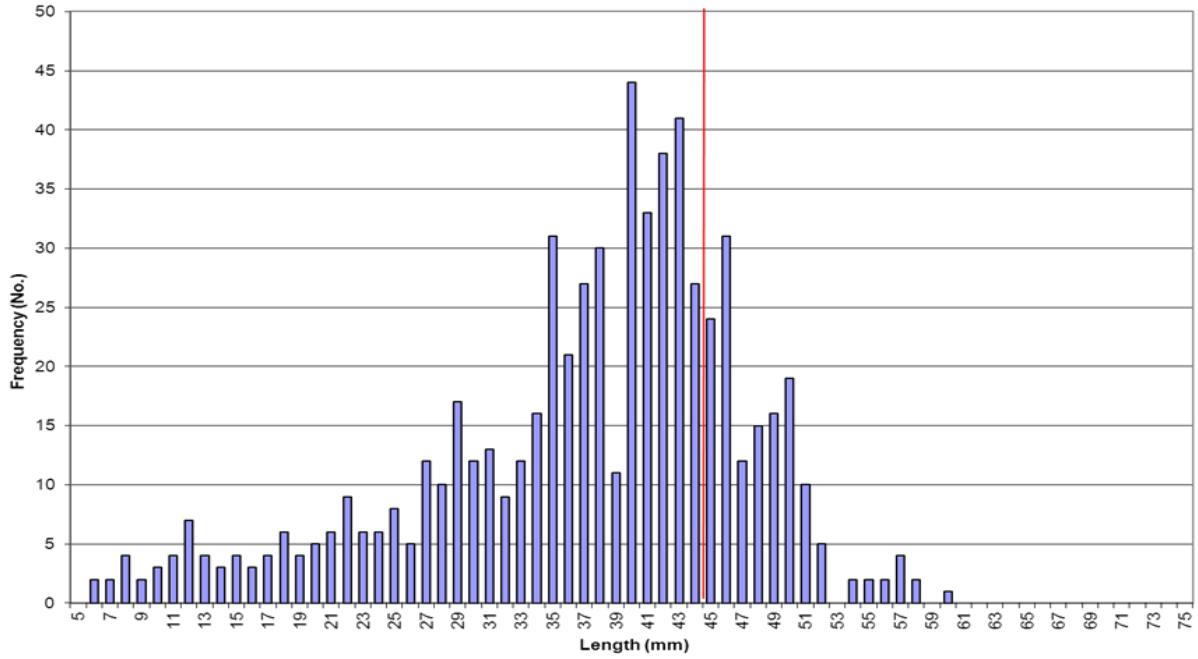

Figure 5 - Mussel size frequency on North Mare Tail - October 2014

Although this bed had been opened to dredge relaying fisheries in October 2013 and again in April/May 2014, it was one of the few beds that had not declined in biomass between the two surveys. The survey found that the fishing effort had mainly been focused on the northern parts of the bed, which being lower, are more easily accessible. This disparity of effort is a common occurrence on this bed and has resulted in a significantly lower mussel coverage to the north.

The inclusion this year of what had formally been a low density patch of mussels to the east of the bed helped the area of the bed to increase from 54.2 hectares to 66.7 hectares. Within the bed the mussel coverage had increased from 36% to 41% but the mean density of the mussel patches had declined from 1.24 kg/0.1m^2 to 0.90 kg/0.1m^2.

Observations indicate some of these changes are the result of the fishery spreading some of the patches, increasing the coverage but reducing the density. From these figures, the mussel biomass on this bed was calculated to be 2,437 tonnes, a slight increase on the figure of 2,398 tonnes recorded the previous year. Of these, 991 tonnes were found to have attained the minimum landing size of 45mm, an improvement to the 900 tonnes recorded in 2013.

The size frequency chart in figure 5 shows that the peak size in the population is just below harvestable size, but that there has been little recent recruitment. This size structure would suggest that if left alone in the coming year, the harvestable biomass is likely to increase but the overall biomass is likely to remain relatively stable.

South Mare Tail

- Area: 35.5 hectares
- Coverage: 28%
- Mean Density: 0.78 kg/0.1m^2
- Total Stock: 782 tonnes
- Stock ≥ 45mm: 214 tonnes

The South Mare Tail bed was surveyed on September 27th. Samples were taken from every fourth "hit", producing 51 samples from five transects. Figure 6 shows the mussel size frequency within the population taken from these samples.

The area of this bed was found to have increased from 30.9 hectares to 55.5 hectares, but within this area the coverage had declined from 36% to 28% and the mean density from 0.81 kg/0.1m^2 to 0.78 kg/0.1m^2. From these figures the biomass of mussels within the bed was calculated to be 782 tonnes, compared to 890 tonnes the previous year. Observations indicate most of these losses were due to mortalities of 3 year-old mussels. Growth had enabled some of the population to attain harvestable size, enabling the biomass of ≥45mm mussels to increase from 121 tonnes to 214 tonnes.

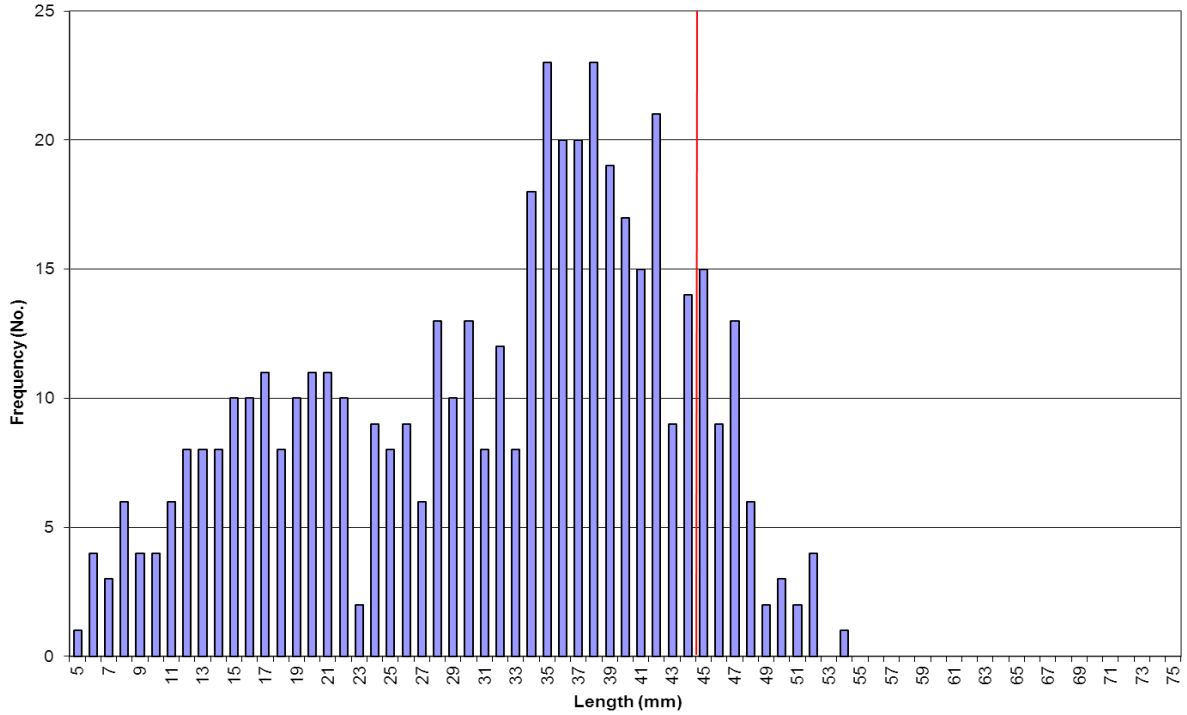

Figure 6 - Mussel size frequency on South Mare Tail - September 2014

East Mare Tail

- Area: 4.7 hectares
- Coverage: 26%
- Mean Density: 0.41 kg/0.1m^2
- Total Stock: 51 tonnes
- Stock ≥ 45mm: 6 tonnes

The East Mare Tail bed was surveyed on September 9th. Samples were collected from every third "hit", resulting in 12 samples being taken from one transect. Figure 7 shows the size distribution of the mussels collected from the samples.

The area of this bed was found to have declined from 7.2 hectares to 4.7 hectares, but within this area the coverage had increased from 23% to 26% and the mean density of the mussel patches from 0.33 kg/0.1m^2 to 0.41 kg/0.1m^2. From these figures the total biomass of mussels in this bed was calculated to be 51 tonnes, a slight decline from the 54 tonnes recorded the previous year. The stock of mussels that had attained marketable size was found to have declined during the same period from 11 tonnes to 6 tonnes.

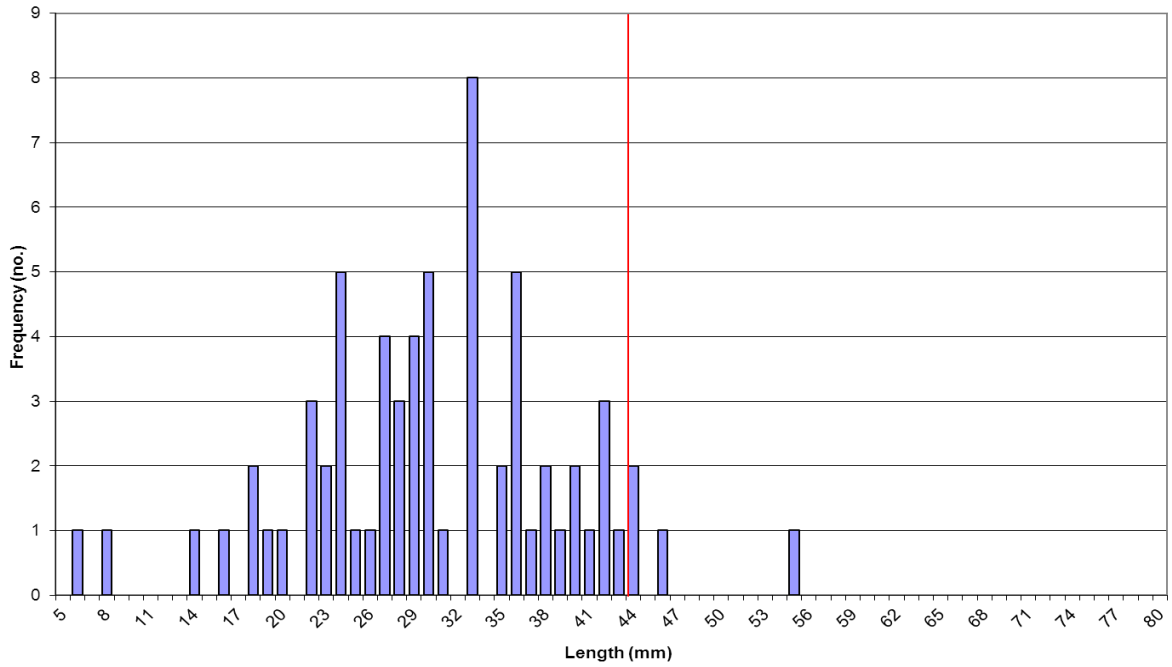

Figure 7 - Mussel size frequency on East Mare Tail – September 2014

Shellridge

- Area: 7.6 hectares
- Coverage: 11%
- Mean Density: 0.31kg/0.1m^2
- Total Stock: 26 tonnes
- Stock ≥ 45mm: 16 tonnes

The Shellridge bed was surveyed on September 30th, during which samples were taken from every third "hit", producing 4 samples from one transect.

In 2006 this bed had covered 23.0 hectares and supported over 500 tonnes of mussels, but disparate fishing effort during the 2006/2007 dredge mussel fishery combined with poor subsequent recruitment caused the bed to decline severely in recent years. By 2013 only a very small patch of the original bed remained, covering an area of 1.0 hectares. The 2014 survey found the bed had increased to 7.6 hectares, but this is thought to be due to the inclusion of a wider area of very low density patches that had been excluded from the previous survey rather than recruitment. The inclusion of these patches meant the coverage declined from 17% to 11% and the mean density from 0.38kg/0.1m^2 to 0.31kg/0.1m^2. From these figures the biomass of mussels on this bed

was calculated to be 26 tonnes, compared to the figure of 6 tonnes recorded the previous year. Of these, 16 tonnes were of harvestable size.

West Mare Tail

- Area: 11.4 hectares
- Coverage: 37%
- Mean Density: 0.80kg/0.1m^2
- Total Stock: 342 tonnes
- Stock ≥ 45mm: 48 tonnes

This bed was surveyed on October 27th, during which samples were taken from every fourth "hit", producing 27 samples from two transect. Figure 8 shows the size distribution of the mussels collected in those samples.

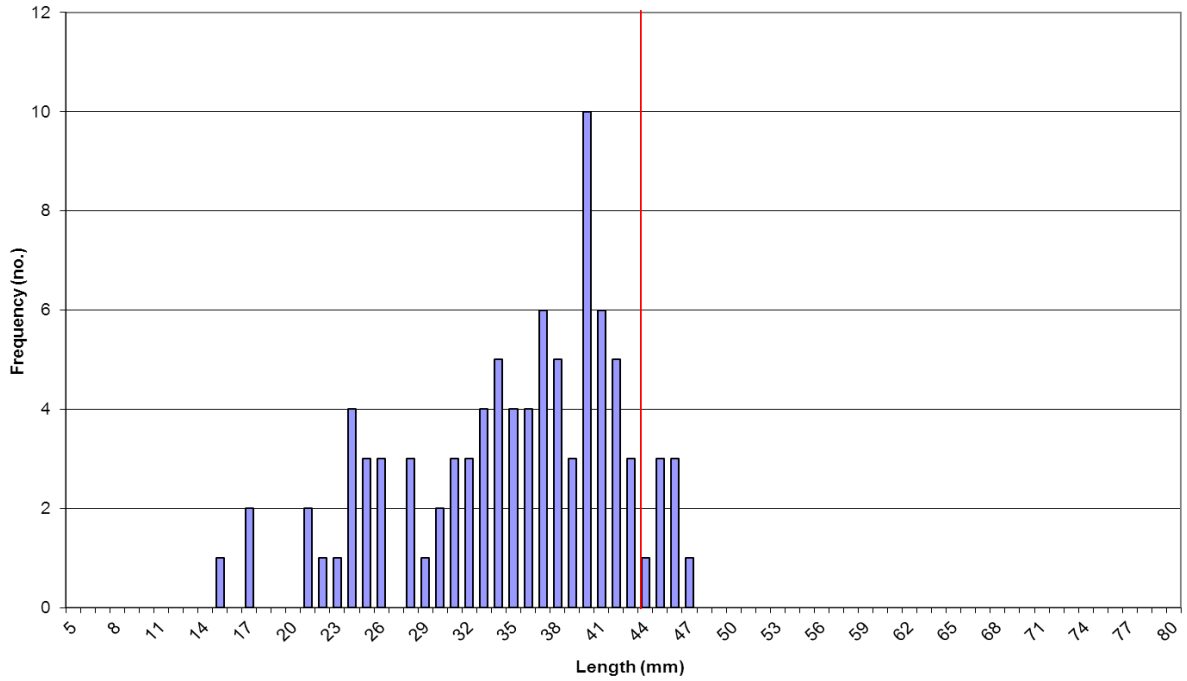

Figure 8 - Mussel size frequency on West Mare Tail – October 2014

Although this bed was only identified and surveyed for the first time in 2014, the size distribution of the mussels in figure 8 suggests the bed more than likely settled prior to 2013. Its proximity to dense cockle beds, and the quantity of shells attached to the samples, suggests it originally settled on ridged cockles. With an area of 11.4 hectares, a coverage of 37% and a mean density of 0.80kg/0.1m^2, the total mussel biomass on the

bed was calculated to be 342 tonnes. Of these, 48 tonnes were found to have attained harvestable size.

The Gat Beds

The Gat sand supports an extensive area of mussels that for survey purposes is divided into three beds (see figure 9). Since the 1990s these beds have been viewed as particularly important by both the fishing industry and conservationists alike. Following overfishing in the late 1980s, the Gat became one of the few inter-tidal beds in the Wash that still supported significant quantities of mussels. In order to protect these remaining stocks, the Gat beds were closed to fishing in 1993. Although they were subject to heavy poaching between 2000 and 2002, they were not officially opened to a major dredge fishery until 2006. Having been closed for so long, these beds matured and, particularly along the exposed northern fringes of the bed, developed important biogenic reef features. When they were eventually opened to a dredge fishery in 2006, and subsequent hand-worked fisheries between 2007 and 2010, the northern edges of the bed remained closed in order to protect these biogenic reef features. Although fisheries on these beds have been restricted and closely managed, they have suffered significant declines since 2010, during which period the beds have declined from a total stock of 5,604 tonnes in 2009 to just 1,246 tonnes in 2014. Observations made during the annual surveys suggest this decline is due to high mortalities among the populations of 3 year-old mussels, coupled with poor recruitment during this period. The result of the decline is evident on the beds, where in many places the mussels are now only thinly distributed amid lots of shell, and the silty hillocks usually associated with a thriving mussel bed are eroding away.

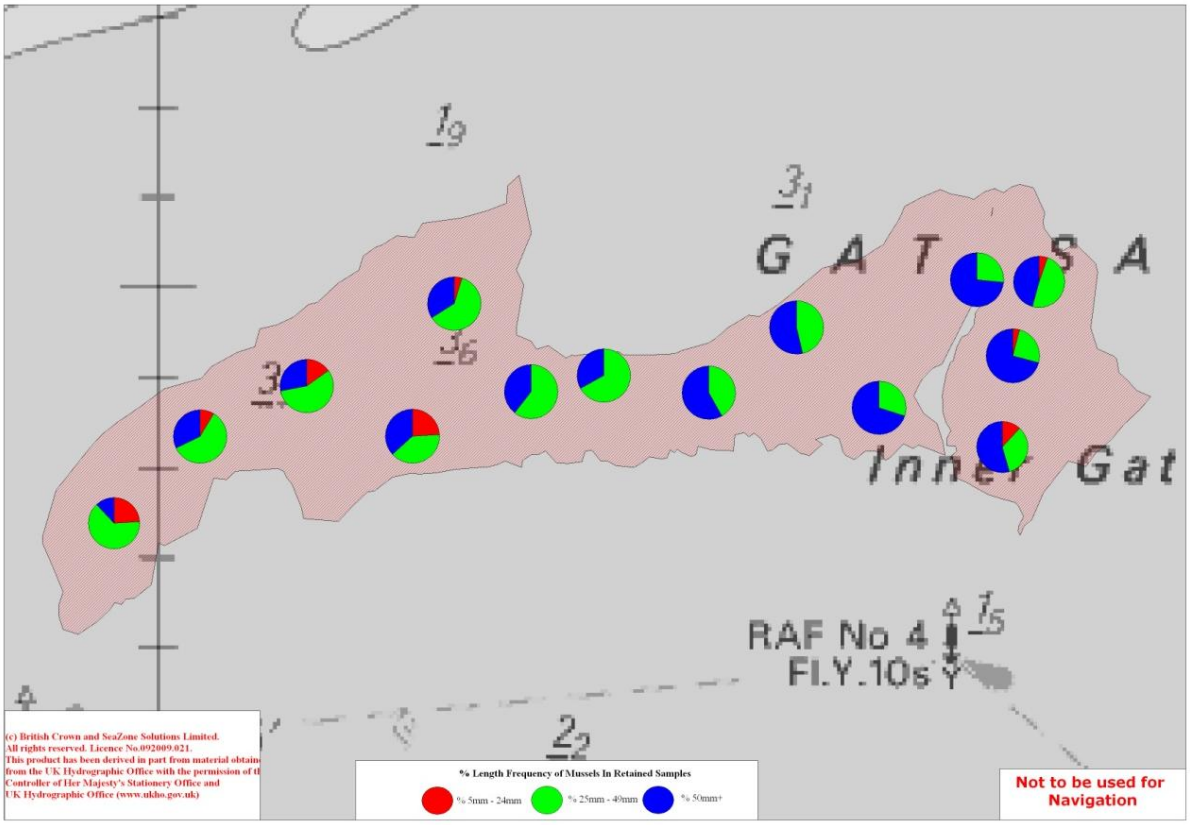

Figure 9 - Mussel size distributions on the Gat mussel beds – October 2014

West Gat

- Area: 43.0 hectares
- Coverage: 30%
- Mean Density: 0.54kg/0.1m^2
- Total Stock: 699 tonnes
- Stock ≥ 45mm: 401 tonnes

The West Gat bed was surveyed on September 24th. Samples were taken from every fourth "hit", producing 63 samples from six transects.

Although the area of the bed was found to have increased from 38.4 hectares in 2013 to 43.0 hectares, the mussel coverage within the bed had declined from 39% to 30% and the mean density from 0.73kg/0.1m^2 to 0.54kg/0.1m^2. From these figures the total mussel biomass on this bed was calculated to have declined from 1,110 tonnes to 699 tonnes. Of these, 401 tonnes had attained harvestable size compared to 563 tonnes the previous year.

Figure 10 shows the mussel size frequency within the population taken from the survey samples. Compared to previous years, this chart highlights that there are far fewer younger mussels in the population on this bed than normal. This supports the observations that young mussels have been dying and recruitment has been poor.

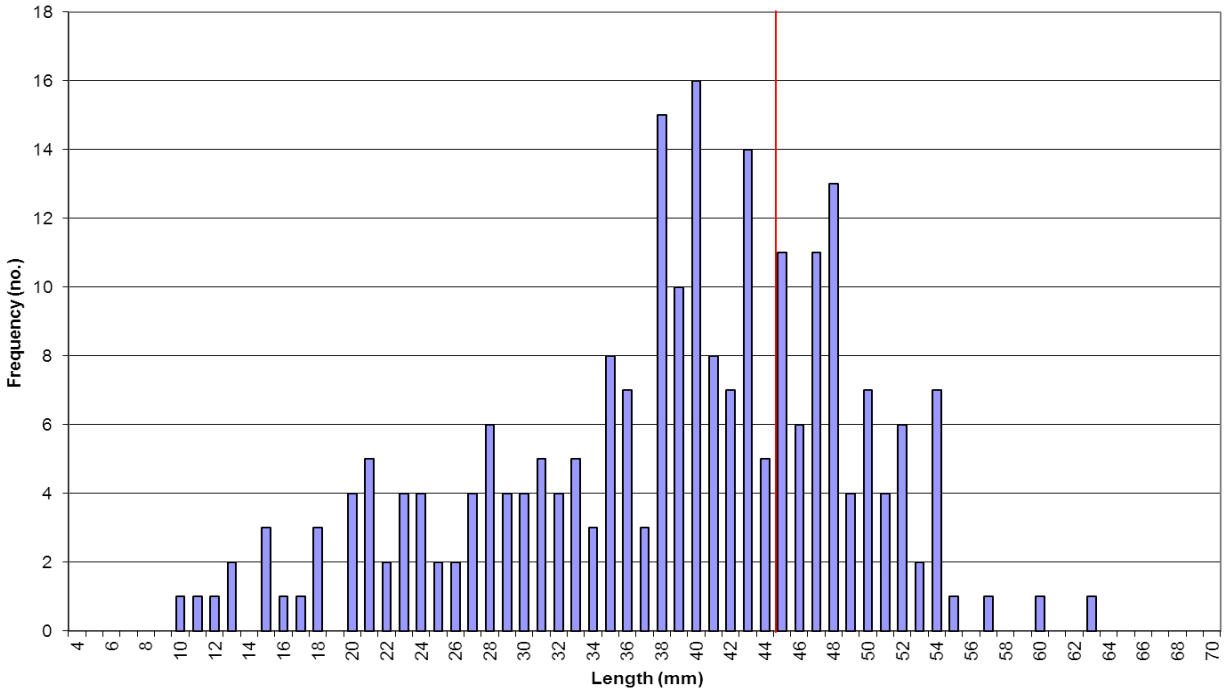

Figure 10 - Mussel size frequency on West Gat - September 2014

2.3.2.2 Mid Gat

- Area: 24.1 hectares
- Coverage: 13%
- Mean Density: 0.58kg/0.1m^2
- Total Stock: 186 tonnes
- Stock ≥ 45mm: 142 tonnes

The Mid Gat was surveyed on September 24th. Samples were collected from every fourth "hit", producing 22 samples from five transects.

The survey found the area of the bed had declined slightly from 24.6 hectares in 2013 to 24.1 hectares. Within this area the coverage was found to have declined significantly from 31% to 13%, while the mean density had improved slightly from 0.51kg/0.1m^2 to 0.58kg/0.1m^2. From these figures the total biomass of mussels on the bed was calculated to have declined from 388 tonnes in 2013 to 186 tonnes. The stock that had

attained a harvestable size of 45mm was calculated to have declined from 215 tonnes to 142 tonnes.

Figure 11 shows the mussel size frequency within the population taken from the survey samples. As had been the case on the West Gat, the population shows a marked reduction in the number of younger mussels present on this bed.

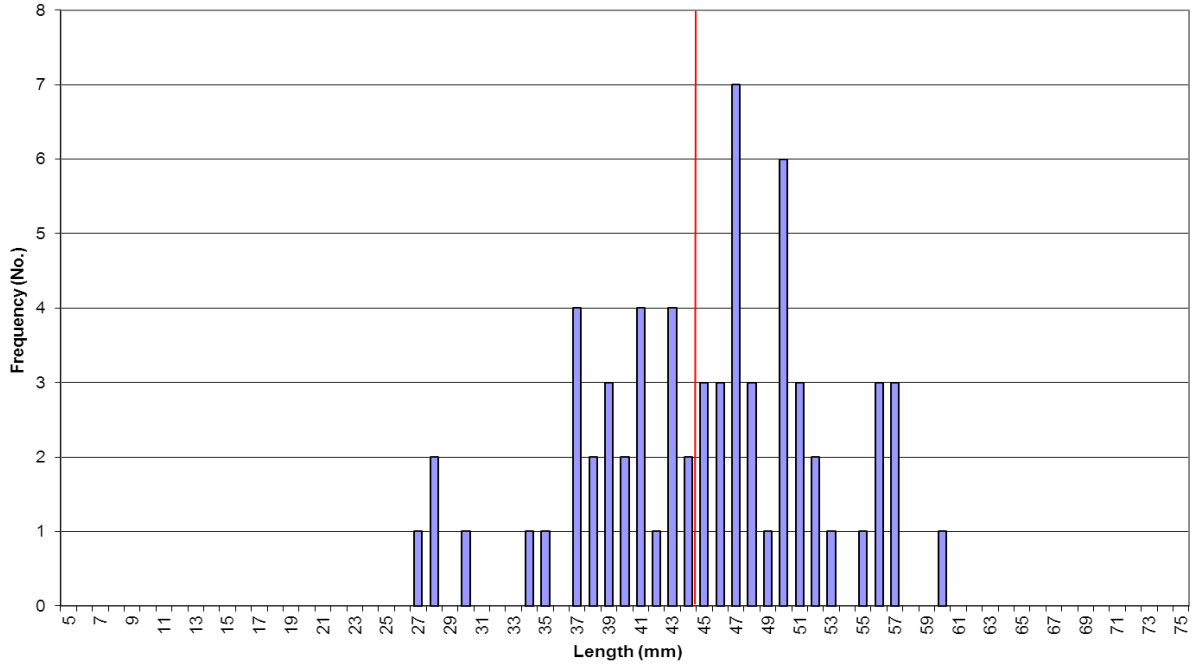

Figure 11 - Mussel size frequency on Mid Gat – September 2014

2.3.2.3 East Gat

- Area: 16.5 hectares
- Coverage: 31%
- Mean Density: 0.71kg/0.1m^2
- Total Stock: 361 tonnes
- Stock ≥ 45mm: 309 tonnes

The East Gat was surveyed on October 8th. Samples were taken from every fourth "hit", producing 36 samples from three transects.

Of the three beds on the Gat, the East bed was the only one that had not declined during the year. Although the area of the bed had fallen slightly from 17.0 hectares to 16.5 hectares, and the coverage from 32% to 31%, these were compensated with an increase in mean density from 0.61kg/0.1m2 to 0.71kg/0.1m^2. From these figures the total mussel biomass on the bed was calculated to have increased from 337 tonnes in 2013 to

361 tonnes. The biomass of mussels that had attained a size of 45mm had also increased from 237 tonnes to 309 tonnes.

Figure 12 shows the mussel size frequency within the population taken from the survey samples. Similar to the other two beds on the Gat, this shows a lower than usual number of smaller mussels in the population.

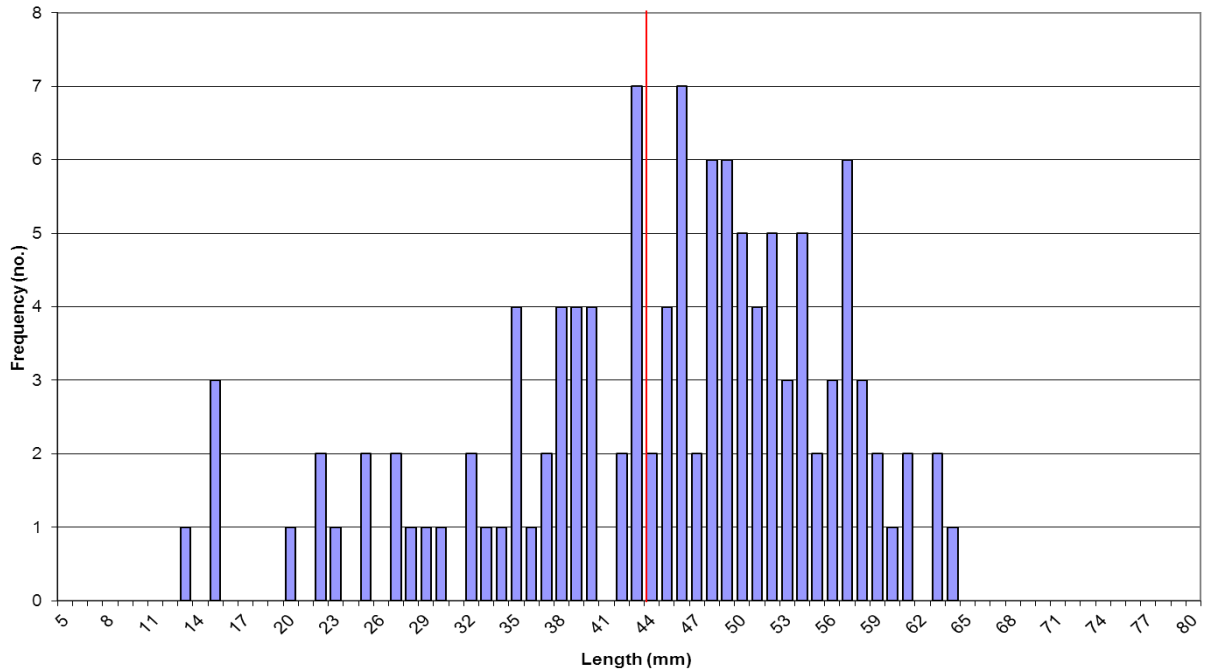

Figure 12 - Mussel size frequency on East Gat – October 2014

Tofts

- Area: 43.1 hectares
- Coverage: 31%
- Mean Density: 1.24 kg/0.1m^2
- Total Stock: 1,638 tonnes
- Stock ≥ 45mm: 1,346 tonnes

Because of the size of this bed, the perimeter was surveyed on September 25th and transects conducted using two teams on the following day. Samples were taken from every fifth "hit", producing 69 samples from nine transects. Figure 13 shows the mussel size distribution over the bed.

Since the previous survey, the area of this bed was found to have decreased slightly from 43.9 hectares to 43.1 hectares. Within this area both the coverage and mean density had decreased, from 33% to 31% and from 1.39 kg/0.1m^2 to 1.24 kg/0.1m^2. From these figures the total biomass of mussels on the bed was estimated to have declined from 2,005 tonnes to 1,638 tonnes. 1,346 tonnes of these had reached a size of 45mm compared with 1,468 tonnes the previous year.

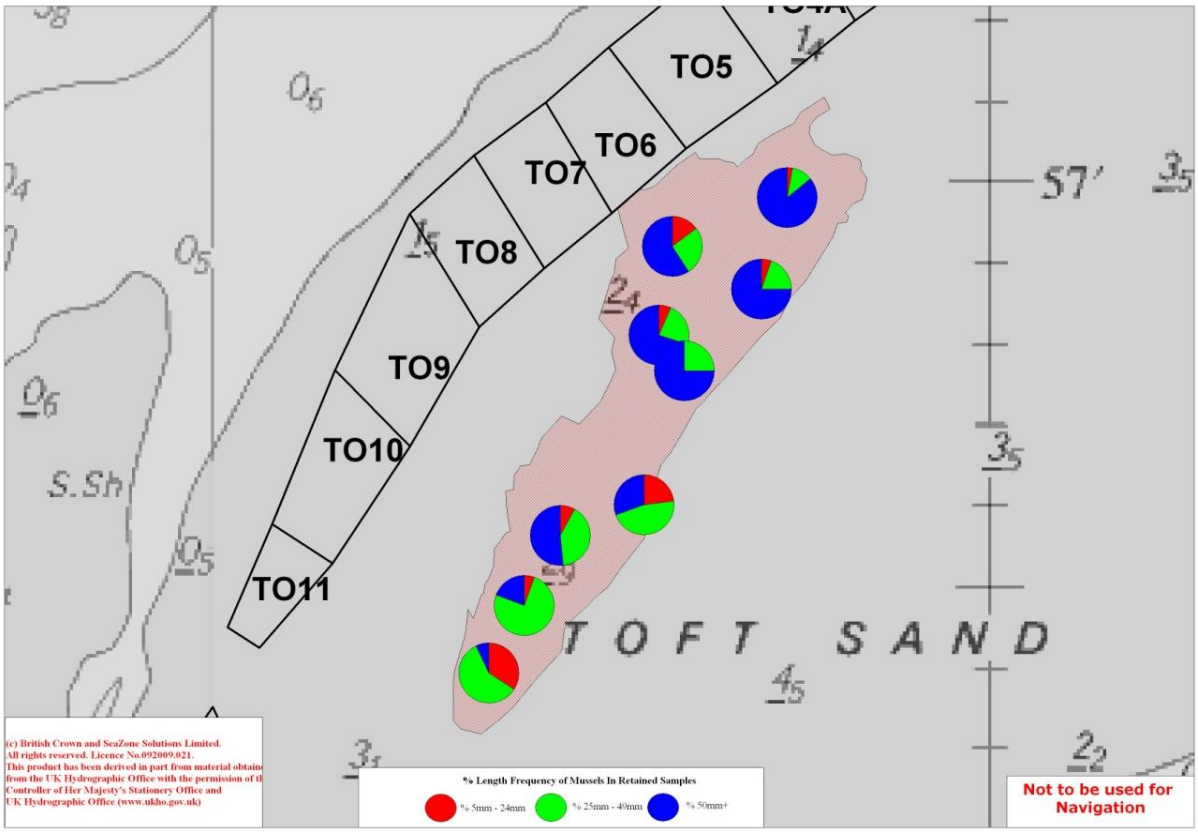

Figure 13 - Mussel size distributions on the Toft mussel bed – September 2014

Following poor recruitment in recent years, and observed mortality of younger mussels, the size frequency chart for this bed (see figure 14) shows fewer smaller mussels in the population than previously.

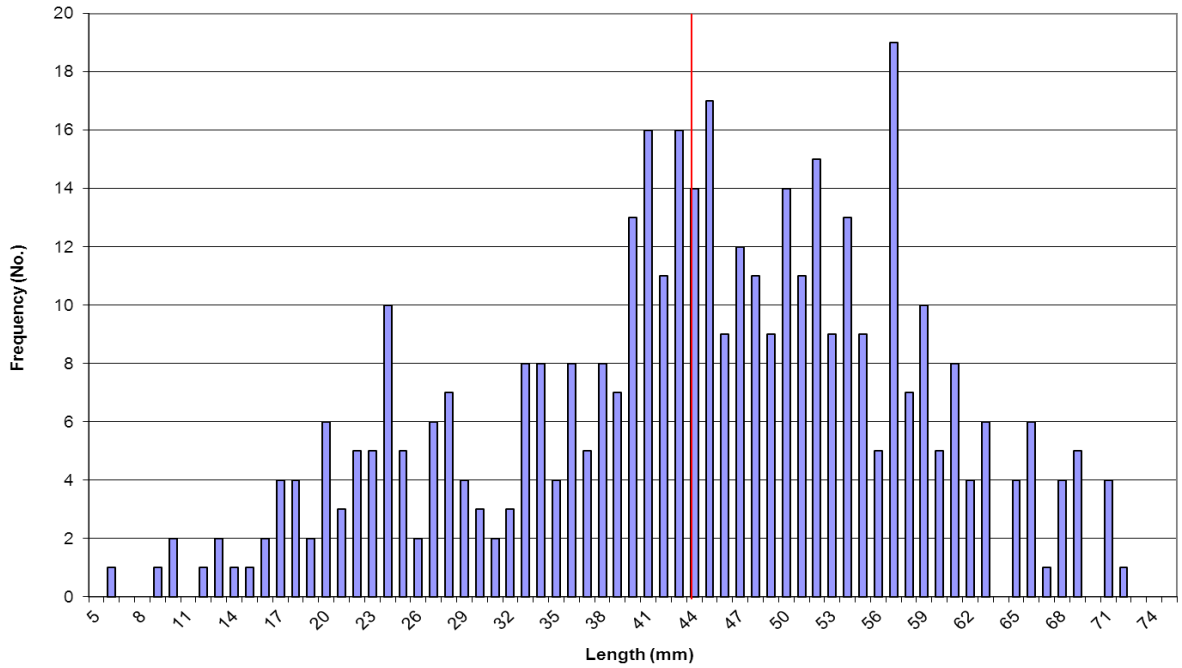

Figure 14 - Mussel size frequency on the Tofts – September 2014

Roger

- Area: 1.6 hectares
- Coverage: 25%
- Mean Density: 0.69 kg/0.1m^2
- Total Stock: 28 tonnes
- Stock ≥ 45mm: 18 tonnes

This small bed was surveyed on September 25th. Samples were collected from every fourth "hit", producing 9 samples from a single transect. Figure 15 shows the mussel size distribution on this bed while figure 16 shows the size frequency within the population.

Since the previous survey, the area of the bed was found to have declined slightly from 1.7 hectares to 1.6 hectares. Within this area the coverage of mussels was found to have declined significantly from 45% to 25% and the mean density from 0.84 kg/0.1m^2 to 0.69 kg/0.1m^2. From these figures the total biomass on the bed was calculated to have declined from 64 tonnes to 28 tonnes and the harvestable sized stock from 43 tonnes to 18 tonnes.

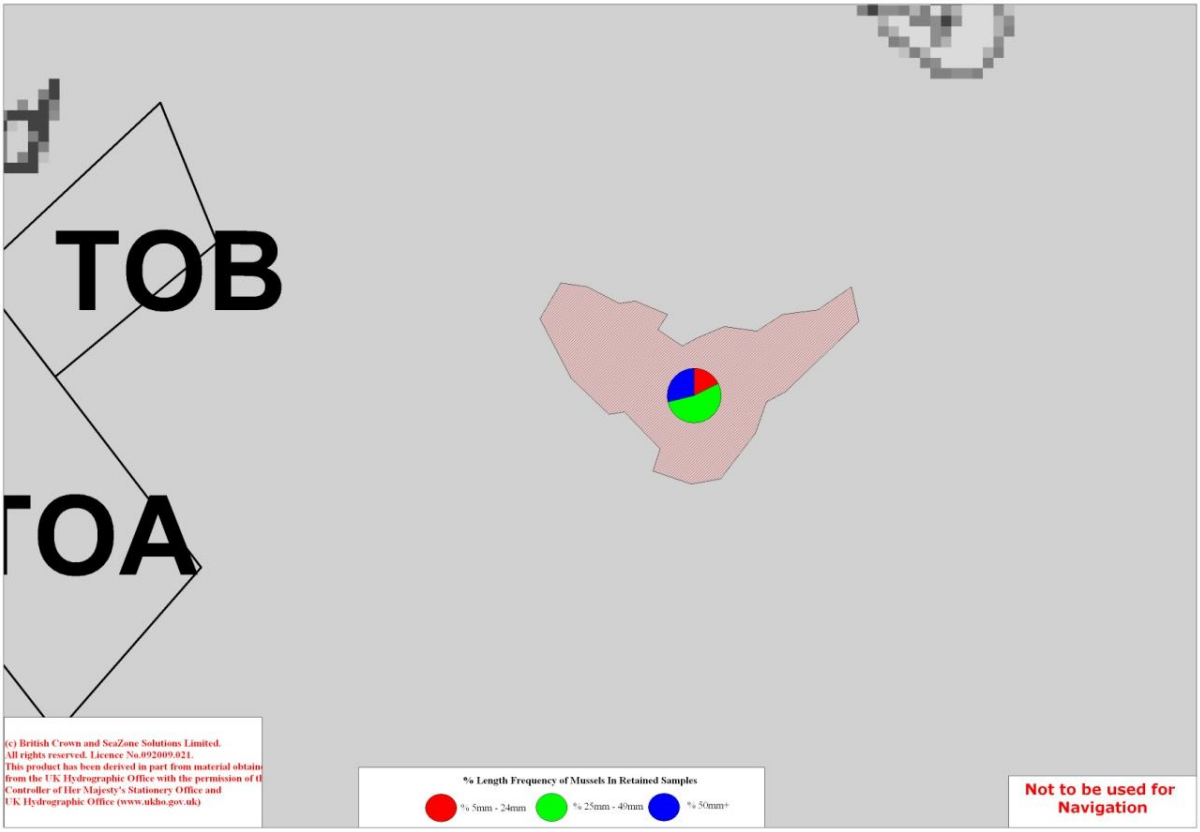

Figure 15 - Mussel size distribution on the Roger mussel bed – September 2014

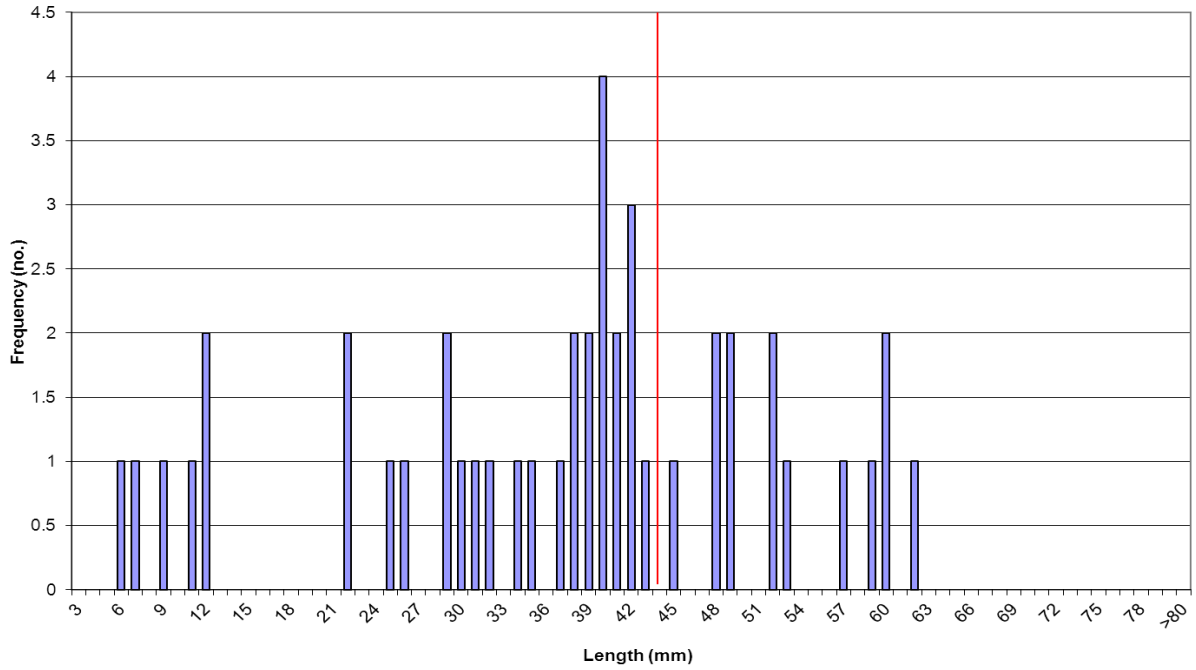

Figure 16 - Mussel size frequency on the Roger – September 2014

Herring Hill

- Area: 25.1 hectares
- Coverage: 38%
- Mean Density: 0.79 kg/0.1m^2
- Total Stock: 710 tonnes
- Stock ≥ 45mm: 96 tonnes

The Herring Hill bed was surveyed on October 9th. Samples were taken from every fifth "hit", producing 48 samples from five transects. Figure 17 shows the mussel size distribution across the bed.

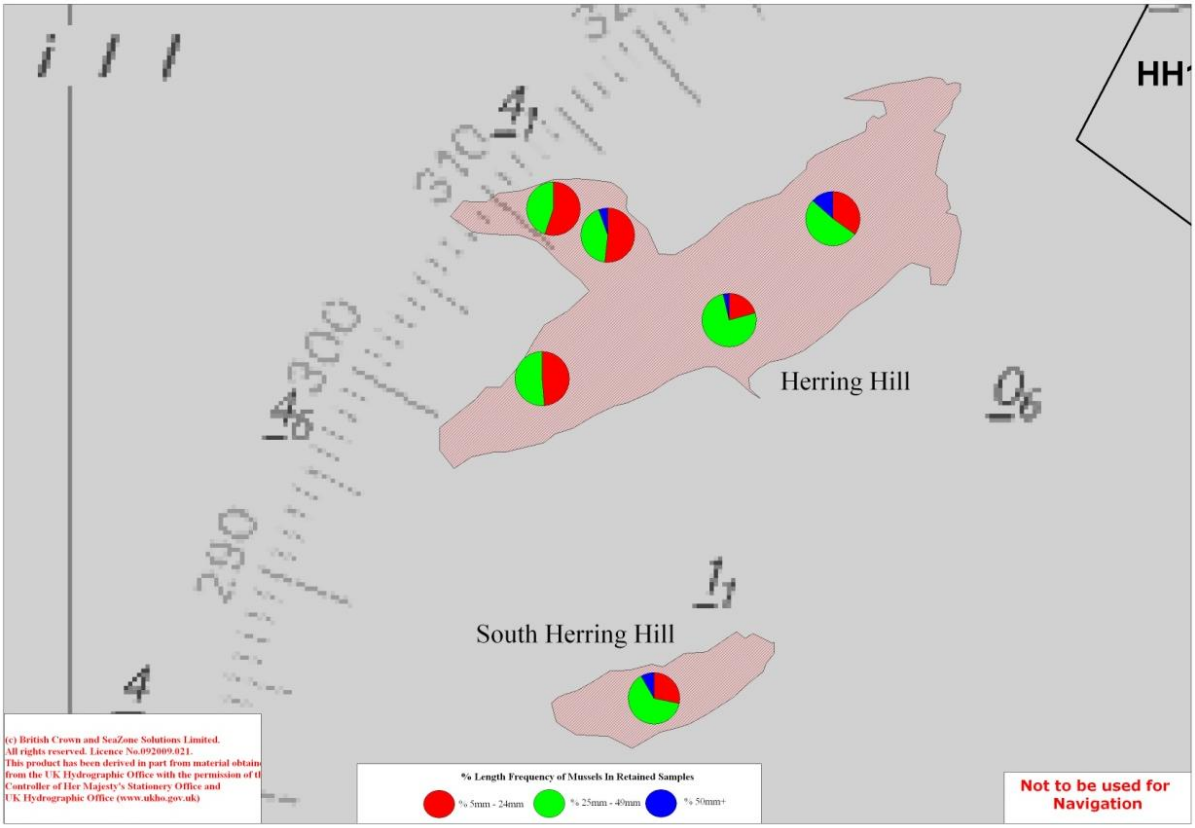

Figure 17 - Mussel size distribution on the Herring Hill mussel beds – October 2014

Erosion around the edges of the best had caused its area to fall from 28.3 hectares in 2013 to 25.1 hectares. Within this area the mussel coverage had increased from 32% to 38%, but the mean density had declined from 0.97 kg/0.1m^2 to 0.79 kg/0.1m^2. From these figures the total mussel biomass on the bed was calculated to have declined from 881 tonnes to 710. This bed had been opened to the fishery in April 2014, but little effort had been targeted there. Most of the losses were, therefore, believed to be natural

rather than due to the fishery. 96 tonnes were found to have reached a size of 45mm compared to 24 tonnes the previous year.

Figure 18, which shows the size frequency of the population on this bed, shows there had been a moderate settlement since the previous survey.

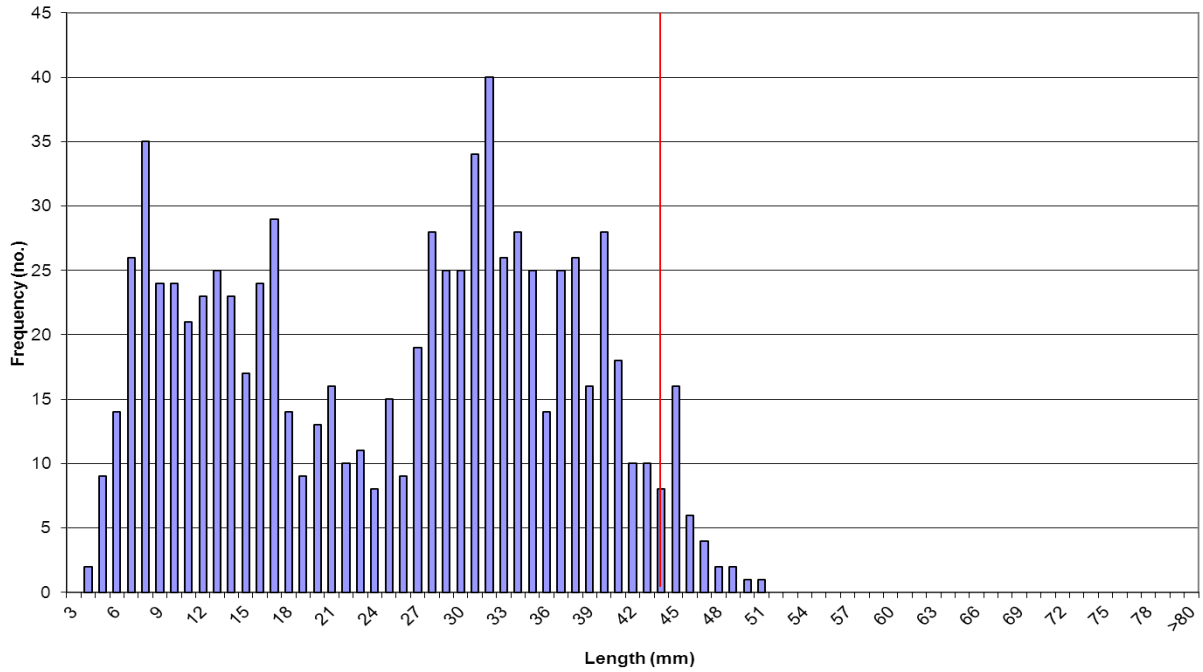

Figure 18 - Mussel size frequency on Herring Hill - October 2014

South Herring Hill

- Area: 3.9 hectares
- Coverage: 38%
- Mean Density: 0.49 kg/0.1m^2
- Total Stock: 71 tonnes
- Stock ≥ 45mm: 15 tonnes

The Herring Hill bed was surveyed on October 27th, during which samples were taken from every third "hit", producing 19 samples from a single transect. The location of the bed is shown in figure 17. Although it is close to the main Herring Hill bed, a deep channel runs between the two making access between them too dangerous to attempt on foot. Although there had been previous suspicions that a small bed was present at this location, difficulties accessing the site meant this was the first time it had been surveyed. For this survey it was accessed from the West Mare Tail bed rather than from

Herring Hill. The size range of the mussels collected during the samples (see figure 19) indicates that the bed has been present for a number of years.

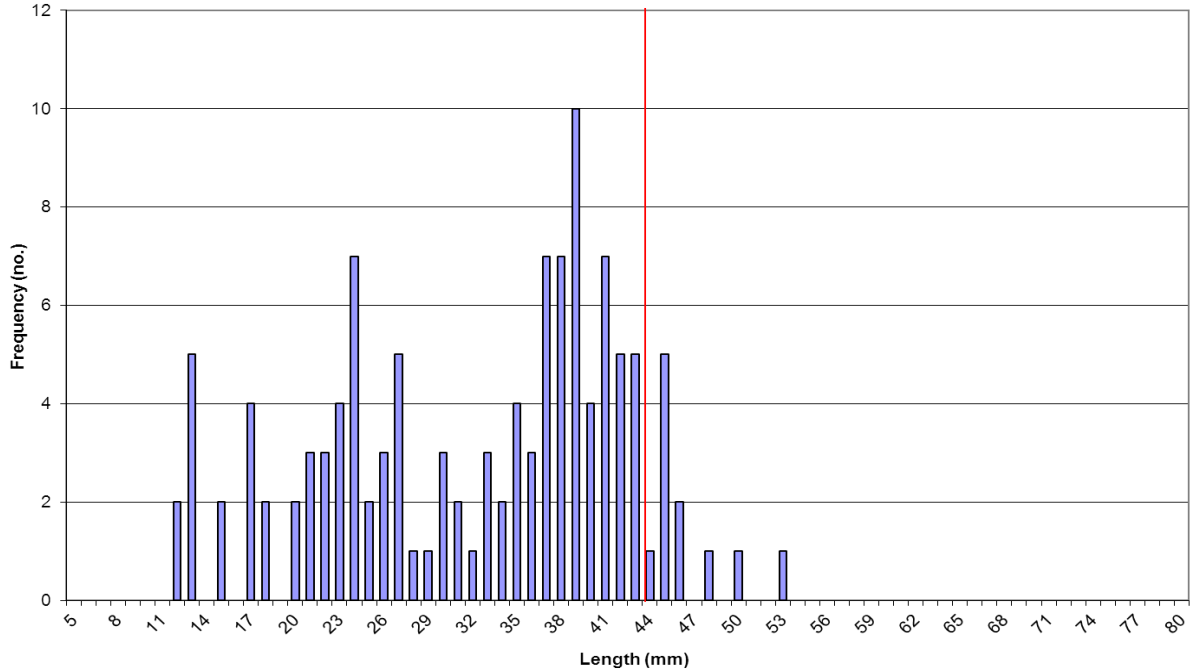

Figure 19 - Mussel size frequency on South Herring Hill - October 2014

Main End

- Area: 6.6 hectares
- Coverage: 29%
- Mean Density: 0.74 kg/0.1m^2
- Total Stock: 141 tonnes
- Stock ≥ 45mm: 111 tonnes

The Main End bed was surveyed on October 11th, during which samples were collected from every third "hit", producing 29 samples from two transects. Figures 20 and 21 show the mussel size distribution across the bed and the mussel size distribution within the samples.

In 2001 this area benefitted from a large settlement of spat. At the time this seed was considered to be vulnerable to storm damage so was opened to the relaying fishery in 2002 before it was lost to natural causes. Following this fishery a small bed remained along the edge of a large run that has remained fairly stable since. The bed has received little settlement since 2001, however, so in recent years mortality among the ageing

population has caused the bed to decline. Most of the remaining mussels in this bed are now situated in submerged ridges in the bottom of the run. This creates difficulties when surveying the bed and explains some of the fluctuations that have been seen between recent annual surveys.

The area of the bed was found to have increased slightly from 5.7 hectares in 2013 to 6.6 hectares. Within this area the coverage of the bed was found to have increased from 21% to 29%, while the mean density had declined from 0.81 kg/0.1m^2 to the 0.74 kg/0.1m^2. From these figures the total mussel biomass in the bed was calculated to have increased from 95 tonnes in 2013 to 141 tonnes. Of these, 111 tonnes were estimated to have attained 45mm compared to 76 tonnes the previous year. As mentioned above, these changes are thought to be an artefact of the difficult surveying conditions posed by this bed's location in a run bottom rather than any significant changes. This is supported by the size frequency of the mussels in the population (see figure 21) being very similar to that of the previous year.

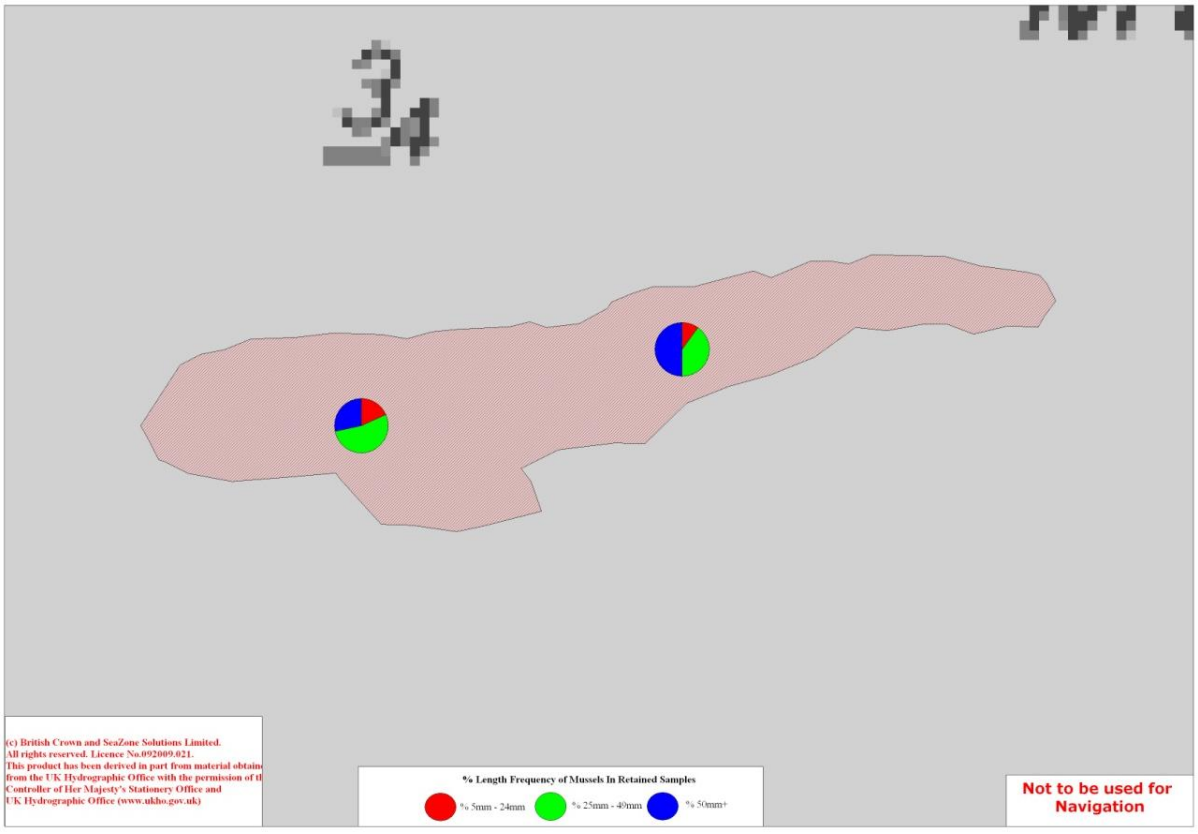

Figure 20 - Mussel size distribution on the Main End mussel bed – October 2014

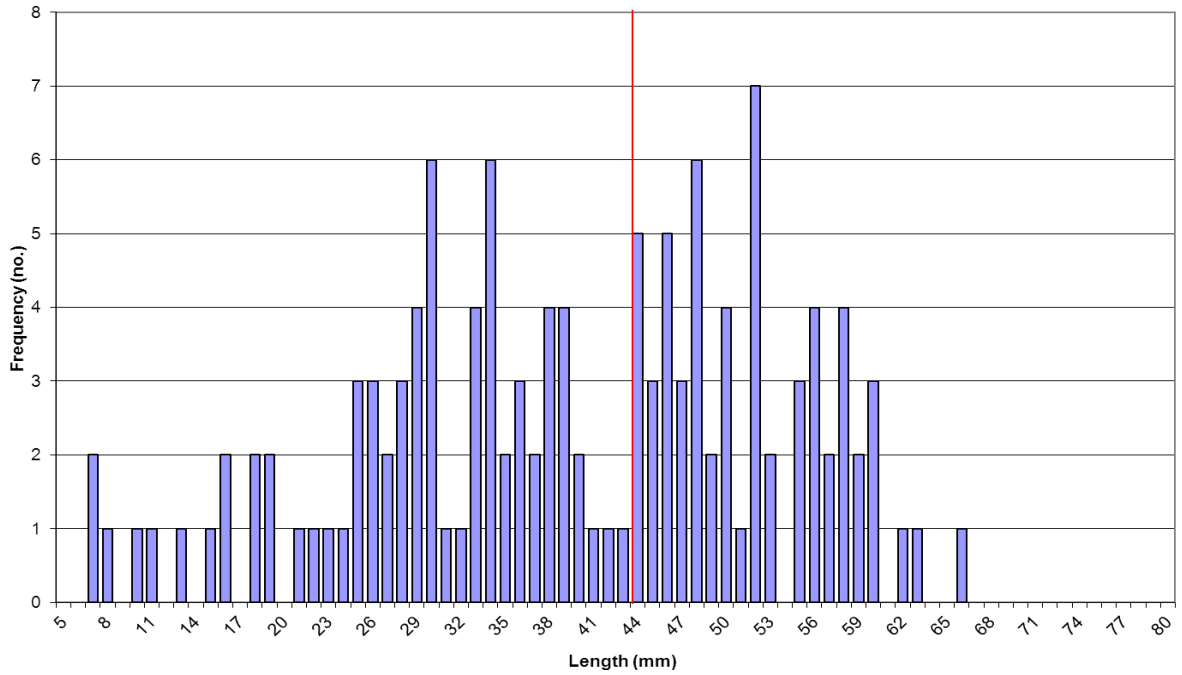

Figure 21 - Mussel size frequency on Main End - October 2014

Holbeach

- Area: 12.4 hectares
- Coverage: 37%
- Mean Density: 0.66 kg/0.1m^2
- Total Stock: 303 tonnes
- Stock ≥ 45mm: 102 tonnes

The Holbeach bed was established during the exceptional spatfall that occurred during 2001. These juveniles were considered at the time to be vulnerable to natural losses so were opened to the relaying fishery. Part of the bed remained after the fishery, which in recent years has attracted some good settlements of spat. This bed was opened to both the 2013 fishery in October and the 2014 fishery in April/May. Evidence of fishing activity was still apparent when the bed was surveyed on September 28th. During this survey samples were collected every fifth "hit", generating 44 samples from four transects. Figures 22 and 23 show the size distribution of mussels across the bed and the mussel size frequency within the population.

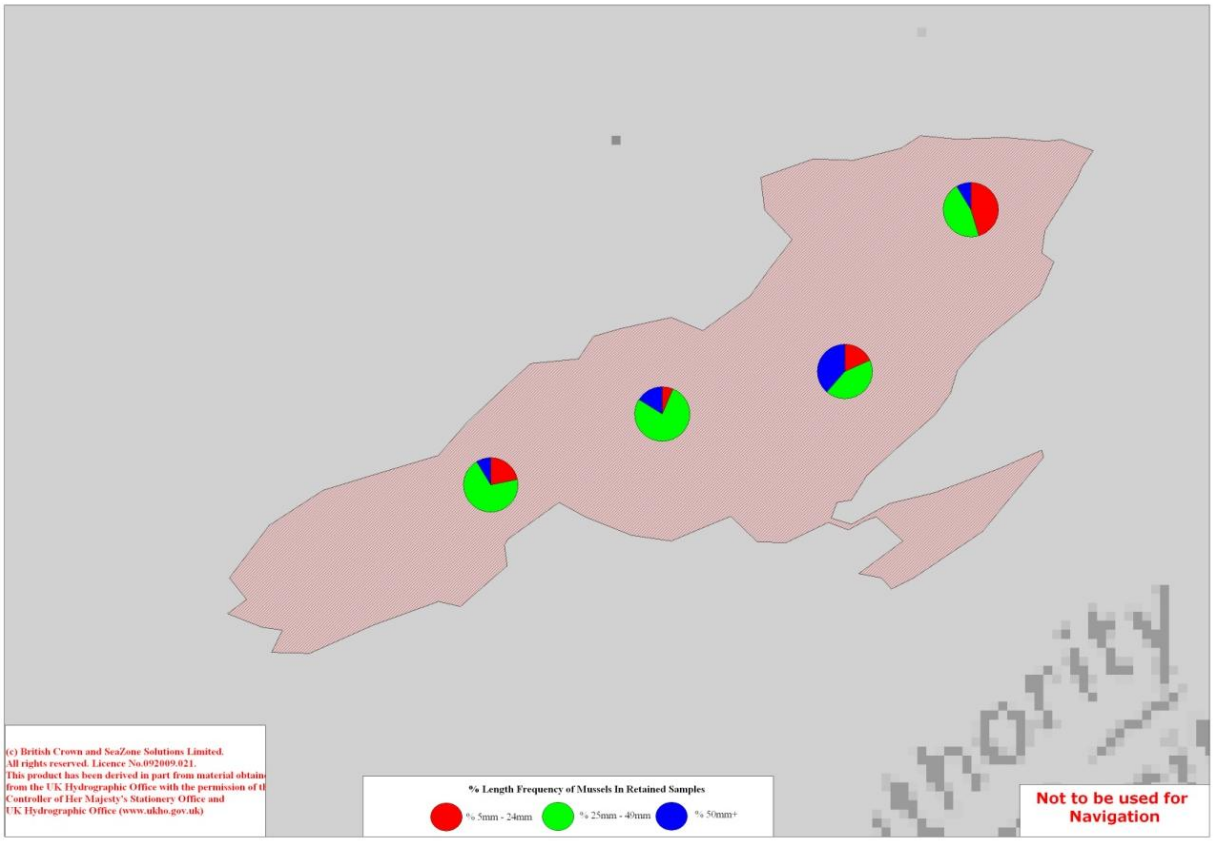

Figure 22 - Mussel size distribution on the Holbeach mussel bed – September 2014

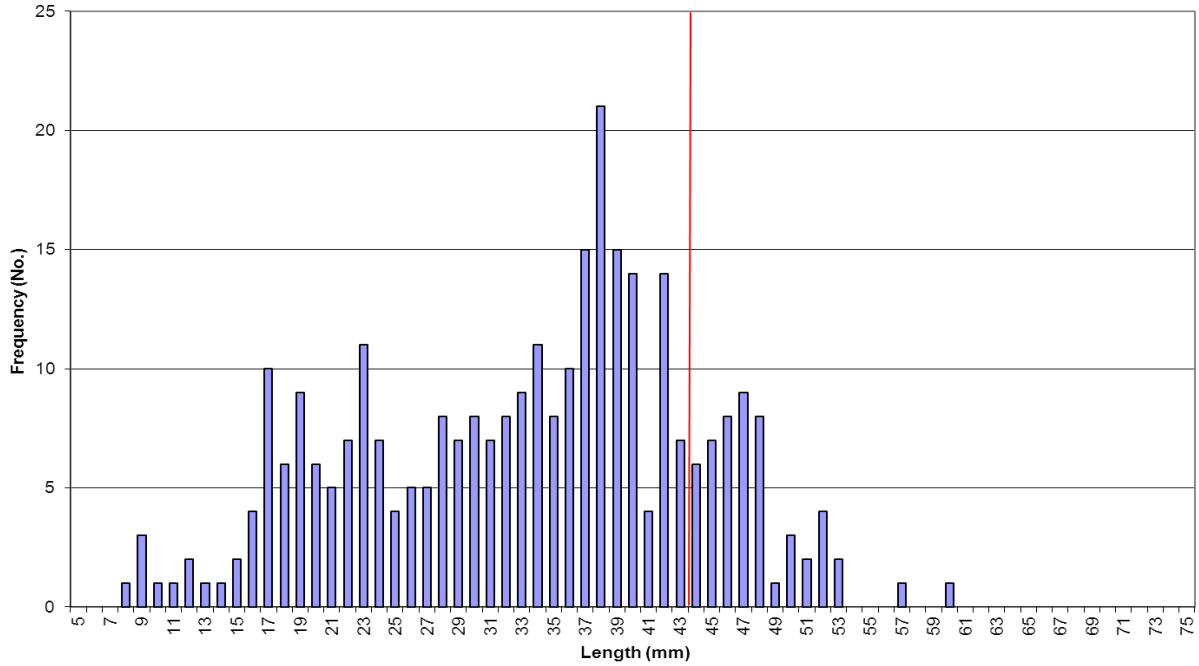

Figure 23 - Mussel size frequency on Holbeach - September 2014

At 12.4 hectares, the area of the bed was found to be similar to the 12.6 hectares recorded the previous year. Within this area, however, the coverage had declined from 45% to 37% and the mean density from 0.89 kg/0.1m^2 to 0.66 kg/0.1m^2. From these changes the total mussel biomass on the bed was calculated to have declined from 502 tonnes to 303 tonnes. Most of these losses have been attributed to the fishery. 102 tonnes of these mussels were found to have attained a size of 45mm compared to 124 tonnes the previous year.

Whereas the size distribution of the mussels in the population had shown a strong bimodal distribution in 2013, indicating a good settlement had occurred that year, this is not apparent in figure 23, showing the size distribution in 2014.

Trial Bank

- Area: 24.9 hectares
- Coverage: 33%
- Mean Density: 0.85 kg/0.1m^2
- Total Stock: 686 tonnes
- Stock $\geq$ 45mm: 137 tonnes

The Trial Bank mussel bed was surveyed on October 24th, during which samples were collected from every fifth "hit", producing 37 samples from four transects. This bed was originally established in 2001 after mussel spat settled on cockle shells. The bed subsequently attracted several other settlements and grew in area and biomass over the next decade. In 2012 the bed was opened to the fishery during which it suffered heavy disturbance, declining in biomass from 1,352 tonnes to 585 tonnes. There was another settlement in 2013 that facilitated some recovery, but the south-eastern area of the bed that had received the heaviest disturbance continued to decline. Although this area of low density mussel was included within the 2013 survey, its continued deterioration meant it was no longer included in the 2014 survey. Figure 24 shows the extent of the bed that has been lost.

Due to the loss of this part of the bed the total area was found to have declined from 44.0 hectares to 24.9 hectares. The loss of this area did mean the average coverage of mussels across the bed had increased, though, from 26% to 33%. The mean density at 0.85 kg/0.1m^2, was found to be similar to the 0.88 kg/0.1m^2 recorded the previous year. From these figures the total mussel biomass on this bed was calculated to have declined

from 1,014 tonnes to 686 tonnes. Growth of the surviving mussels meant the biomass of harvestable sized mussels had increased from 117 tonnes to 137 tonnes.

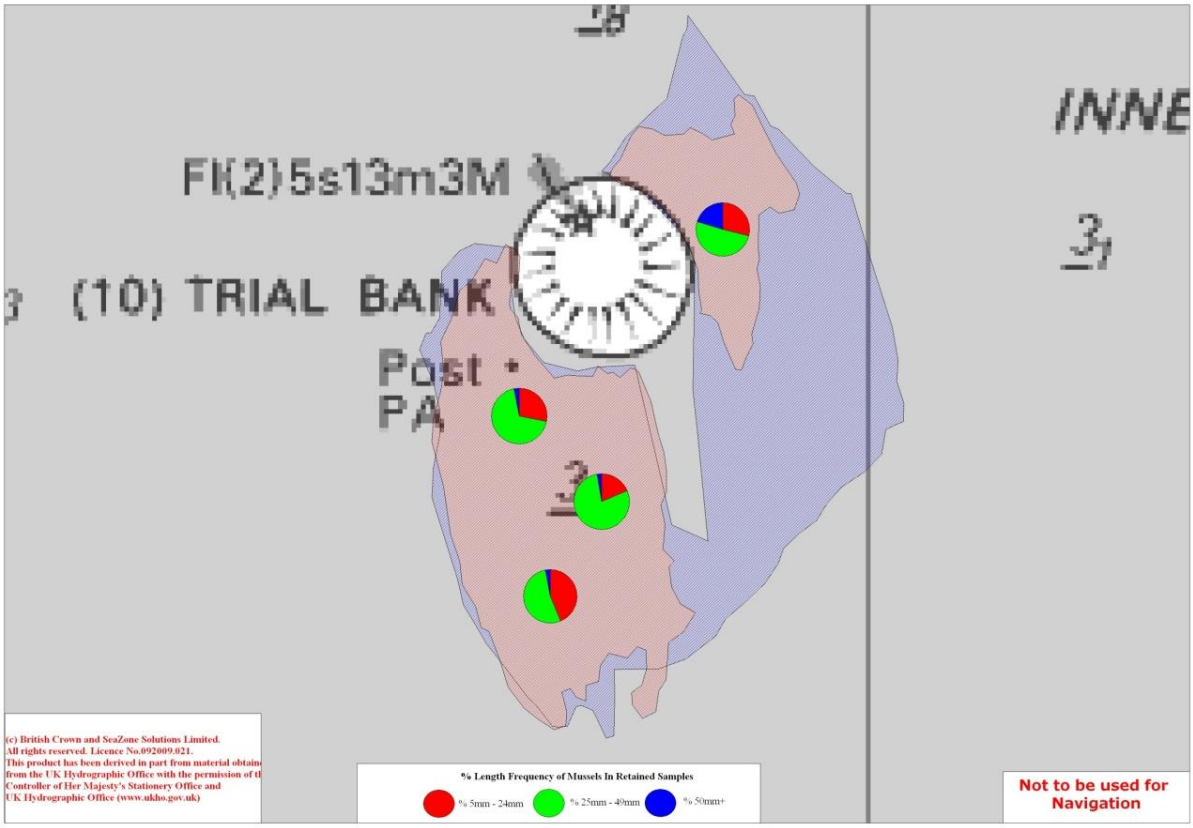

Figure 24 - Mussel size distribution on the Trial Bank mussel bed – October 2014. Extent of bed in September 2013 highlighted in blue.

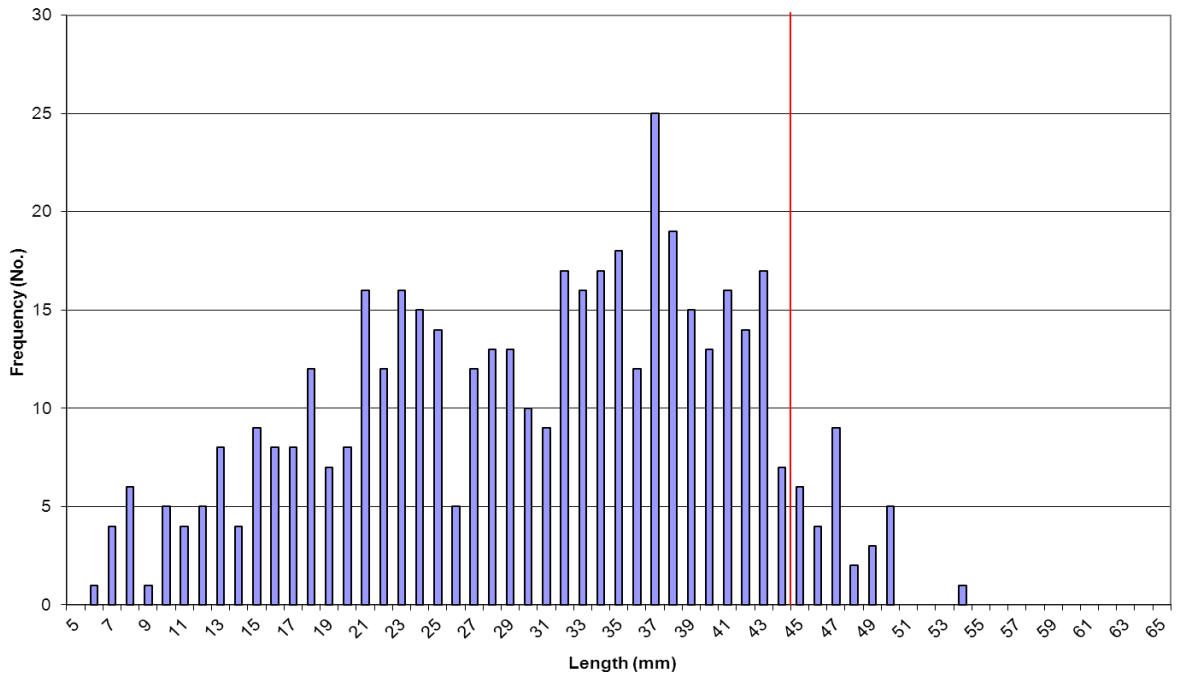

Figure 25 - Mussel size frequency on Trial Bank - October 2014

Figure 25 shows the size frequency of the mussels in the population. While the chart from the previous year showed a strong bimodal distribution following a successful settlement, this year's chart shows that those juveniles have grown but this year's settlement has been poor.

Breast Sand

In 2001 a good settlement of spat created three discrete mussel beds on the Breast sand, which for survey purposes were surveyed and reported separately. Over time the West bed extended towards the Middle bed until only a run that had originally delineated the western edge of the Middle bed separated them. Since then, disparate fishing effort on these beds resulted in the Middle bed declining in size until only the western edge remained. A good settlement of spat over the whole area in 2011 enabled both the West and East beds to increase in size. Although this encroached over ground that had formally been part of the Middle bed, this recent development resulted in two distinct beds rather than three. As such, the surveys conducted since 2011 have reported the stocks from this area as being from two rather than three beds. Figure 26 shows the mussel size distribution over these beds following the 2013 surveys.

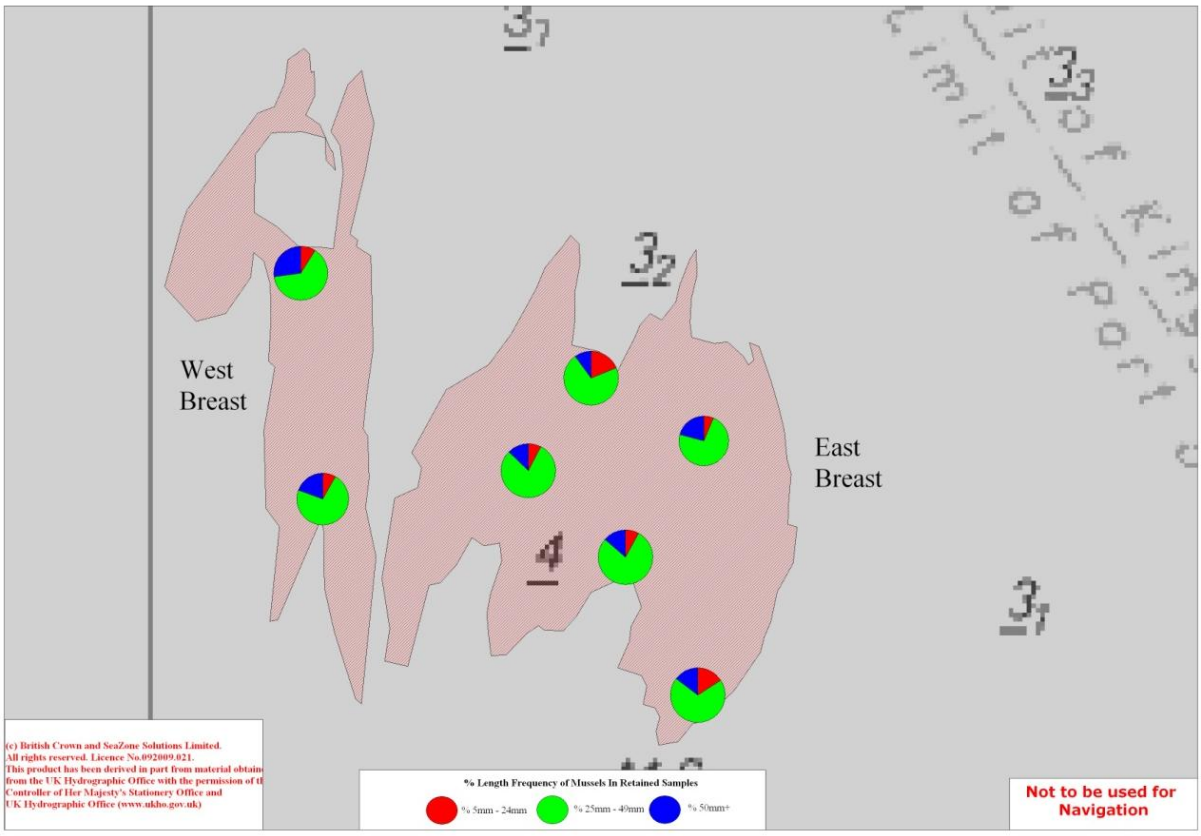

Figure 26 - Mussel size distribution on the Breast mussel beds – October 2014

West Breast

- Area: 15.4 hectares
- Coverage: 12%
- Mean Density: 0.91kg/0.1m^2
- Total Stock: 162 tonnes
- Stock ≥ 45mm: 55 tonnes

The West Breast bed was surveyed on October 23rd, during which samples were collected from every fourth "hit", producing 5 samples from two transects. Figure 27 shows the mussel size frequency within the population taken from these samples.

The area of the bed was found to have declined from 19.7 hectares in 2013 to 15.4 hectares. Within this area the coverage of mussels was found to have declined from 21% to 12%, but growth had enabled the mean density of the patches to increase from 0.76 kg/0.1m^2 to 0.91 kg/0.1m^2. From these figures the total biomass of mussels on this bed was calculated to have decreased from 316 tonnes to 162 tonnes. Individual growth helped the stock of mussels that had reached harvestable size increase from 32 tonnes to 55 tonnes.

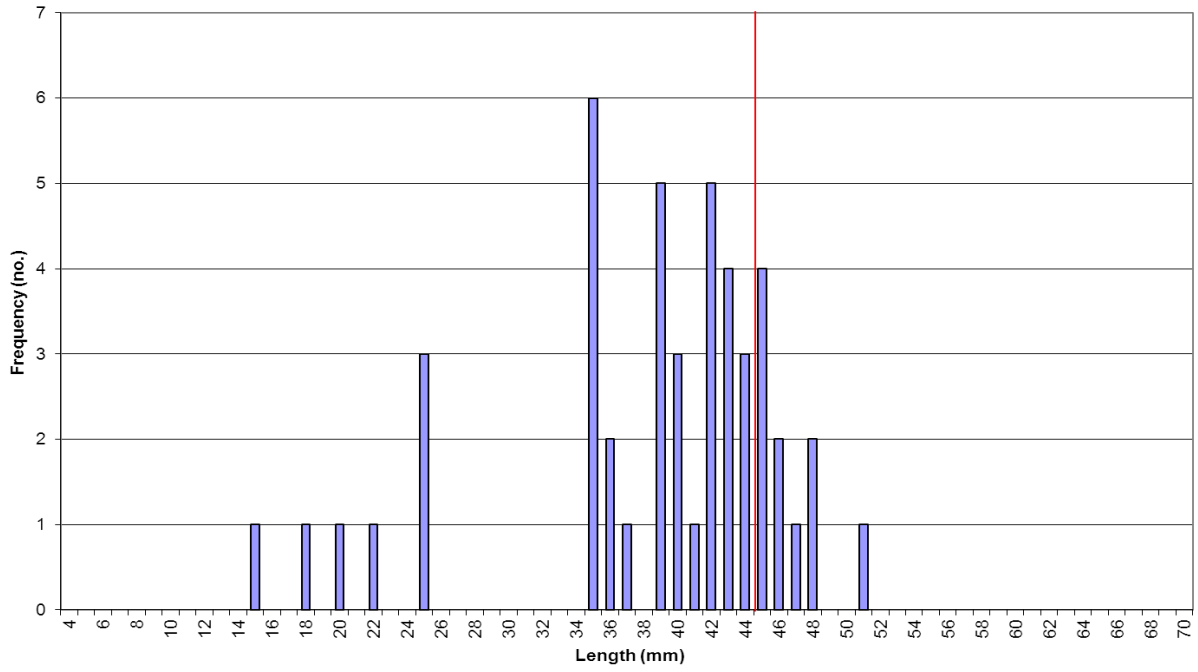

Figure 27 - Mussel size frequency on West Breast – October 2014

East Breast

- Area: 31.7 hectares
- Coverage: 26%
- Mean Density: 1.08 kg/0.1m^2
- Total Stock: 893 tonnes
- Stock ≥ 45mm: 247 tonnes

The East Breast bed was surveyed on October 23rd, during which samples were collected from every fourth "hit", producing 49 samples from five transects.

At 31.7 hectares, the area of the bed was similar to the 31.9 hectares recorded the previous year. Within this area, though, the mussel coverage was found to have declined from 30% to 26% and the mean density from 1.20 kg/0.1m^2 to 1.08 kg/0.1m^2. From these figures the total biomass of mussels on this bed was calculated to have declined from 1,154 tonnes to 893 tonnes. The bed had been opened to the both of the dredged relaying fisheries in October 2013 and April 2014 so these losses had been anticipated. Growth of the surviving mussels in the bed helped the biomass of harvestable sized mussels increase from 143 tonnes to 247 tonnes.

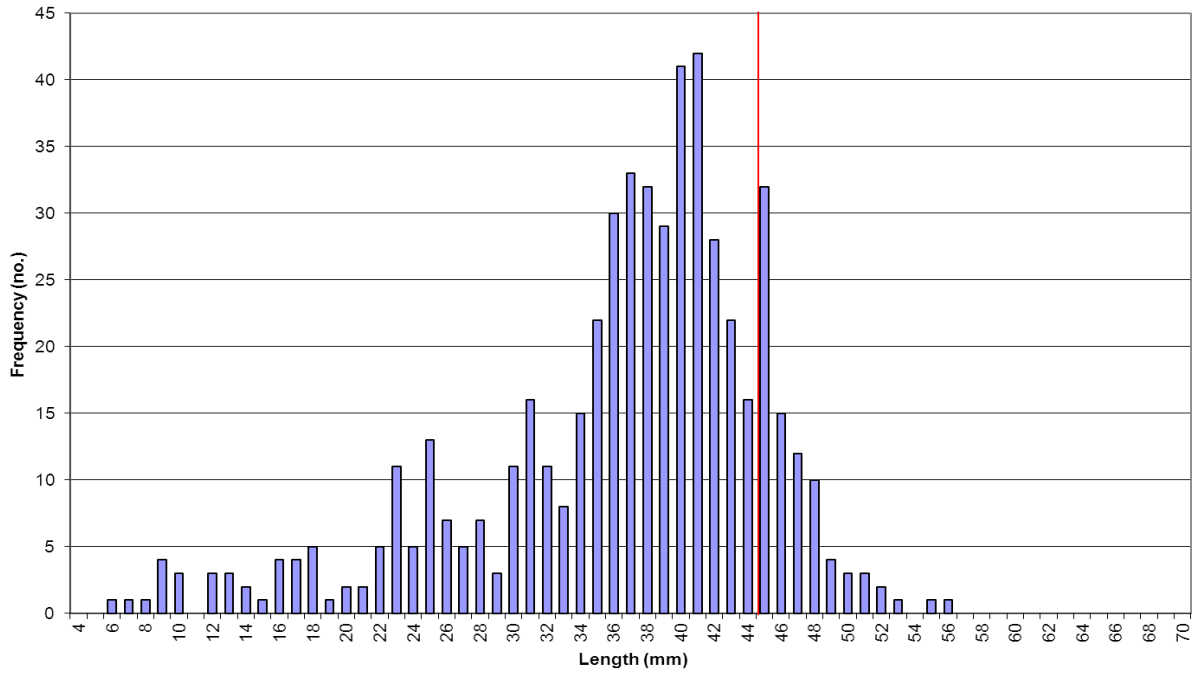

Figure 28 - Mussel size frequency on East Breast – October 2014

Figure 28, which shows the size frequency of mussel in the population on this bed, highlights settlement has been poor this year.

East Scotsman's Sled

- Area: 36.9 hectares
- Coverage: 24%
- Mean Density: 0.33 kg/0.1m^2
- Total Stock: 291 tonnes
- Stock ≥ 45mm: 78 tonnes

The Scotsman's Sled bed was surveyed on September 29th, during which samples were collected from every fourth "hit", producing 35 samples from four transects. Figures 29 and 30 show the mussel size distribution over the bed and the mussel size frequency within the population taken from these samples.

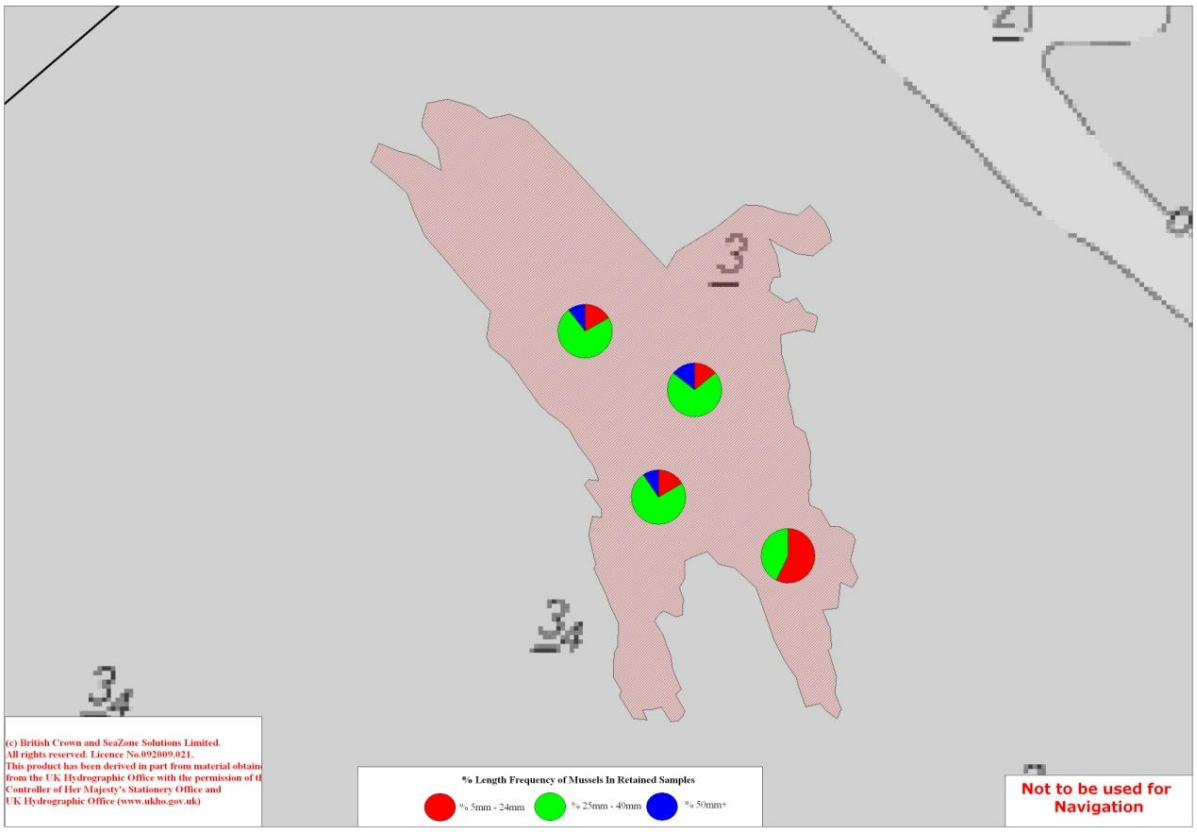

Figure 29 - Mussel size distribution on the East Scotsman's Sled mussel bed – September 2014

The survey found that following a light settlement of mussel spat in 2013, the bed was slowly extending north-west into an area that had formally supported mussels until they had been removed during a dredge fishery in 2004. Although the mussel density in this area is still very low, it is the first sign of any recovery following that fishery. Further

expansion in this area meant the area of the bed had increased from 31.0 hectares to 36.9 hectares. Within this area the mussel coverage over the bed had increased from 21% to 24% but the mean density had declined from 0.55 kg/0.1m^2 to 0.33 kg/0.1m^2. From these figures the total biomass of mussels on the bed was calculated to have declined from 365 tonnes to 291 tonnes. Of these, 78 tonnes had attained a size of 45mm compared to 106 tonnes the previous year.

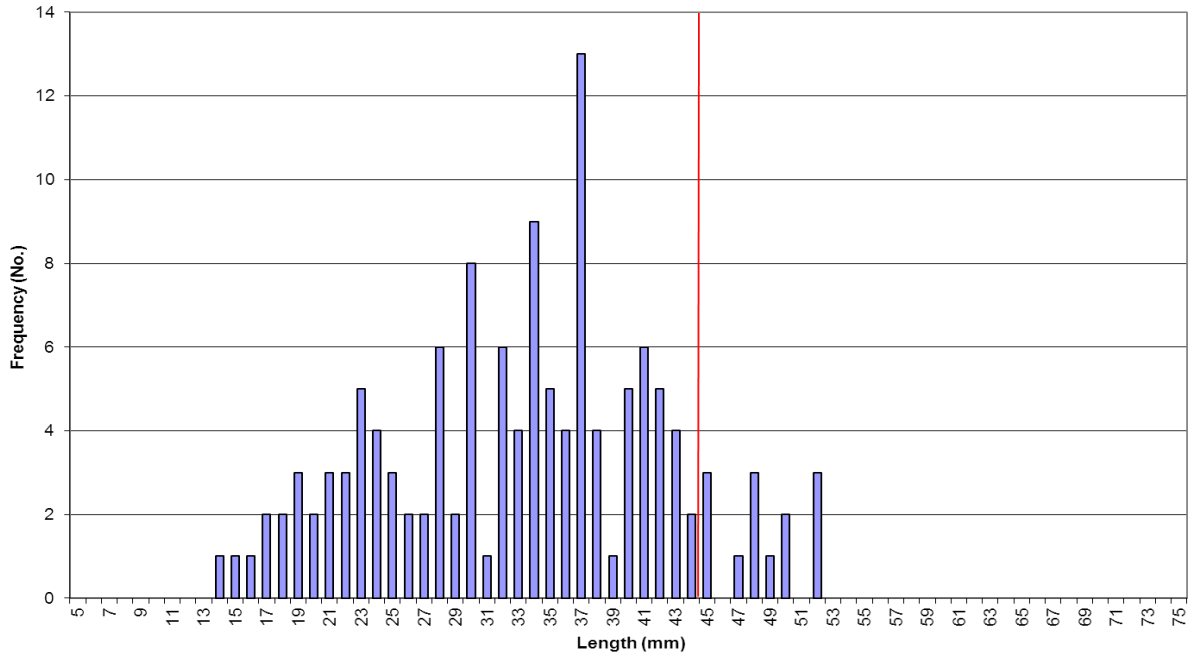

Figure 30 - Mussel size frequency on East Scotsman's Sled - September 2014

2.3.10 Pandora

- Area: 9.5 hectares
- Coverage: 21%
- Mean Density: 0.74 kg/0.1m^2
- Total Stock: 149 tonnes
- Stock ≥ 45mm: 139 tonnes

The Pandora bed was surveyed on October 7th, during which samples were collected from every second "hit", producing 32 samples from two transects. Figure 31 shows the mussel size distribution within the bed while figure 32 shows the mussel size frequency within the population taken from the samples.

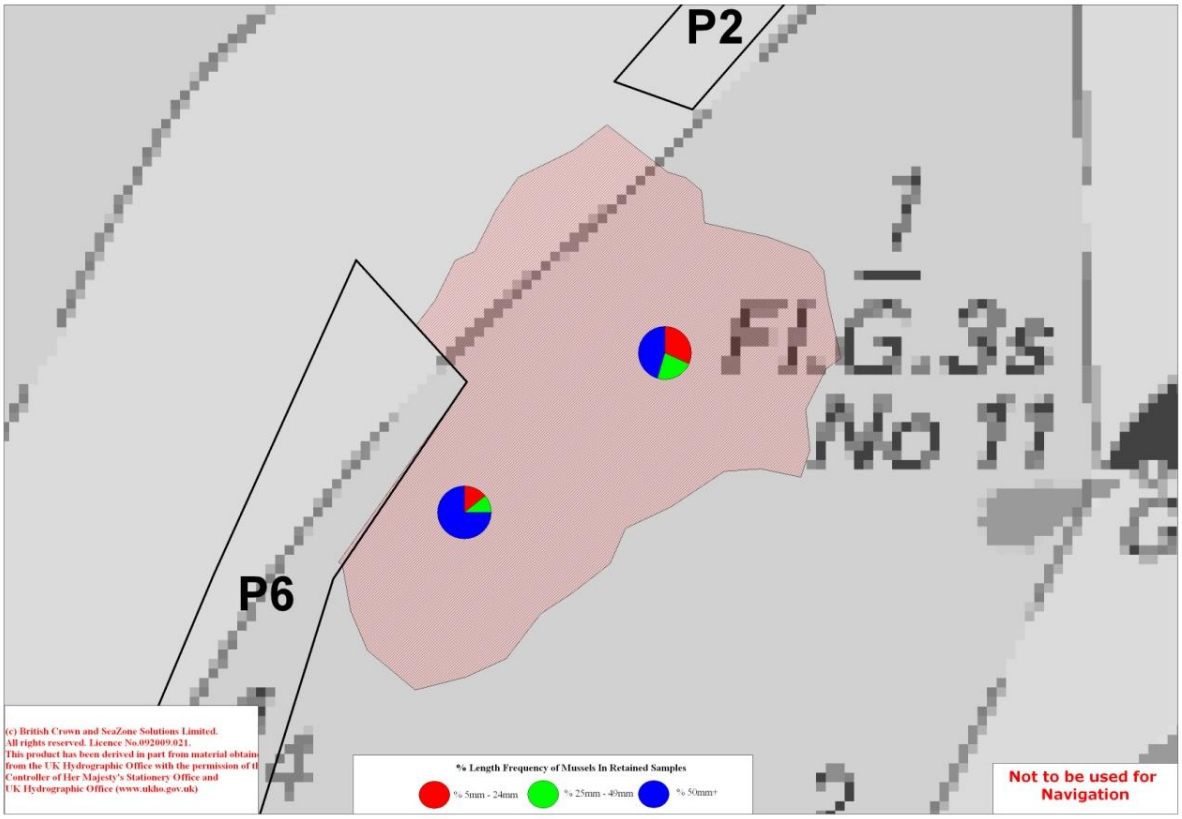

Figure 31 - Mussel size distribution on the Pandora mussel bed – October 2014

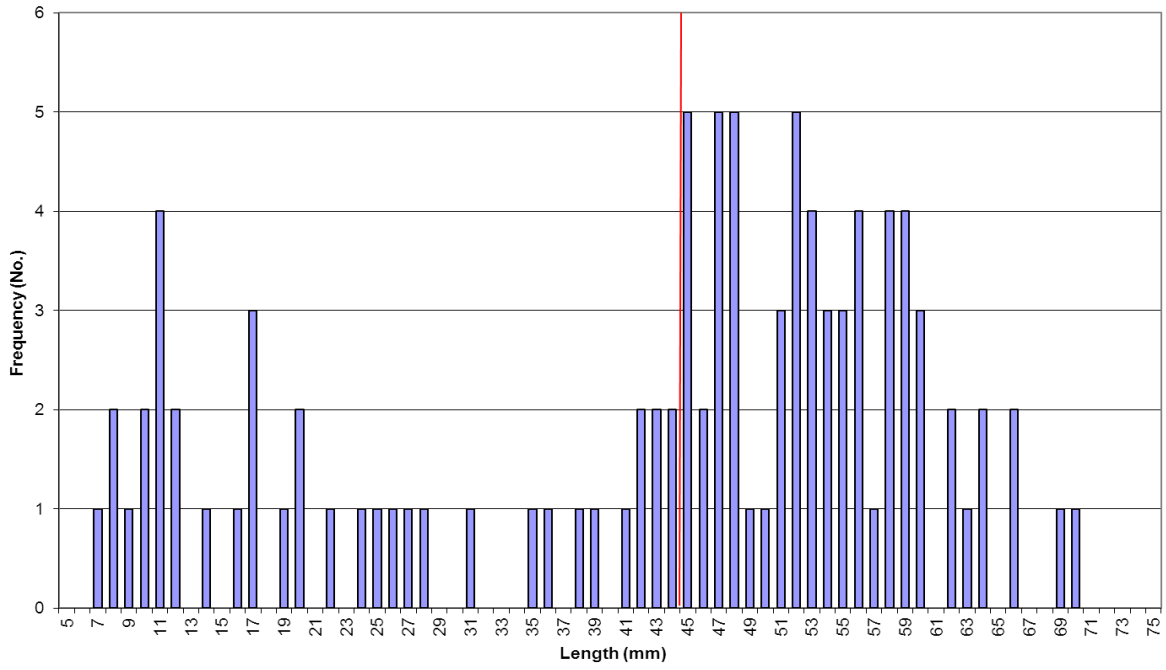

Figure 32 - Mussel size frequency on East Scotsman's Sled – October 2014

The Pandora bed was established during the exceptional settlement that occurred in 2001. Since that initial settlement the bed has attracted little further natural recruitment, resulting in an ageing population. Over most of this bed the mussels are

now present in low densities in small scattered clumps situated in ridges of mussel and clam shells. This makes surveying the bed difficult, particularly when trying to determine the extent of the bed amid the shells. As a result, successive annual surveys often show more variation in the statistics for this bed than actually occurs. During the recent survey the area of the bed was estimated to be 9.5 hectares, almost double the 5.2 hectares recorded the previous year. This is more than likely due to lower density patches around the periphery of the bed being included in this year's survey but not in the one from 2013. The decline of the mussel coverage from 26% to 21% and the mean density from 0.99 kg/0.1m^2 to 0.74 kg/0.1m^2 supports this. From these figures the total biomass of mussels on this bed was calculated to be 149 tonnes, compared to 135 tonnes in 2013. Of these, 139 tonnes were found to have attained a size of 45mm.

Blackshore

- Area: 21.6 hectares
- Coverage: 17%
- Mean Density: 0.46 kg/0.1m^2
- Total Stock: 171 tonnes
- Stock $\geq$ 45mm: 104 tonnes

The Blackshore bed was surveyed on September 23rd, during which samples were collected from every third "hit", producing 43 samples from five transects. Figures 33 and 34 show the mussel size distribution within the bed and the mussel size frequency of the population taken from these samples.

This bed was first established in 2010 and following a second settlement in 2011, grew quickly in size to a peak biomass of 852 tonnes in 2012. It was opened during both the 2012 and 2013 fisheries but did not attract much fishing effort. The 2013 survey found there had been high mortalities among the 3 year-old mussels on this bed, however, that reduced the biomass to less than half of what it had been. The 2014 survey found this decline had continued, with many of the 2011 year-class cohort having died. As a consequence, the area of the bed had declined from 23.2 hectares to 21.6 hectares, the coverage from 26% to 17% and the mean density from 0.68 kg/0.1m^2 to 0.46 kg/0.1m^2. From these figures the total biomass of mussels on the bed was calculated to have declined from 386 tonnes to 171 tonnes. Of these, 104 tonnes had reached a size of 45mm compared to 187 tonnes the previous year.

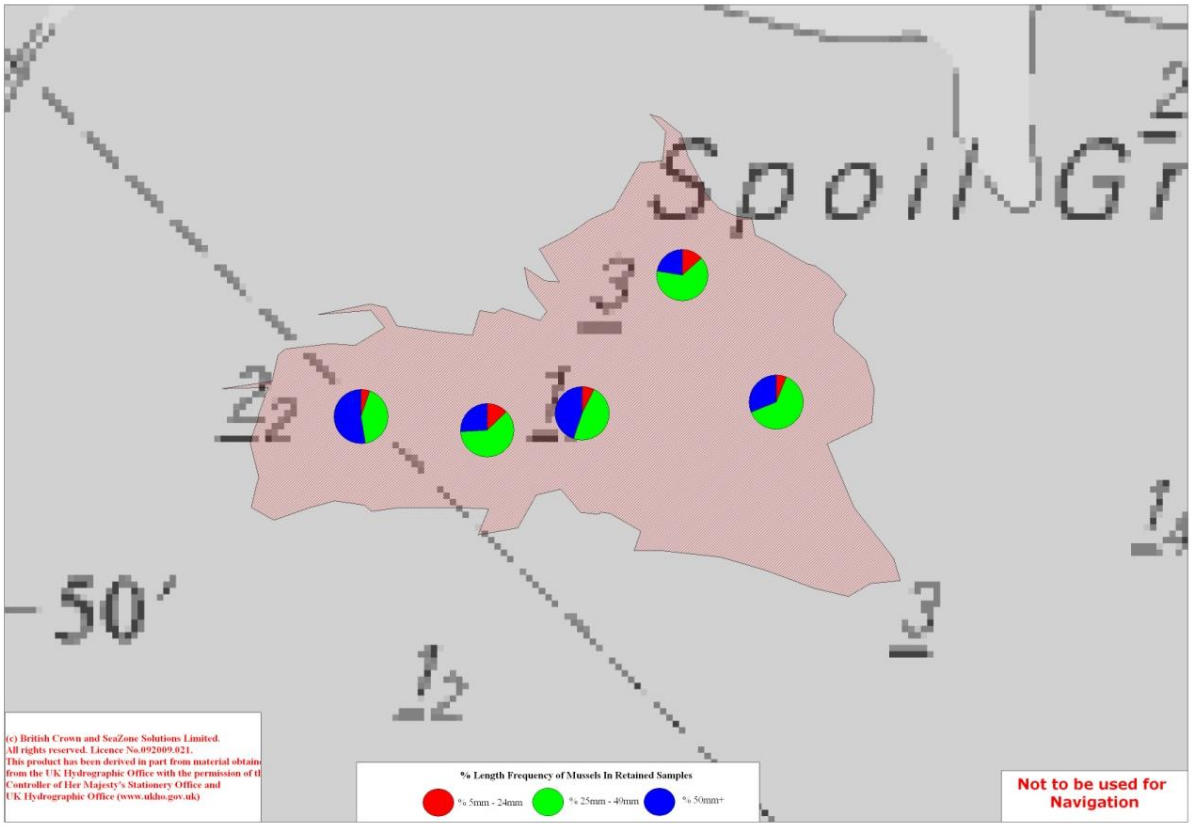

Figure 33 - Mussel size distribution on the Blackshore mussel bed – September 2014

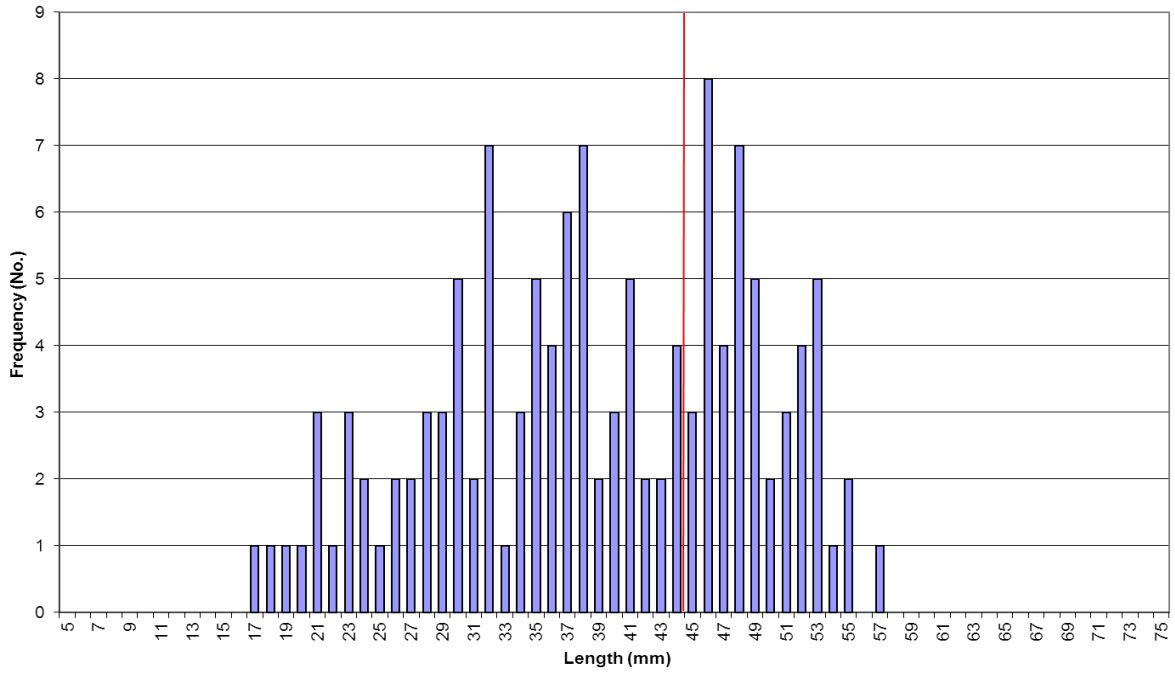

Figure 34 - Mussel size frequency on Blackshore - September 2014
Welland Bank

- Area: 1.6 hectares
- Coverage: 72%
- Mean Density: 1.87 kg/0.1m^2
- Total Stock: 210 tonnes
- Stock ≥ 45mm: 127 tonnes

Historically the rocks forming the north-west bank of the River Welland training wall have supported mussels. This wall is completely immersed during high water periods, and consequently in places mussels are found attached to the rocks on both sides of the wall. Although it is only possible to hand work these stocks, in some years over twenty vessels have exploited the mussels found there.

Figure 35 - Photograph of the River Welland at mid-water, showing the exposed banks

Because of the nature of the wall, it is not possible to measure the perimeter of the stocks in the usual manner. Instead an area of coverage is calculated by measuring the width of the band that the mussels are growing along, and multiplying this figure by the distance which the mussels maintain this width. The coverage and mean density are measured using a similar method to that used on the intertidal beds, but as it would be dangerous to attempt walking transects along the wall, a series of samples are tested at

distances along the wall (see figure 36). As the best coverage of mussels on this wall is found at the lower extremities, the survey is preferably conducted at low water on the largest possible tide.

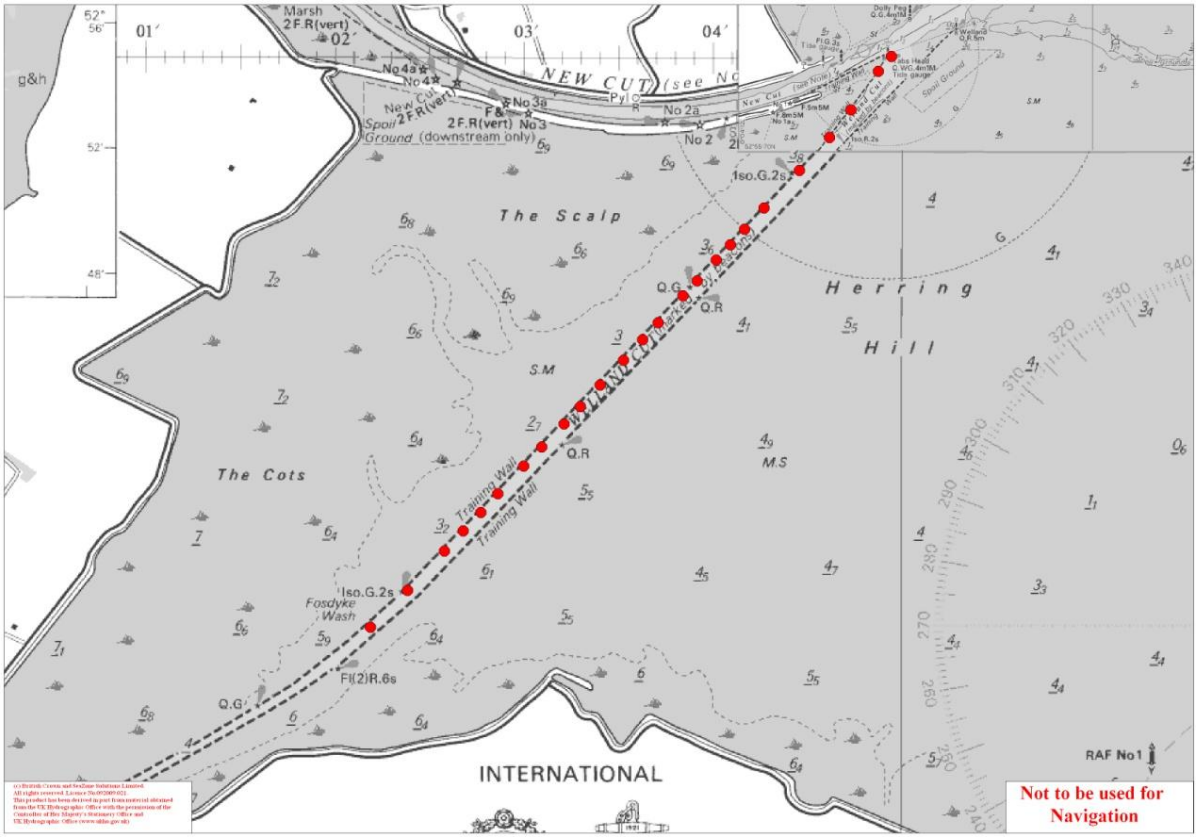

Figure 36 Chart showing the positions of sample sites on the Welland Bank – October 2014

The Welland Bank survey was conducted on October 10th, over the low water period of an 8.3m tide. Samples were collected from every second "hit", producing 25 samples from 25 sample stations. Figure 37 shows the mussel size frequency of the population taken from these samples.

The area occupied by mussels was found to have declined from 2.3 hectares to 1.6 hectares. Within this band the coverage of mussels was found to have increased from 69% to 72% but the mean density had declined from 2.12 kg/0.1m^2 to 1.87 kg/0.1m^2. From these figures the total biomass of mussels on the bank was calculated to be 210 tonnes, a reduction from the 328 tonnes recorded there the previous year. Of these, 127 tonnes were of harvestable size compared to 214 tonnes the previous year.

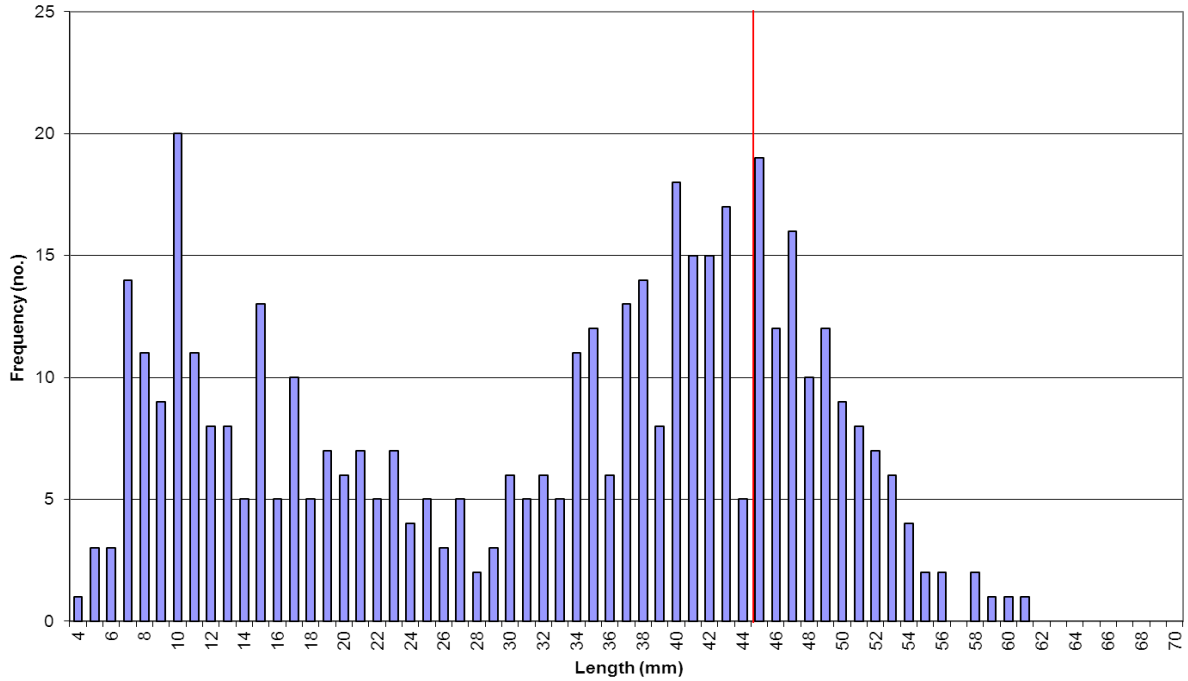

Figure 37 - Mussel size frequency on Welland Bank – October 2014

Discussion

Figure 38 shows the biomass of mussels that have been present on the inter-tidal beds of the Wash since 2002, and how these compare to the Conservation Objective targets for the site. Although from the chart it can be seen that management measures stabilized the stocks around their respective Conservation Objective targets between 2004 and 2009, since then they have ran into difficulties. Following high mortalities during 2010, attributed to the copepod parasite, *Mytilicola intestinalis*, stock levels crashed and have never fully recovered. While the biomass of juvenile mussels has since fluctuated, the adult stock has remained consistently low. Even though there was only a small fishery during in 2014, and the survey identified two new beds, the overall stock declined from 12,100 tonnes to 10,127 tonnes.

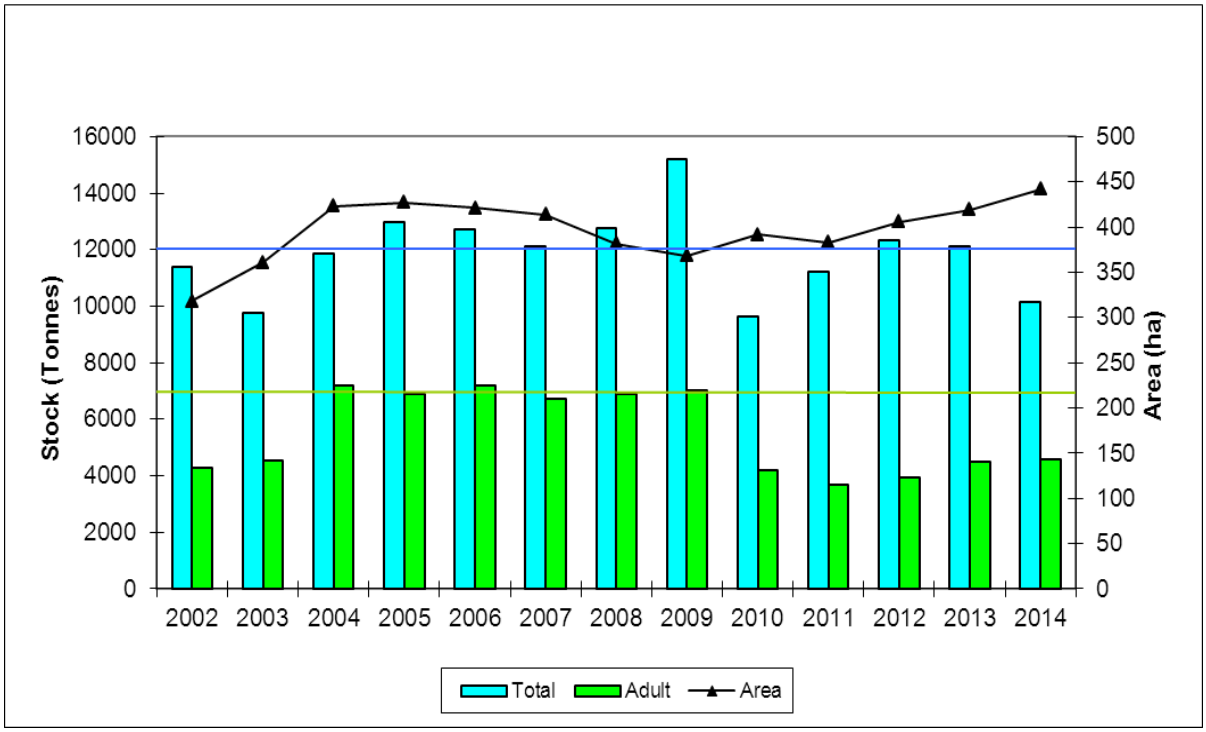

Figure 38 – Intertidal mussel stock levels in the Wash since 2002 and the Conservation Objective targets

The main reason for the decline in recent years is due to the high levels of mortality that has been observed among three-year old mussels. The causal factor(s) for the mortalities are not presently known but are having a serious impact on the number of juvenile mussels that are able to recruit to the adult stock. This in turn is having serious implications on the size of the spawning stock and the overall mussel biomass. Usually mussels are a relatively long-lived species, offering a degree of stability to the beds during periods when spatfalls are poor. The current level of mortality occurring among each subsequent year-3 cohort is endangering this stability, however. Because the

average life-expectancy of the population has been reduced, there is a greater reliance on annual recruitments to replenish losses. Unfortunately, recruitment has been generally poor for several years and particularly so during 2014. As an outcome, most of the beds are declining at alarming rates and are showing little sign of recovery. This in itself creates a vicious circle. In the Wash the best settlements have been observed to occur either within existing clumps of mussels or, less frequently, on areas of ridged-out cockles. Healthy mussel beds provide a raised matrix composed of live mussels and dead shells bound together with byssus threads. Such structures not only provide ideal conditions for seed to settle, but also provide shelter from adverse weather and predators. As the beds decline, however, these raised matrices disappear making the beds less likely to attract new seed.