# 2018 WFO Inter-tidal mussel stock assessment

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# 2018 WFO MUSSEL STOCK ASSESSMENT

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## 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. Despite their importance, heavy fishing activity coupled with low recruitment, resulted in a crash in the stocks in the 1990s. Irrespective of draconian fishery management measures being applied following the crash, recovery was slow until an exceptional spatfall in 2001 rejuvenated several of the beds and helped new ones to develop. Following this recovery, an increasing awareness of the mussel beds as an important environmental resource led to a comprehensive review of the management measures for shellfish in The Wash being conducted. In addition to fishery management measures being introduced for reasons of stock sustainability, the beds became protected under the SAC and SSSI designations of the site and Conservation Objective targets were introduced. To help managers achieve these conservation targets, a suite of shellfish management policies was agreed between the Authority, Natural England and fishermen in 2008. These policies have subsequently formed the framework guiding the management measures for The Wash mussel and cockle fisheries since then.

Two of the main conservation targets that affect the mussel fishery are the requirements to maintain a total stock of mussels above 12,000 tonnes and an adult[1] stock above 7,000 tonnes. Following the introduction of these targets the mussel stocks have stabilised from the “boom and bust” fishery patterns seen the 1980s and 1990s but have still been subject to natural variations that on occasions have caused stocks to fall below target levels. The most impacting of these occurred between 2009 and 2010, when the stocks declined from a

[1] Mussels ≥45mm length

healthy level of 15,188 tonnes to 9,626 tonnes and the adult stock biomass declined from 7,011 tonnes to 4,189 tonnes. Cefas attributed the cause of this die-off to an unusually high abundance of the parasitic copepod, *Mytilicola intestinalis* that were present in samples.

Although in the three years following this crash there was sufficient recovery for the total stock of mussels to achieve its 12,000 tonnes Conservation Objective target in 2012, since then the figures have fluctuated between 9,366 tonnes.in 2015 and 15,953 tonnes in 2017. During the same period, the adult mussel population has failed to recover sufficiently reach its 7,000 tonnes target. This has mainly been due to unusually high levels of mortality among younger mussels (typically 2 or 3 years old), which has resulted in their recruitment into the adult population being insufficient to replace those adults lost to natural mortality. As a consequence of these high mortalities, most of the beds have suffered severe declines and are in poor condition. In many cases, prolonged periods of decline have resulted in reduced mussel densities, culminating in loss of habitat as erosion has caused bare patches to appear within beds or the outer edges of beds to retreat inwards.

The reason for the high mortality rates among young mussels is not currently known, but the *Mytilicola intestinalis* parasite, which Cefas considered was a causal factor in the 2010 die-off, is still present in the stocks. Scientific literature, however, is divided over whether this parasite is responsible for widespread die-offs among its hosts (Bower, 2009). It is thought, therefore, that if *Mytilicola* is a causal factor in the mortalities, other environmental factor must also be contributing. Mortalities seem to be higher on the wild beds than have been reported from the lays, suggesting the high elevation of the wild beds could be an added stress. The particularly high mortality rates among 2 and 3 year-old mussels could also indicate spawning behaviour may be having an influence, too.

## Method

The intertidal mussel surveys in The Wash are conducted on foot 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).

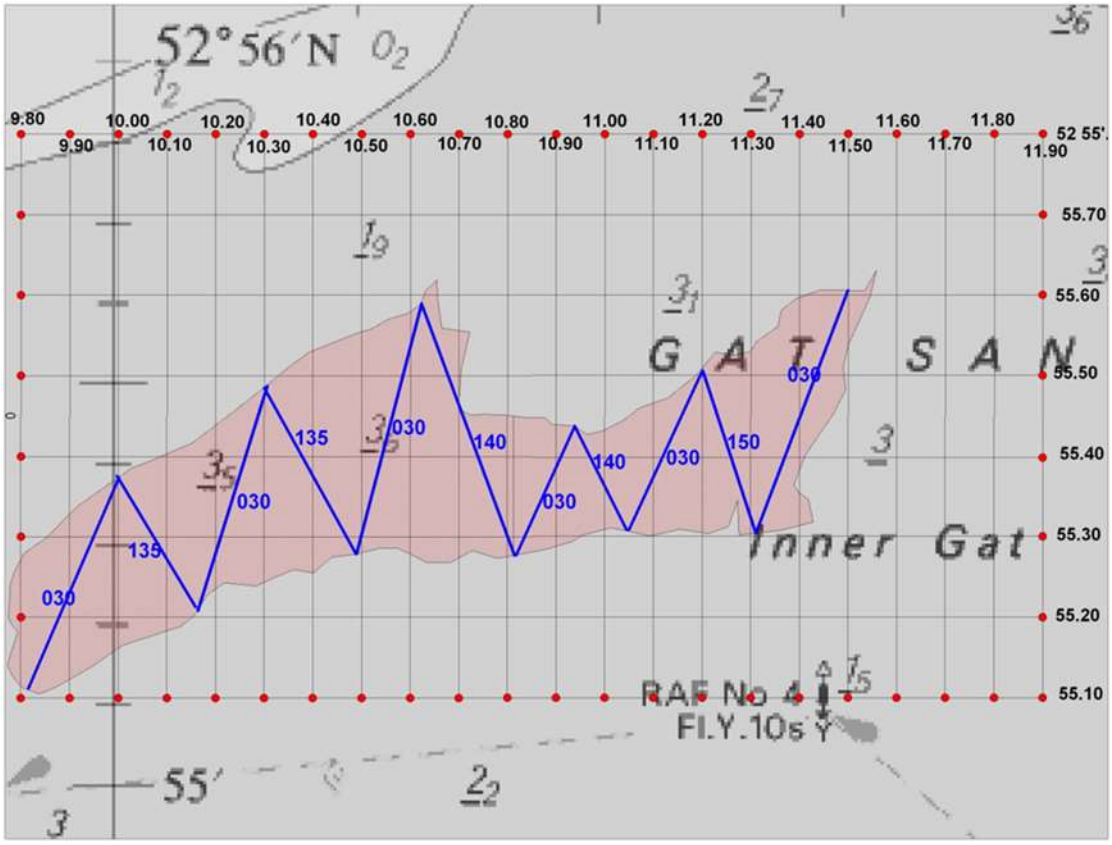


**Figure 1 – Chart showing the area of a mussel bed, the transect lines to be surveyed, their bearings and an overlaid grid showing the latitude and longitude**

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 sample 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.

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. Since 2012 the number and weight of mussels ≥25mm length have 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 inter-tidal mussel beds in The Wash are usually surveyed each autumn between September and October, when mussels tend to peak in yield. However, this year recurring difficulties with both poor weather and vessel breakdowns severely impacted on the planned survey programme. This resulted in some of the surveys being conducted in February and 4 of the 20 beds remaining unsurveyed. These included Herring Hill, West Mare Tail, West Breast and Pandora. In addition to the inter-tidal beds, the mussels on the Welland Bank were also surveyed. The distribution of the surveyed (red) and unsurveyed (blue) beds are shown in Figure 2'

Following a widespread settlement of mussel seed in 2016, that had benefited most of the inter-tidal beds and helped the stocks to reach 15,953 tonnes in 2017, there was concern that the beds could be vulnerable to high mortalities during 2018 due to the high proportion of young mussels in the population. The 2018 surveys found these concerns were justified, with all but one of the surveyed beds declining in mussel biomass. Figure 3 highlights were these changes in biomass occurred.

After stock estimations had been made for the 4 unsurveyed beds, the total mussel stock was estimated to have declined to 12,482 tonnes. There had been a relaying fishery in the spring, but this had only been lightly targeted with 109 tonnes being removed - mainly from the Trial Bank bed. Most of the reduction appeared to be natural, therefore, mainly as a result of high mortalities among young mussels of the 2016 year-class cohort. In addition to the decline in mussel biomass, the overall extent of the mussel beds was found to have decreased from 521 hectares to 495 hectares, mostly due to the loss of some of the areas that had newly settled in 2017.

Table 1 details the stocks present at the time of the 2018 surveys (including estimated figures for the 4 unsurveyed beds).

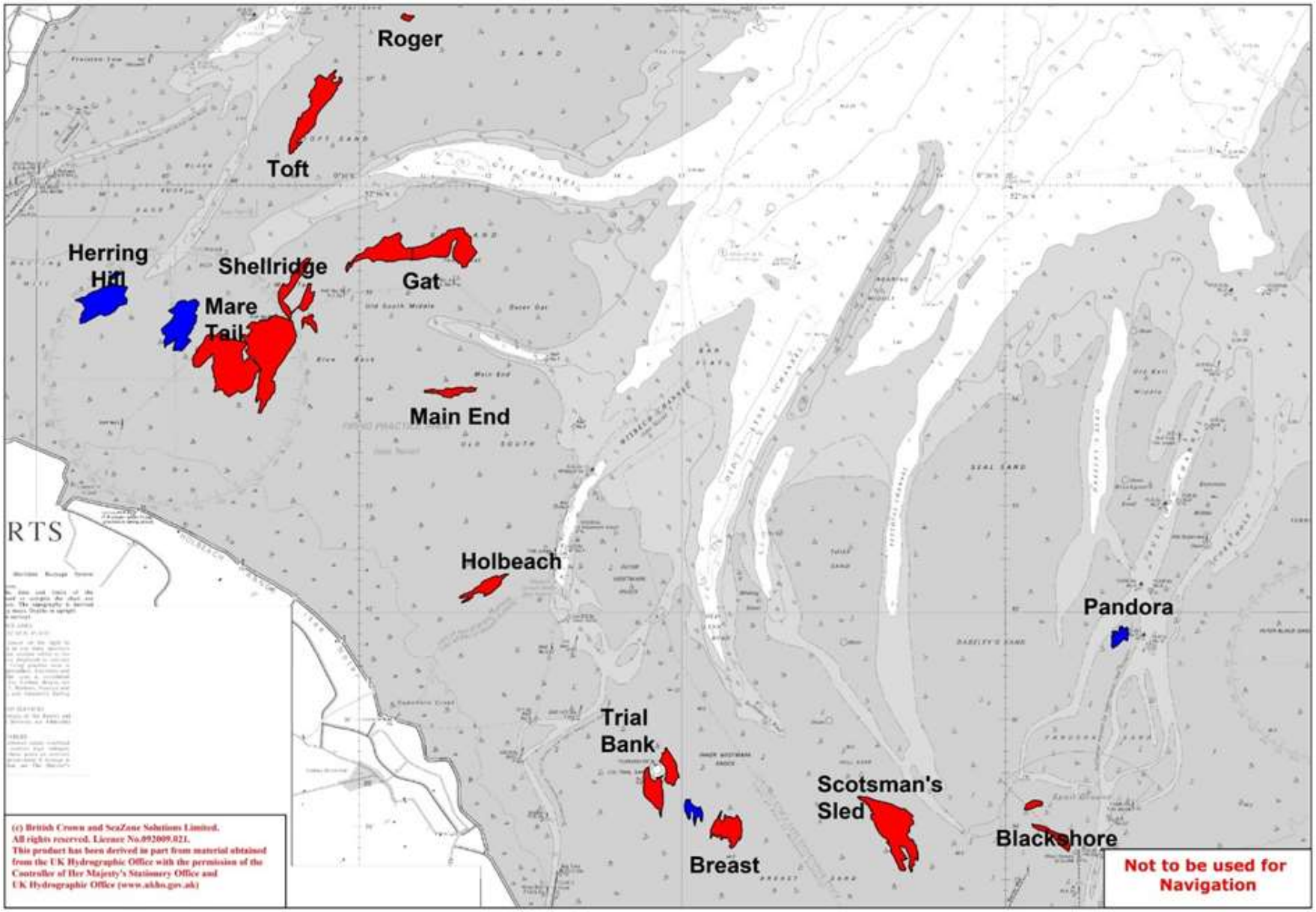


**Figure 2 - Distribution of intertidal mussel beds surveyed (red) and unsurveyed (blue) during 2018 surveys**

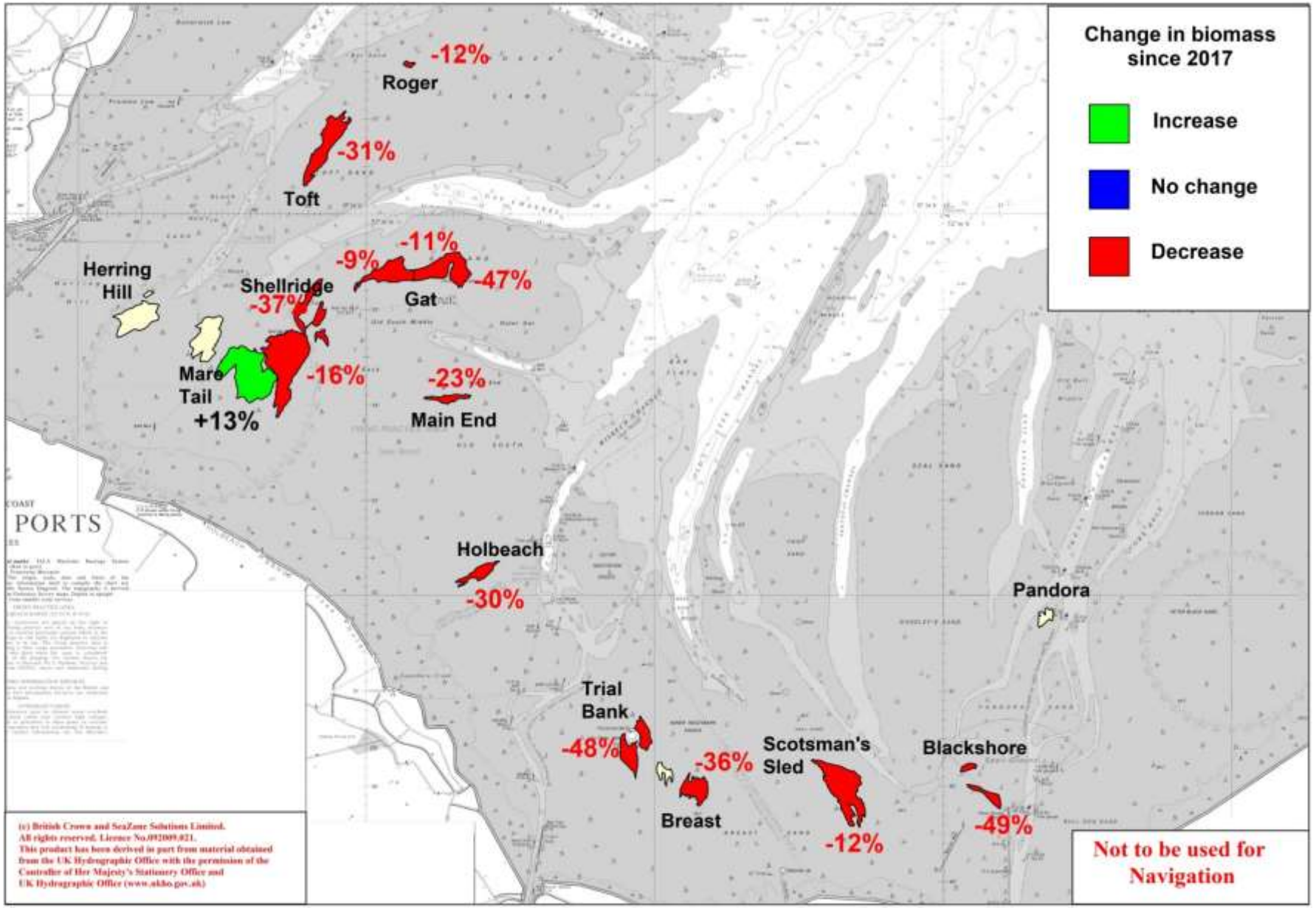


**Figure 3 – Changes to stocks on the intertidal mussel beds between the 2017 and 2018 surveys**

**Table 1 – Summary of the mussel stocks on individual beds at the time of the 2018 surveys**

| | 2018 | | | | | | | 2017 | |
|---|---|---|---|---|---|---|---|---|---|
| BED | AREA (ha) | COVERAGE (%) | DENSITY (kg/0.1m) | TOTAL STOCK (tonnes) | STOCK >45MM (tonnes) | % ≥45MM (%) | BED DENSITY (Tonnes/ha) | TOTAL STOCK | % CHANGE |
| Mare Tail North | 75.8 | 34 | 1.03 | 2665 | 949 | 35.6 | 35.2 | 3176 | -16.1 |
| Mare Tail South | 72.4 | 24 | 0.8 | 1506 | 240 | 15.9 | 20.8 | 1328 | 13.4 |
| Mare Tail East | 3.6 | 24 | 0.66 | 56 | 11 | 19.6 | 15.6 | 124 | -54.8 |
| Mare Tail West | 34.3* | | | 621** | 83** | 13.4 | 18.1 | 803 | -22.7 |
| Shellridge | 20.7 | 42 | 0.39 | 345 | 41 | 11.9 | 16.7 | 548 | -37.0 |
| Toft | 37.7 | 27 | 1.27 | 1294 | 1104 | 85.3 | 34.3 | 1878 | -31.1 |
| Roger | 1.7 | 36 | 0.75 | 45 | 35 | 77.8 | 26.5 | 51 | -11.8 |
| Gat, West | 28.6 | 42 | 0.96 | 1145 | 589 | 51.4 | 40.0 | 1255 | -8.8 |
| Gat, Mid | 21.2 | 24 | 0.77 | 393 | 268 | 68.2 | 18.5 | 443 | -11.3 |
| Gat, East | 17.3 | 18 | 0.6 | 188 | 132 | 70.2 | 10.9 | 356 | -47.2 |
| Main End | 7.8 | 19 | 0.72 | 110 | 80 | 72.7 | 14.1 | 142 | -22.5 |
| Holbeach | 12 | 32 | 0.83 | 318 | 42 | 13.2 | 26.5 | 452 | -29.6 |
| Herring Hill | 35.6* | | | 895** | 285** | 31.8 | 25.1 | 1157 | -22.6 |
| Trial bank | 27.2 | 28 | 1.15 | 881 | 214 | 24.3 | 32.4 | 1701 | -48.2 |
| Breast, West | 6.6* | | | 73** | 14** | 19.2 | 11.1 | 95 | -23.2 |
| Breast, East | 19.1 | 27 | 0.94 | 489 | 144 | 29.4 | 25.6 | 764 | -36.0 |
| Scotsman's Sled, East | 55.7 | 22 | 0.89 | 1101 | 314 | 28.5 | 19.8 | 1253 | -12.1 |
| Blackshore - a | 3.1 | 21 | 1.2 | 78 | 41 | 52.6 | 25.2 | 217 | -64.1 |
| Blackshore - b | 7.9 | 23 | 0.74 | 133 | 30 | 22.6 | 16.8 | 210 | -36.7 |
| Pandora | 6.6* | | | 146** | 107** | 73.3 | 22.1 | | - |
| **TOTAL** | **494.9** | | | **12482** | **4723** | 37.8 | **25.2** | **15953** | -21.8 |
| Welland Bank | 1.8 | 79 | 2.38 | 339 | 262 | 77.3 | 264.2 | 456 | -25.7 |

***Figures based on 2017 values**
****Figures estimated by applying the average decline seen on the surveyed beds to the 2017 values.**

## 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 beds and include the North, South, West and East Mare Tail beds, plus the Shellridge. Figure 4 shows the distribution of these beds.

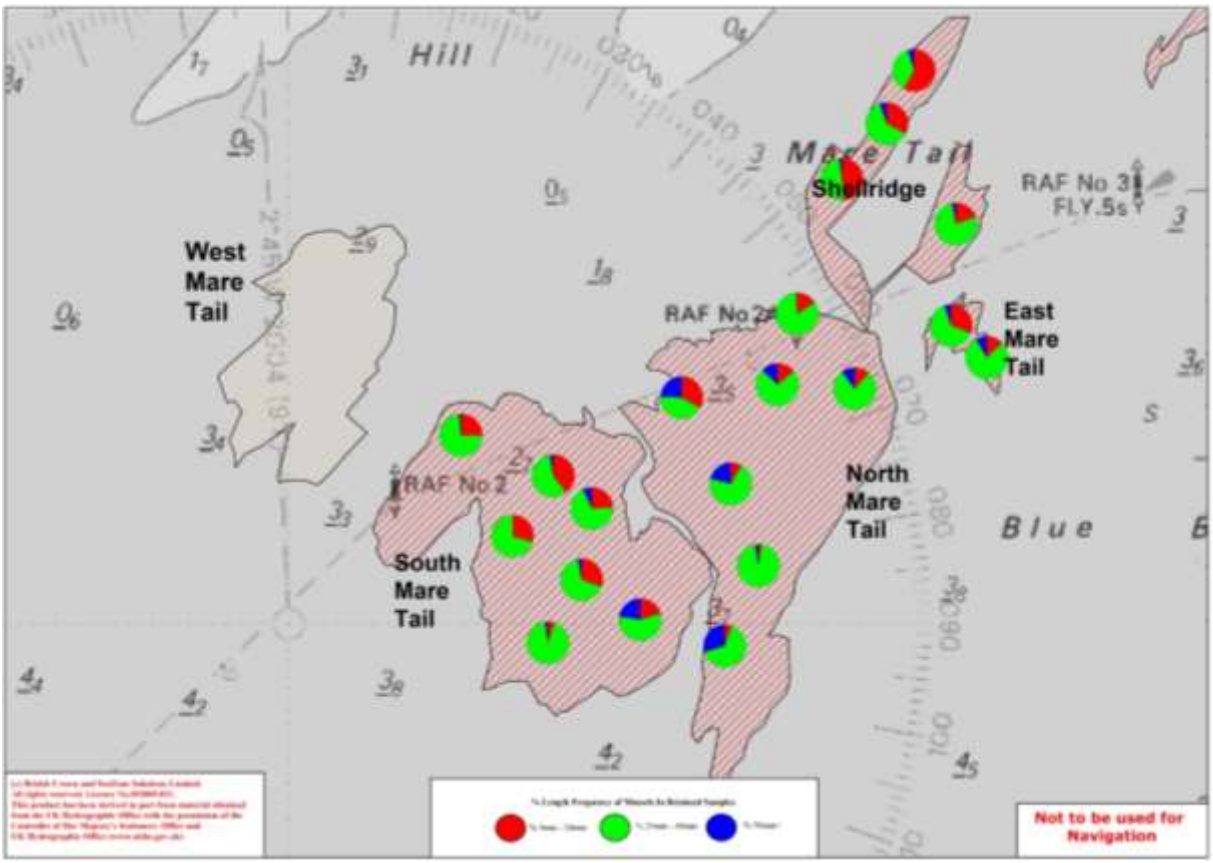


**Figure 4 - Mussel size distributions on the Mare Tail mussel beds – December 2018**

## North Mare Tail

- Area: 75.8 hectares
- Coverage: 34%
- Mean Density: 1.03 kg/0.1m$^2$
- Total Stock: 2,665 tonnes
- Stock ≥ 45mm: 949 tonnes

The North Mare Tail bed was surveyed on September 29th, during which samples were collected from every sixth “hit”, producing 50 samples from six transects. Figure 5 shows the mussel size frequency within the population taken from these samples.

During the past decade, this bed has been one of the largest and most stable areas of mussel bed in The Wash. Although it has supported several dredge fisheries during this period, it has tended to attract regular settlements of seed that have facilitated its recovery. Like many of the other inter-tidal beds, in recent years it has suffered die-offs of young mussels that have caused the biomass to fluctuate. Settlements of seed around the edges of the bed, particularly to the north, have helped it to grow in area over the past three years from 62.0 hectares in 2015 to 75.8 hectares in 2018. Although this year the area of the bed was found to have increased by 7 hectares since the 2017 survey, the coverage of mussels within the bed had decreased from 41% to 34% and the mean density from 1.14 kg/0.1m$^2$ to 1.03 kg/0.1m$^2$. From these figures, the mussel biomass on the bed was calculated to have decreased from 3,176 tonnes in 2016 to 2,665 tonnes. The biomass of mussels that had attained 45mm had decreased from 1,543 tonnes to 949 tonnes.

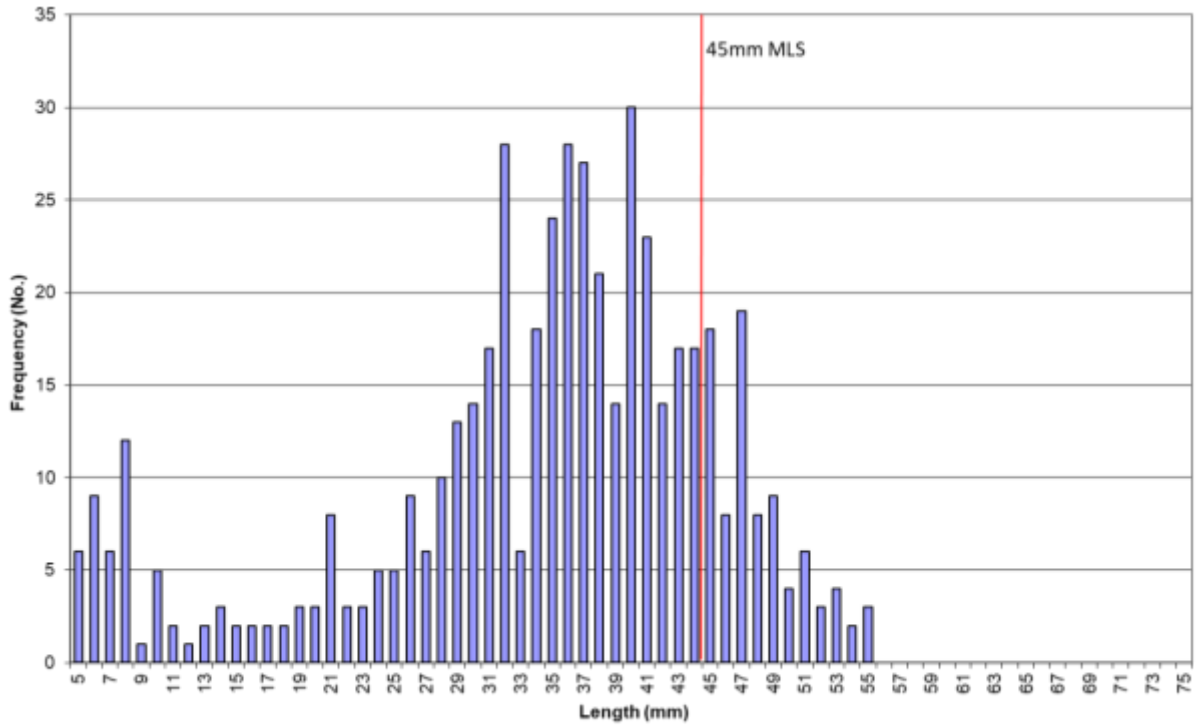


**Figure 5 - Mussel size frequency on North Mare Tail - September 2018**

**South Mare Tail**

- Area: 72.4 hectares
- Coverage: 24%
- Mean Density: 0.80 kg/0.1m$^2$
- Total Stock: 1,506 tonnes
- Stock ≥ 45mm: 240 tonnes

The South Mare Tail bed was surveyed on September 30th. Samples were taken from every fifth "hit", producing 51 samples from seven transects. Figure 7 shows the mussel size frequency within the population taken from these samples.

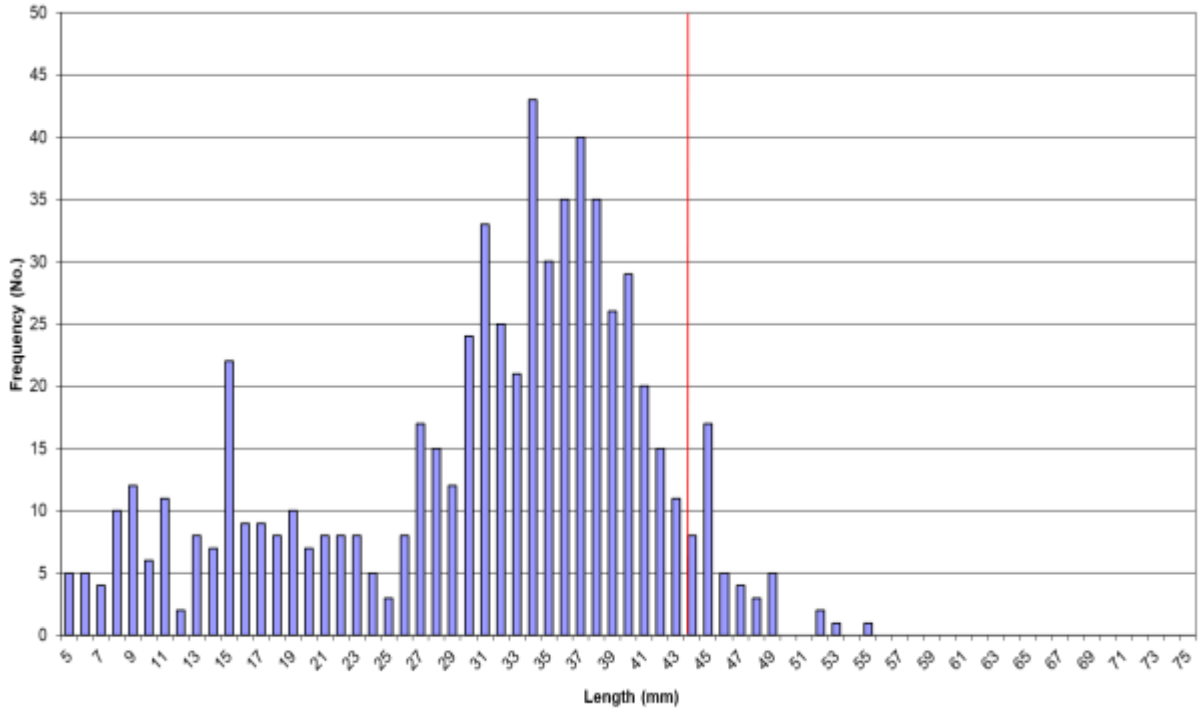


**Figure 7 - Mussel size frequency on South Mare Tail - September 2018**

In 2016 a settlement of mussel spat settled in gullies among ridged-out cockles to the north of this bed. Although still sparsely distributed, by 2017 these had grown sufficiently to be included in the survey, helping the bed to increase in area from 45.6 hectares to 65.1 hectares. The recent survey found the coverage of these young mussels extended further west, covering part of what had once been the RAF No.2 mussel bed (figure 8). This settlement is the first signs of recovery of the former RAF

No.2 bed, that had disappeared after being fished in 2004. This further expansion of the South Mare Tail bed helped its area to increase further to 72.4 hectares.

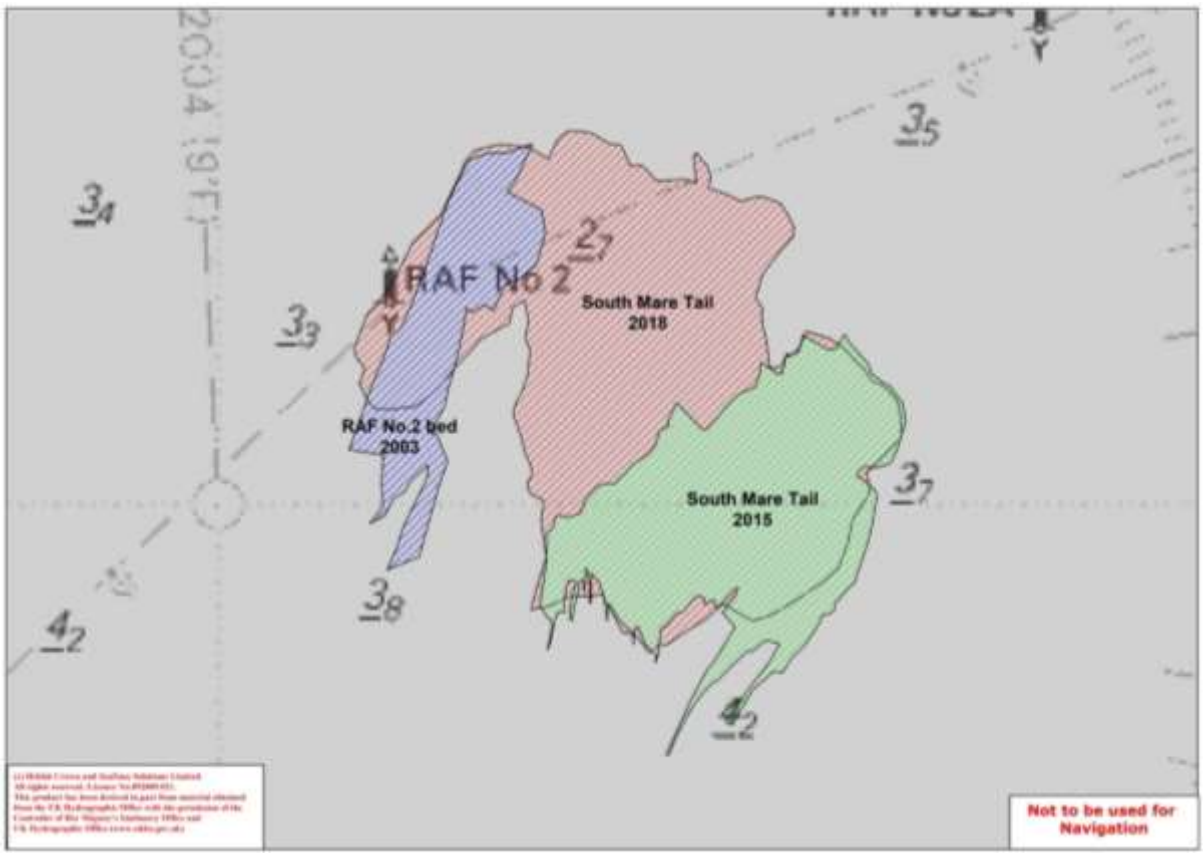


**Figure 8 – The recent expansion of the South Mare Tail mussel bed into an area once covered by the RAF No.2 bed.**

The inclusion in the survey of area of new patches of mussels that were generally sparser than elsewhere in the bed caused the overall coverage to decline from 28% to 24% but growth of mussels from the previous year helped the mean density to increase from 0.73 kg/0.1m$^2$ to 0.80 kg/0.1m$^2$. Together, these results meant the total stock on this bed had increased from 1,328 tonnes to 1,506 tonnes. The biomass of ≥45mm mussels had increased from 172 tonnes to 240 tonnes.

**West Mare Tail**

- Area: 34.3 hectares (estimated)
- Coverage: Unknown
- Mean Density: Unknown
- Total Stock: 621 tonnes (estimated)
- Stock ≥ 45mm: 83 tonnes (estimated)

A combination of poor weather and vessel breakdowns meant it was not possible to survey this bed during the 2018 survey programme. For management purposes, the stock on this bed was estimated by adjusting the 2017 survey figures by the mean changes seen on the other surveyed beds during the same period.

**East Mare Tail**

- Area: 3.6 hectares
- Coverage: 24%
- Mean Density: 0.66kg/0.1m$^2$
- Total Stock: 56 tonnes
- Stock ≥ 45mm: 11 tonnes

The East Mare Tail bed was surveyed on September 27th. Samples were collected from every third “hit”, resulting in 23 samples being taken from two transects. Figure 9 shows the size distribution of the mussels collected from the samples.

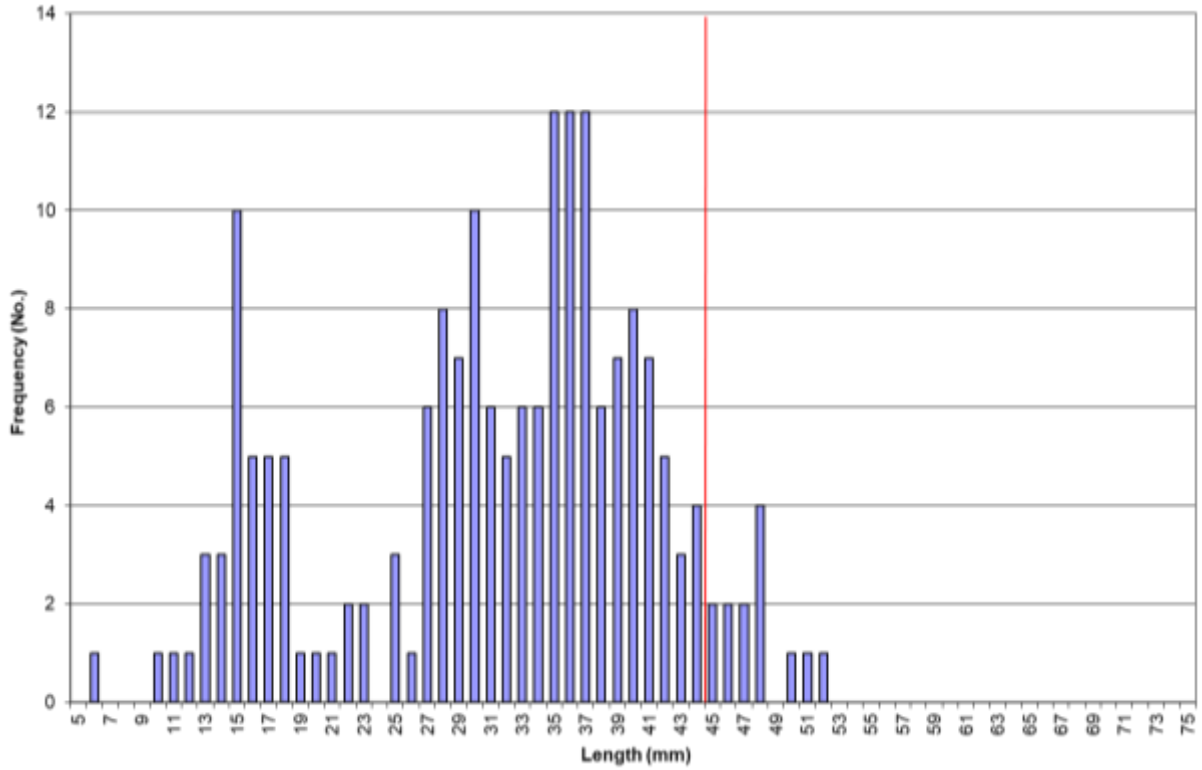


**Figure 9 - Mussel size frequency on East Mare Tail – September 2018**

This bed is usually separated from the North Mare Tail bed by an area of sand. In 2017, however, new settlement within the sandy area increased the area of the East Mare Tail bed and caused the two beds to join together. The 2018 survey found this new seed had washed away, causing the two beds to separate once more. This resulted in the area of the bed declining from 5.6 hectares to 3.6 hectares. Within the bed, the mussel coverage had declined from 39% to 24% but the mean mussel density within the patches had increased from 0.57kg/0.1m$^2$ to 0.66kg/0.1m$^2$.

From these figures the total biomass of mussels was calculated to have decreased from 124 tonnes in 2017 to 56 tonnes in 2018. The biomass of mussels that had attained a size of ≥45mm had also declined from 23 tonnes to 11 tonnes.

**Shellridge**

- Area: 20.7 hectares
- Coverage: 42%
- Mean Density: 0.39kg/0.1m$^2$
- Total Stock: 345 tonnes
- Stock ≥ 45mm: 41 tonnes

The Shellridge bed was surveyed on September 27$^{th}$. Samples were collected from every fourth “hit”, resulting in 58 samples being taken from four transects. Figure 10 shows the size distribution of the mussels collected from the samples.

After being damaged during the 2007 hydraulic dredge cockle fishery, this bed declined from a stock of 505 tonnes to 183 tonnes. Subsequent high mortalities in 2011 reduced the stock to a sparse coverage of just 13 tonnes, after which the bed almost disappeared. After missing a survey in 2016, however, the 2017 survey found this bed had benefitted from a good settlement of seed the previous year. This covered 33.2 hectares, which was larger than its previous extent in 2006 and had a biomass of 548 tonnes. The 2018 survey, however, found a large area of this seed in the middle of the bed had disappeared, reducing the area to 20.7 hectares. Within the remaining area the mussel coverage had increased from 40% to 42% but the mean density had declined from 0.41kg/0.1m$^2$ to 0.39kg/0.1m$^2$. From these figures the total biomass of mussels was calculated to have decreased from 548 tonnes in 2017 to 345 tonnes in

2018. The biomass of mussels that had attained a size of ≥45mm had also declined from 79 tonnes to 41 tonnes.

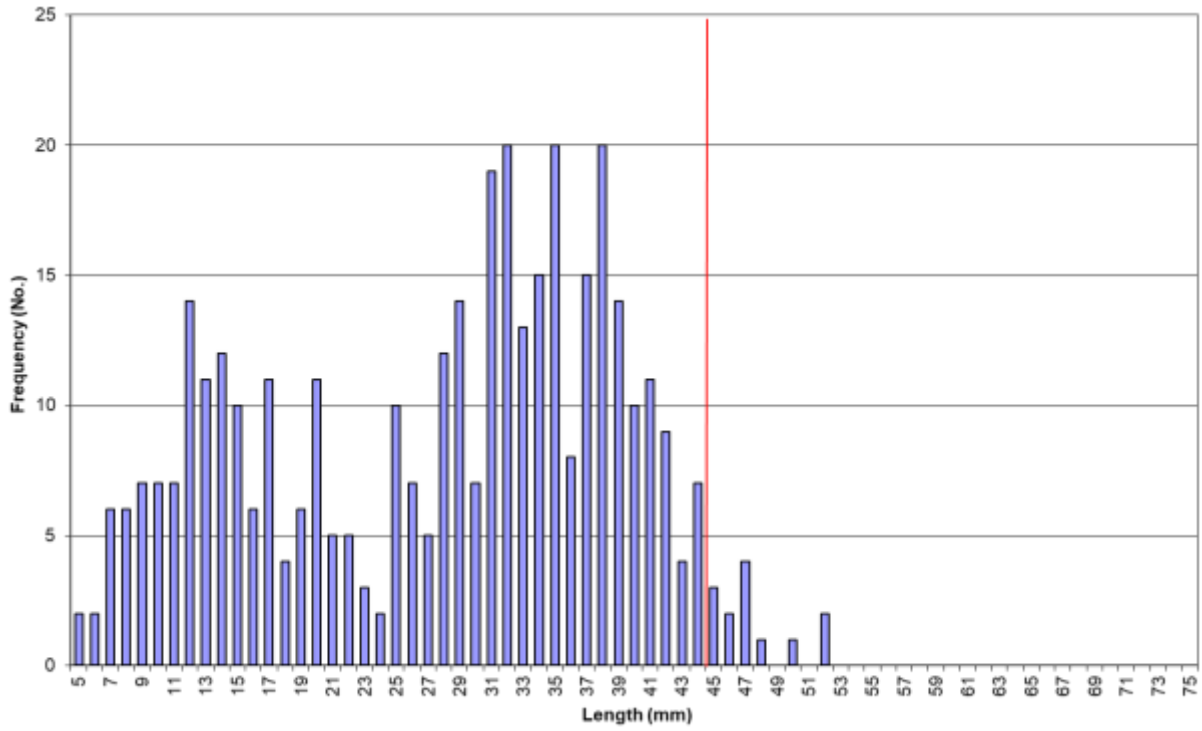


**Figure 10 - Mussel size frequency on Shellridge – September 2018**

**The Gat Beds**

The Gat sand supports an extensive area of mussels that for survey purposes is divided into three beds (see figure 11). Following overfishing throughout The Wash in the late 1980s, the Gat became one of the few inter-tidal beds that still supported significant quantities of mussels. As such they were viewed as being particularly important by both the fishing industry and conservationists alike. Barring some heavy poaching that occurred on them between 2000 and 2002, they were closed to fishing between 1993 and 2006. This long closure helped them to mature and develop some important biogenic reef features, particularly along the exposed northern fringes of the bed. 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 there have been no fisheries on these beds since 2010, they have suffered significant declines since then, during which the stocks fell from 5,604 tonnes in 2009 to 1,246 tonnes in

2014. There has been some recovery since 2014, enabling the stocks to increase back to levels exceeding 2,000 tonnes, but all three beds are in poor condition and are considered to be vulnerable to further losses.

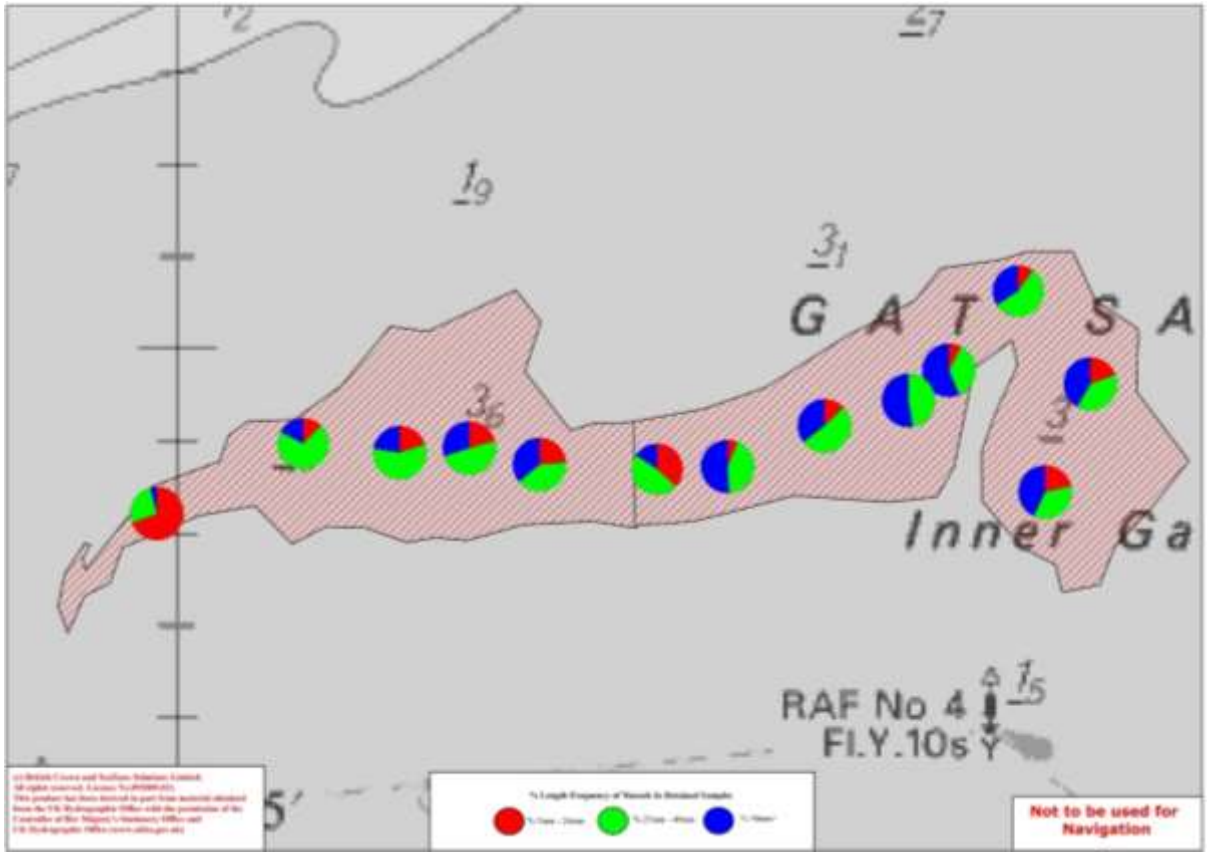


**Figure 11 - Mussel size distributions on the Gat mussel beds – September 2018**

**West Gat**

- Area: 28.6 hectares
- Coverage: 42%
- Mean Density: 0.96kg/0.1m$^2$
- Total Stock: 1,145 tonnes
- Stock ≥ 45mm: 589 tonnes

The West Gat bed was surveyed on September 26$^{th}$. Samples were taken from every fifth “hit”, producing 62 samples from five transects. Figure 12 shows the size frequency of mussels found in the samples taken during this survey.

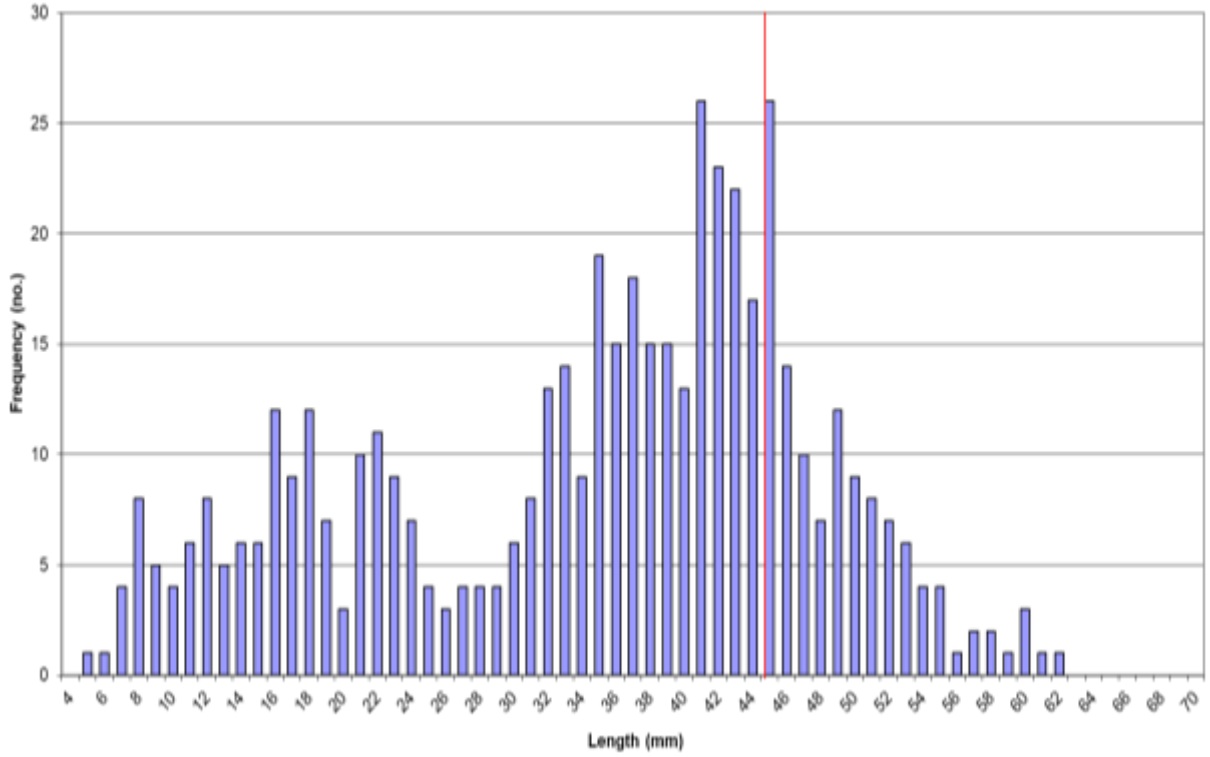


**Figure 12 - Mussel size frequency on West Gat – September 2018**

Since 2010 this bed has suffered declining populations as a result of high mortalities. This has caused the mussel populations to thin over much of the bed and has caused large bare patches to form where mussel densities are no longer sufficient to prevent erosion. Since 2017 this has been particularly noticeable along the western edge of the bed, where only a thin strip of mussels now remains. During this period the area of the bed has declined from 35.5 hectares in 2016 to 33.0 hectares in 2017 and 28.6 hectares in 2018. A light settlement of seed in 2016 had helped to thicken the mussels up within the bed by 2017, but by 2018 the coverage had declined from 47% to 42%. Growth of these mussels, however, meant the mean patch density had increased from 0.81kg/0.1m$^2$ to 0.96kg/0.1m$^2$. From these figures, the total mussel biomass on the bed was calculated to have declined from 1,255 tonnes to 1,145 tonnes. The biomass of mussels that had reached 45mm had increased from 540 tonnes to 589 tonnes.

**Mid Gat**

- Area: 21.2 hectares
- Coverage: 24%
- Mean Density: 0.77kg/0.1m$^2$
- Total Stock: 393 tonnes
- Stock ≥ 45mm: 268 tonnes

The Mid Gat was surveyed on September 26th. Samples were collected from every fifth “hit”, producing 31 samples from five transects. Figure 13 shows the size frequency of the mussels collected in these samples.

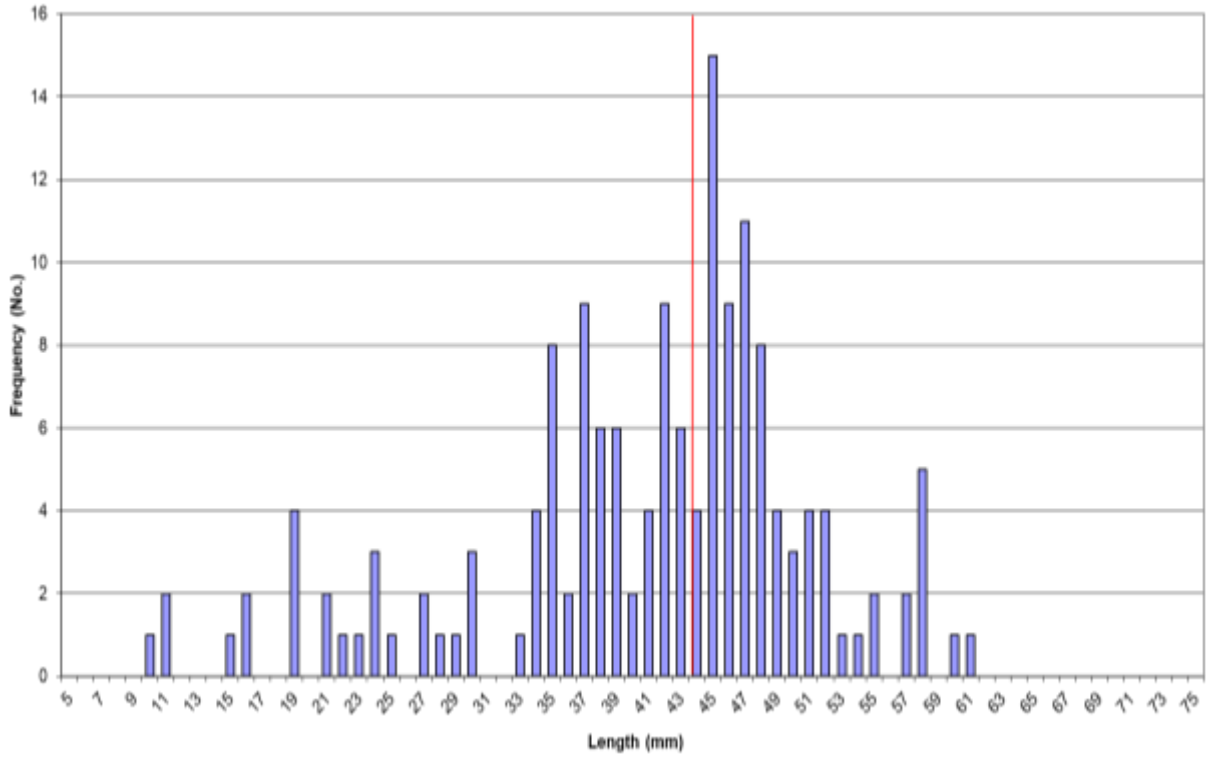


**Figure 13 - Mussel size frequency on Mid Gat – September 2018**

The 2018 survey found that while there had been a slight settlement on the bed in 2016, further mortalities within the bed meant there was still an overall decline in stocks. The area of the bed had increased from 20.5 hectares to 21.2 hectares, but the coverage within it was found to have declined from 32% to 24%. Growth of the mussels within the patches helped the mean patch density increase from 0.68kg/0.1m$^2$ to 0.77kg/0.1m$^2$. From these figures, the total biomass of mussels on the bed was

calculated to have decreased from 443 tonnes to 393 tonnes. The stock of ≥45mm mussels had increased from 228 tonnes to 268 tonnes.

**East Gat**

- Area: 17.3 hectares
- Coverage: 18%
- Mean Density: 0.60kg/0.1m$^2$
- Total Stock: 188 tonnes
- Stock ≥ 45mm: 132 tonnes

Because of problems with poor weather condition and vessel breakdowns, the East Gat was surveyed later than usual on January 24th 2019. Samples were taken from every fourth “hit”, producing 18 samples from three transects. Figure 14 shows the size frequency of the mussels collected in these samples.

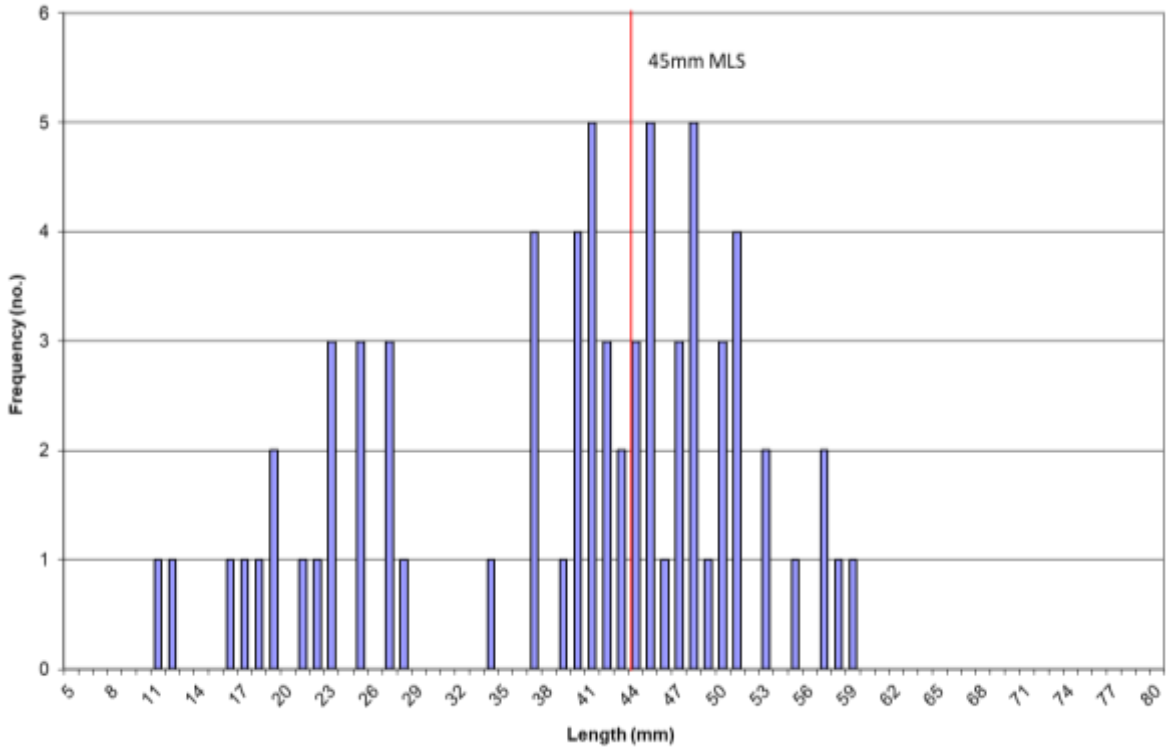


**Figure 14 - Mussel size frequency on East Gat – January 2019**

The area of the bed had increased from 17.1 hectares in 2016 to 21.3 hectares in 2017, but the recent survey found it had declined again to 17.3 hectares. Further mortalities meant the mussel coverage within the bed had declined from 25% to 18% and the patch density from 0.67kg/0.1m$^2$ to 0.60 kg/0.1m$^2$. From these figures, the total mussel biomass on the bed was calculated to have declined from 356 tonnes to 188 tonnes. Of these, 132 tonnes had attained 45mm compared to 288 tonnes the previous year.

**Tofts**

- Area: 37.7 hectares
- Coverage: 27%
- Mean Density: 1.27 kg/0.1m$^2$
- Total Stock: 1,294 tonnes
- Stock $\geq$ 45mm: 1,104 tonnes

Because of the large size of this bed, the perimeter was surveyed on September 24$^{th}$, allowing two teams to conduct the survey transects on September 25$^{th}$. Samples were taken from every fifth “hit”, producing 51 samples from seven transects. Figure 15 shows the mussel size distribution over the bed, while figure 16 shows the size frequency of the mussels in the samples.

In 2016 mussel seed settled amongst cockles adjacent to the south east edge of the mussel bed, increasing the area of the bed by approximately 10 hectares. Although these juvenile mussels appeared well-established at the time of the 2017 survey, the 2018 survey found most of these had disappeared. This caused the area of the bed to decline from 46.0 hectares to 37.7 hectares. The mussel coverage within the bed was also found to have declined from 37% to 27% but the mean patch density had increased from 1.10 kg/0.1m$^2$ to 1.27 kg/0.1m$^2$. From these figures, the total biomass of mussels in the bed was calculated to have declined from 1,878 tonnes to 1,294 tonnes. Of these, 1,104 tonnes had reached 45mm compared to 1,518 tonnes the previous year.

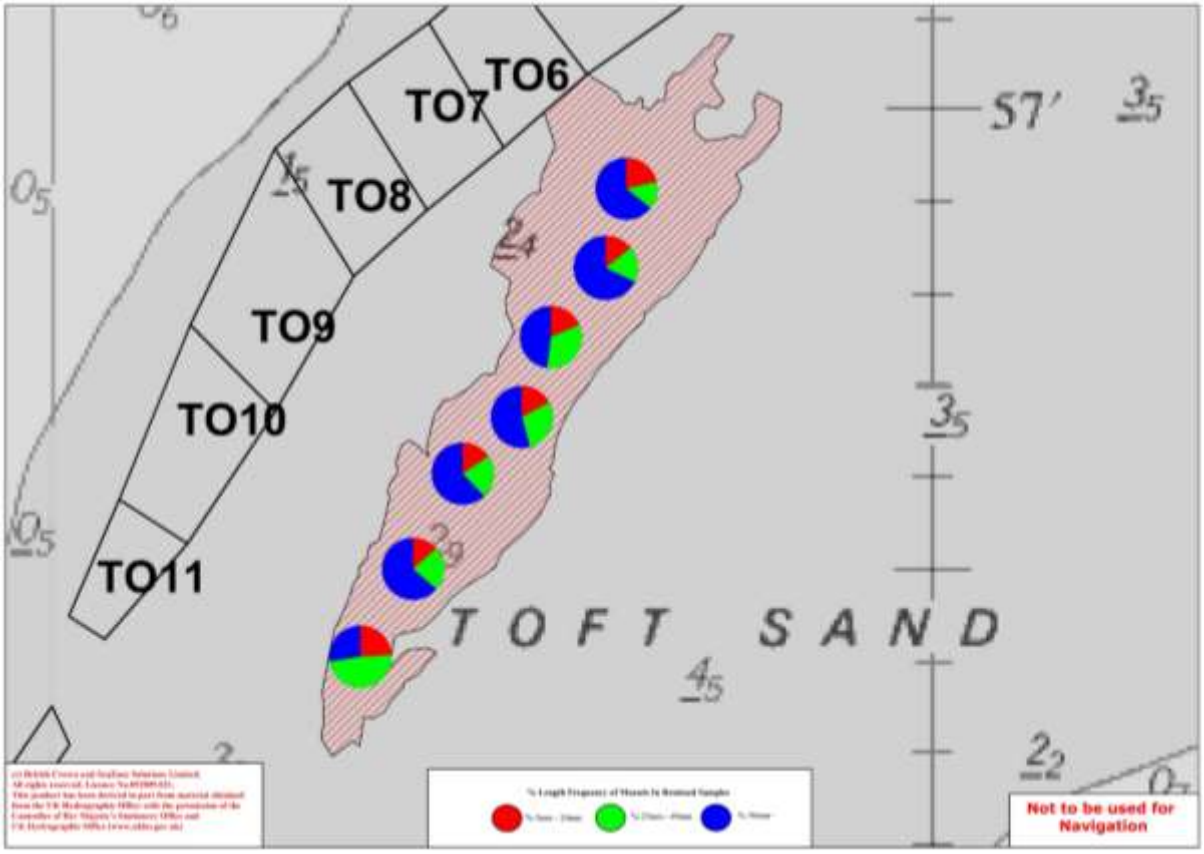


**Figure 15 - Mussel size distributions on the Toft mussel bed – September 2018**

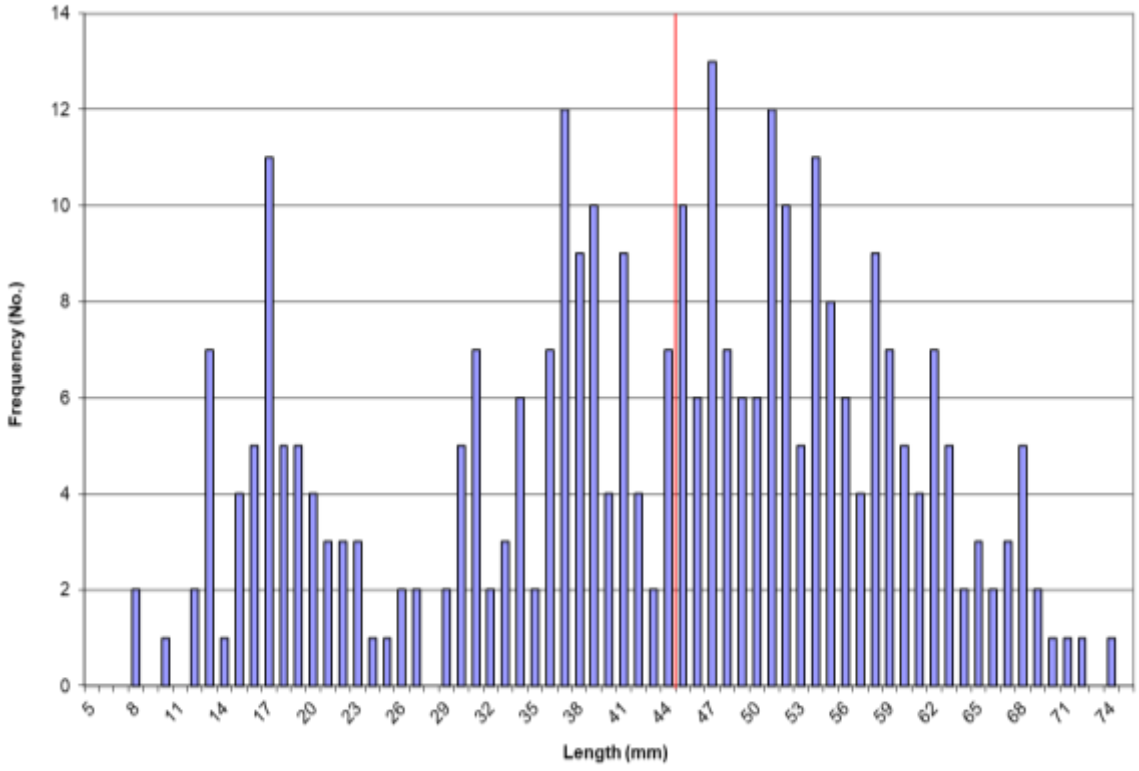


**Figure 16 - Mussel size frequency on the Tofts – September 2018**

**Roger**

- Area: 1.7 hectares
- Coverage: 36%
- Mean Density: 0.75 kg/0.1m$^2$
- Total Stock: 45 tonnes
- Stock ≥ 45mm: 35 tonnes

This small bed was surveyed on September 24th. Samples were collected from every third “hit”, producing 15 samples from a single transect. Figure 17 shows the mussel size distribution on this bed while figure 18 shows the size frequency within the population.

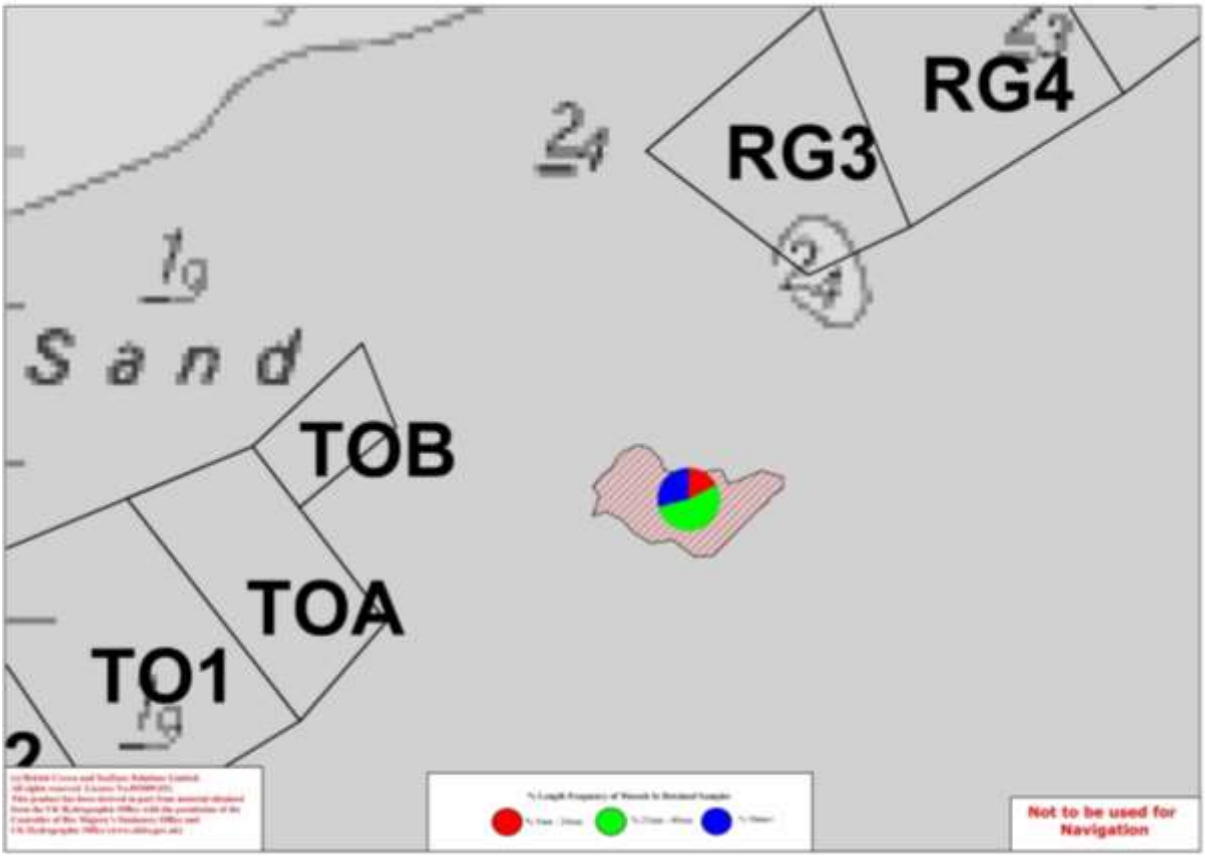


**Figure 17 - Mussel size distribution on the Roger mussel bed – September 2018**

The 2018 survey found this small bed had decreased in area slightly from 1.9 hectares to 1.7 hectares. Within this area the coverage of mussels was found to have increased from 29% to 36% but the patch density had declined from 0.92 kg/0.1m$^2$ to 0.75 kg/0.1m$^2$. From these figures the total mussel biomass was calculated to have

declined from 51 tonnes to 45 tonnes. During the same period the biomass of those that had attained 45mm had increased from 29 tonnes to 35 tonnes.

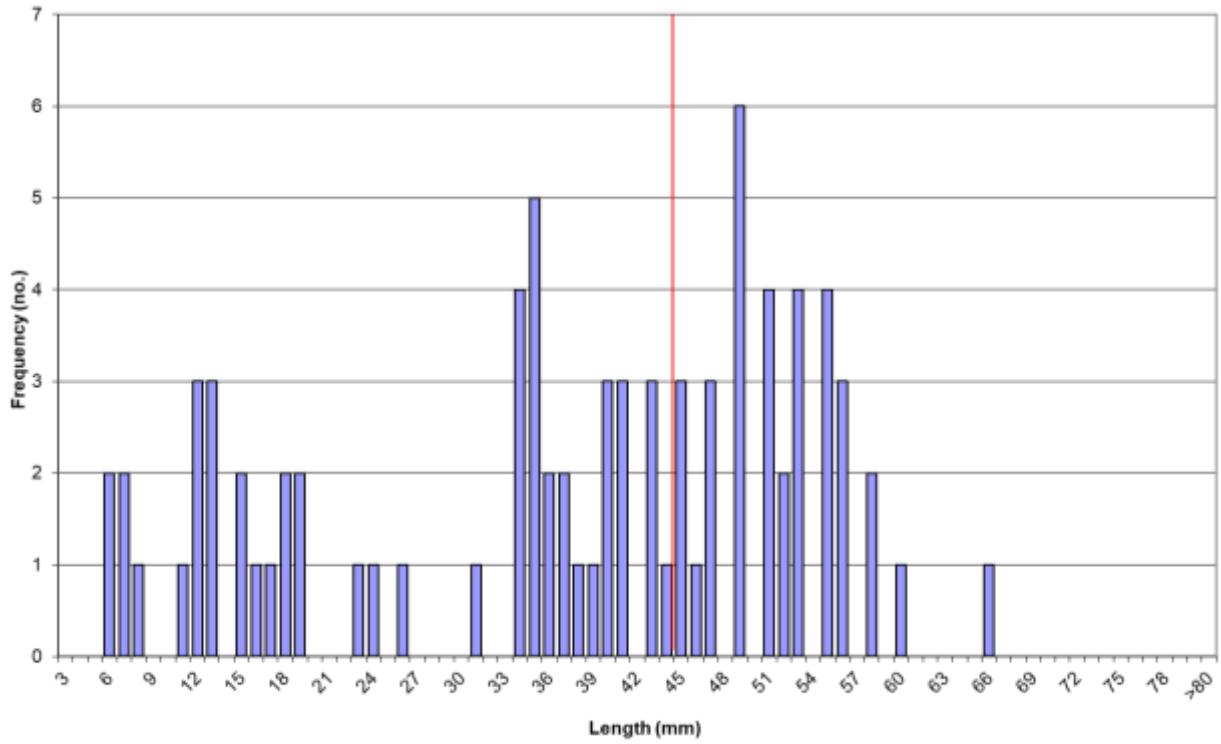


**Figure 18 - Mussel size frequency on the Roger – September 2018**

**Herring Hill**

- Area: 35.6 hectares (estimated)
- Coverage: Unknown
- Mean Density: Unknown
- Total Stock: 895 tonnes (estimated)
- Stock ≥ 45mm: 285 tonnes (estimated)

A combination of poor weather and vessel breakdowns meant it was not possible to survey this bed during the 2018 survey programme. For management purposes, the stock on this bed was estimated by adjusting the 2017 survey figures by the mean changes seen on the other surveyed beds during the same period.

**Main End**

- Area: 7.8 hectares
- Coverage: 19%
- Mean Density: 0.72 kg/0.1m$^2$
- Total Stock: 110 tonnes
- Stock ≥ 45mm: 80 tonnes

The Main End bed was surveyed on November 10th, during which samples were collected from every third “hit”, producing 19 samples from two transects. Figures 19 and 20 show the mussel size distribution across the bed and the mussel size distribution within the samples.

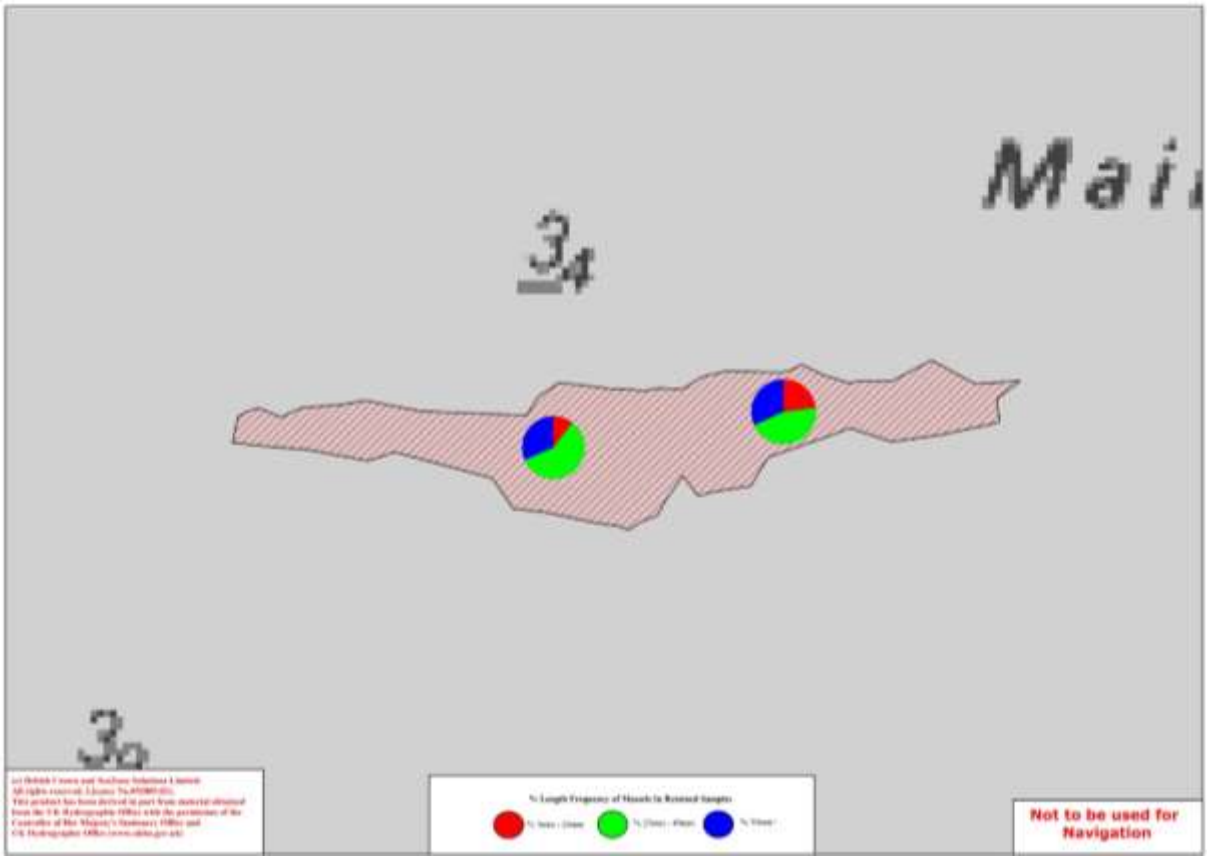


**Figure 19 - Mussel size distribution on the Main End mussel bed – November 2018**

This bed originally developed after the area benefitted from an exceptional settlement of seed in 2001. 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 and in the bottom of a wide run and has remained relatively 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 2018 survey found the bed had decreased in area from 8.9 hectares to 7.8 hectares. Within this area the mussel coverage was found to have declined from 29% to 19% but the mean density had increased from 0.54 kg/0.1m$^2$ to 0.72 kg/0.1m$^2$. From these figures the total mussel biomass was calculated to be 110 tonnes, down from the 142 tonnes recorded the previous year. Of these, 80 tonnes were estimated to have attained 45mm compared to 96 tonnes the previous year.

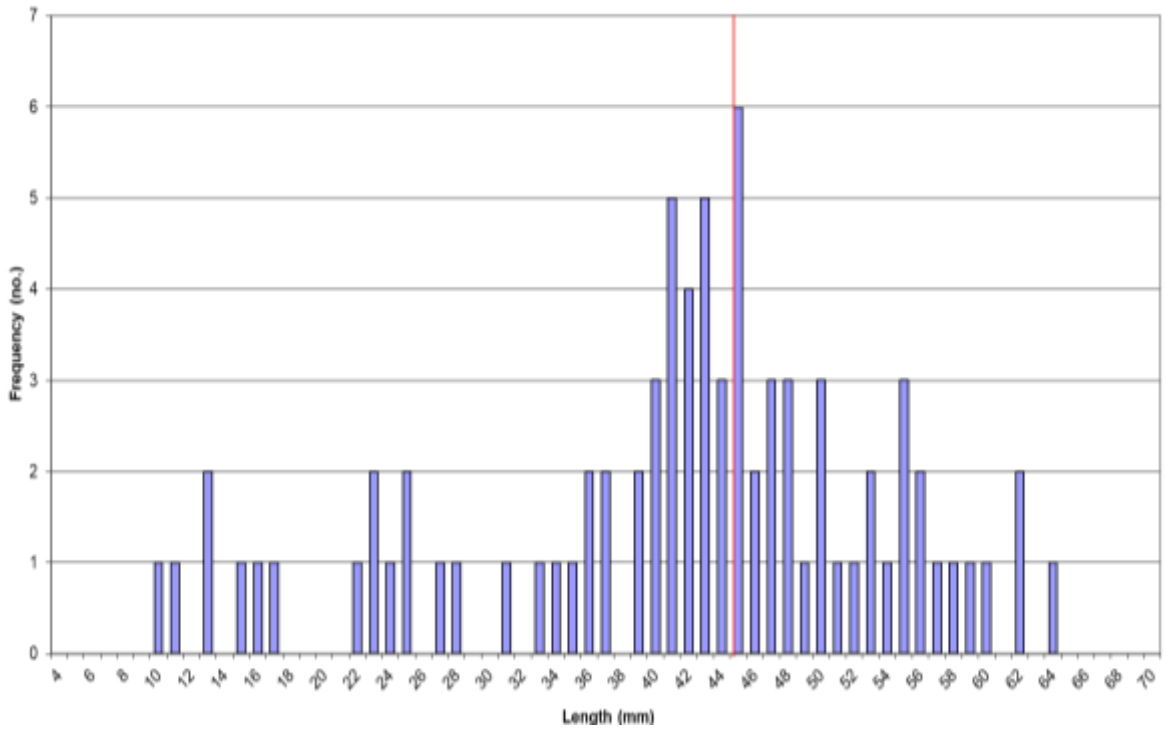


**Figure 20 - Mussel size frequency on Main End - November 2018**

**Holbeach**

- Area: 12.0 hectares
- Coverage: 32%
- Mean Density: 0.83 kg/0.1m$^2$
- Total Stock: 318 tonnes
- Stock ≥ 45mm: 42 tonnes

The Holbeach bed was surveyed on October 13$^{th}$. Samples were collected from every fourth “hit”, generating 36 samples from four transects. Figures 21 and 22 show the size distribution of mussels across the bed and the mussel size frequency within the population.

This bed originally developed following the exceptional spatfall that occurred during 2001. Like the Main End bed, at the time this area was considered to be vulnerable to natural losses so the bed was opened to the seed fishery in 2002. Part of the bed remained after this fishery, and in subsequent years has attracted some good settlements of seed. Like most of the other inter-tidal beds, however, it has suffered from high mortalities in recent years.

This bed benefited from a good settlement of seed in 2016, which helped it to increase in mussel biomass in 2017. Like many of the beds in 2018, however, there has been a subsequent decline. The area of the bed was found to have declined from 13.8 hectares to 12.0 hectares. Within this area the mussel coverage had fallen from 49% to 32%, but growth of the mussels had helped the mean density increase from 0.67 kg/0.1m$^2$ to 0.83 kg/0.1m$^2$. From these figures, the total mussel biomass on the bed was calculated to have decreased from 452 tonnes to 318 tonnes. Of these, 42 tonnes were found to have reached 45mm, compared to 54 tonnes the previous year.

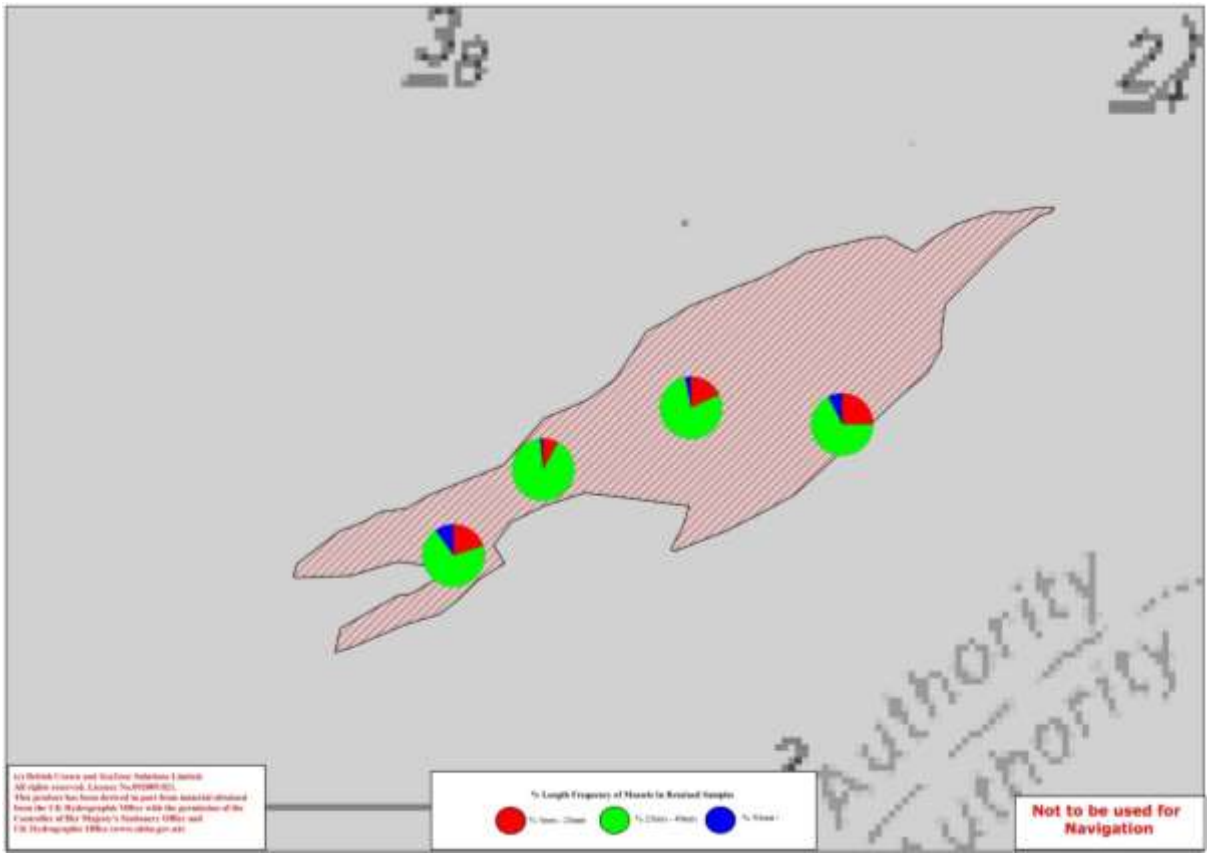


**Figure 21 - Mussel size distribution on the Holbeach mussel bed – October 2018**

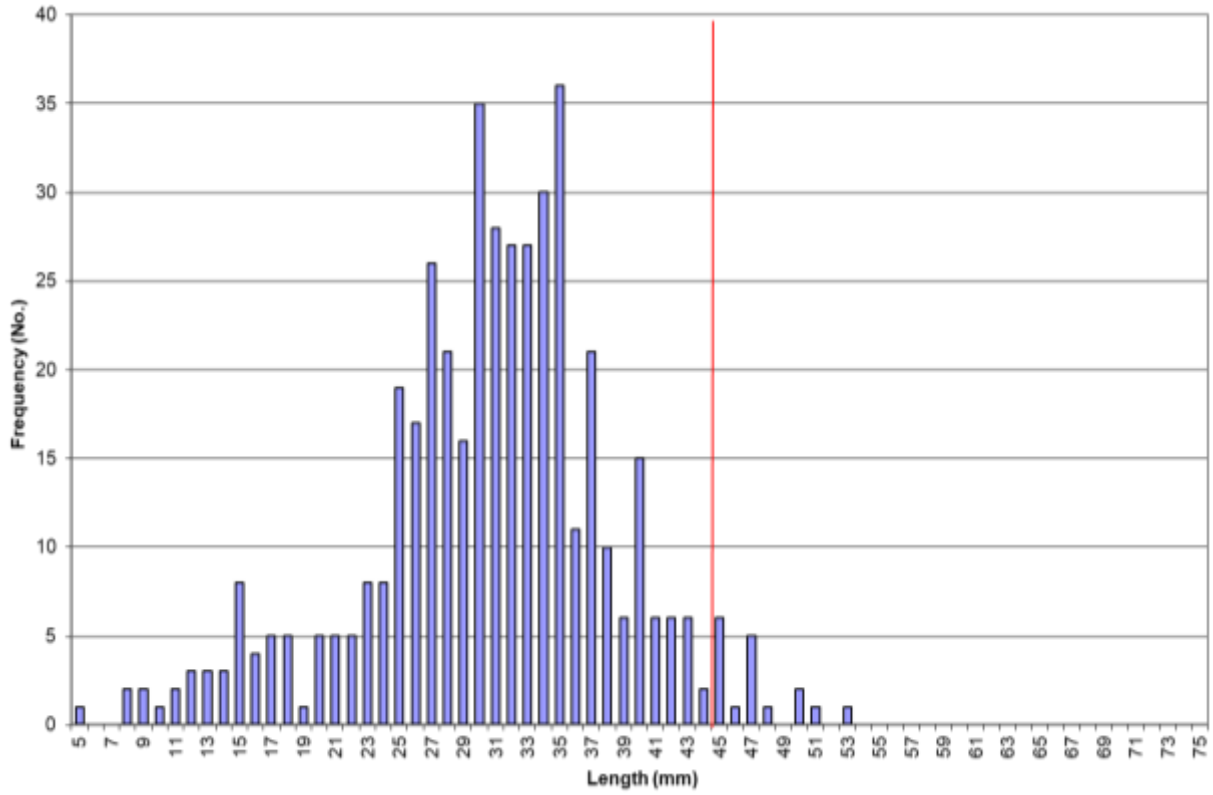


**Figure 22 - Mussel size frequency on Holbeach – October 2018**

**Trial Bank**

- Area: 27.2 hectares
- Coverage: 28%
- Mean Density: 1.15 kg/0.1m$^2$
- Total Stock: 881 tonnes
- Stock ≥ 45mm: 214 tonnes

The Trial Bank mussel bed was surveyed on October 25th, during which samples were collected from every fifth “hit”, producing 39 samples from five transects. Figures 23 and 24 show the size distribution of mussels across the bed and the mussel size frequency within the population.

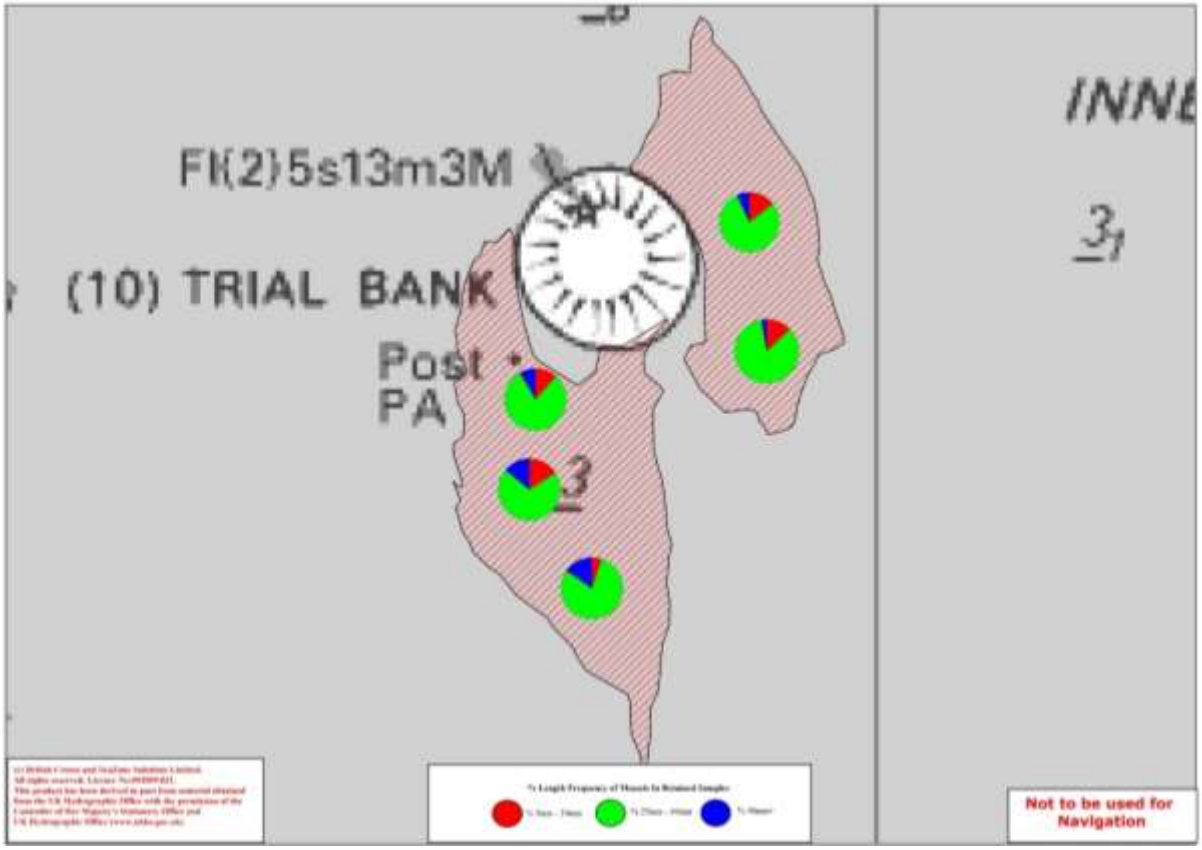


**Figure 23 - Mussel size distribution on the Trial Bank mussel bed – October 2018**

This bed, which first established in 2001 after mussel spat settled among an area of dense cockles and shells, has attracted several settlements since and reached a peak biomass of 1,352 tonnes in 2012. These settlements have helped it to support several

fisheries since then, but disparate fishing effort in some parts of the bed have caused those to deteriorate. Following one such fishery the south-eastern quarter of the bed was lost and this has not subsequently recovered. A good settlement of seed in 2016 helped some parts of the bed to recover, but fishing effort in 2018 thinned the bed further. Since 2017 the area of the bed has declined from 31.6 hectares to 27.2 hectares, the mussel coverage from 40% to 28% and the mean density from 1.34 kg/0.1m$^2$ to 1.15 kg/0.1m$^2$. From these figures, the total biomass of mussels in the bed was calculated to have declined from 1,701 tonnes to 881 tonnes. The biomass of mussels that had reached 45mm had declined during the same period from 393 tonnes to 214 tonnes.

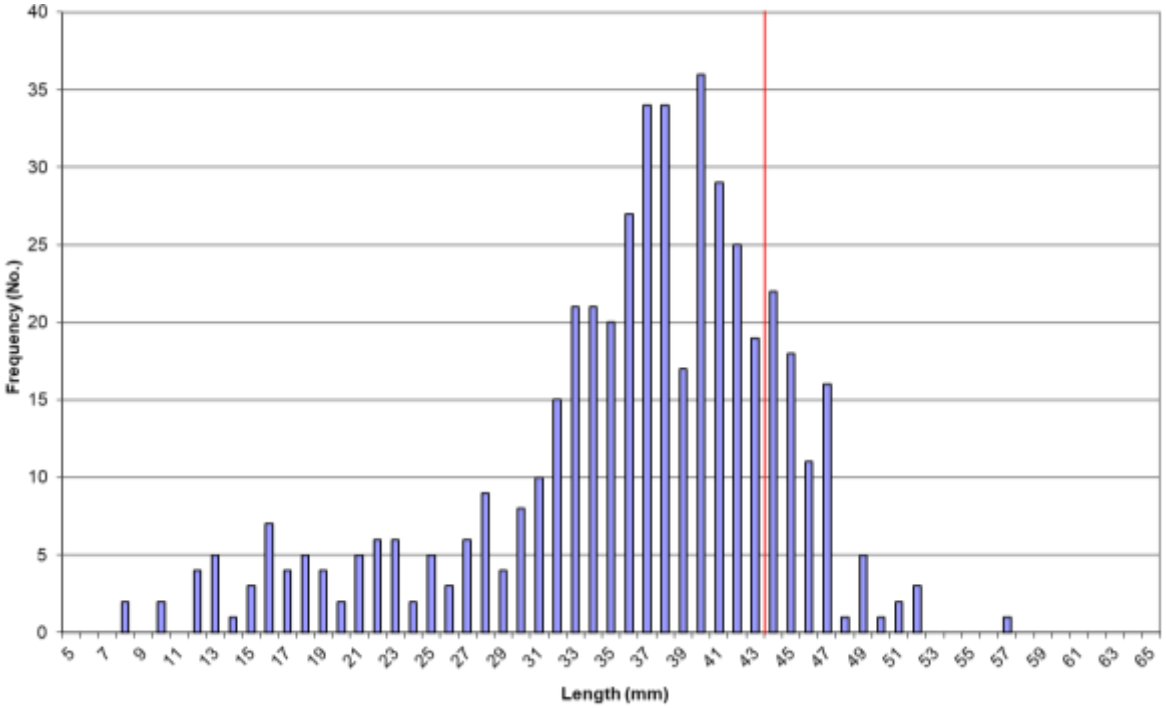


**Figure 24 - Mussel size frequency on Trial Bank - October 2018**

**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. Following disparate fishing effort on these beds in 2010, however, the middle bed disappeared. In 2011 another good settlement of spat in this area enabled both the West and East beds to increase in size. Although this growth enabled them to encroach over ground

that had formally been part of the Middle bed, they still formed two 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. For a time, the mussel coverage was sufficient for the two beds to join, but recent surveys have found the mussel patches have thinned along the eastern edge of the West bed, creating a gap between the two beds once more. It was not possible to survey the West Breast bed during the 2018 survey programme so figure 25 shows the mussel size distribution on the East Breast bed and the location of the West Breast bed when previously surveyed in 2017.

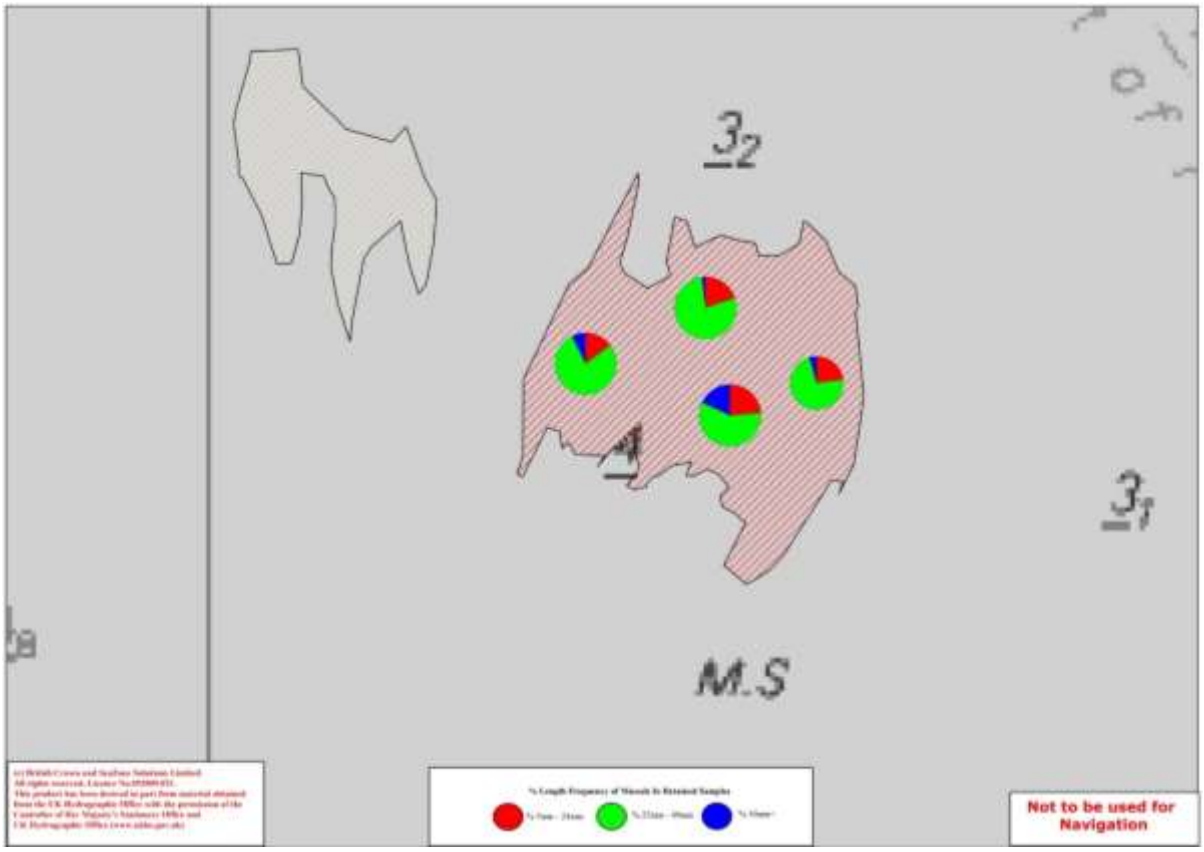


**Figure 25 - Mussel size distribution on the Breast mussel beds – January 2019**

**West Breast**

- Area: 6.6 hectares (estimated)
- Coverage: Unknown
- Mean Density: Unknown
- Total Stock: 73 tonnes (estimated)
- Stock ≥ 45mm: 14 tonnes (estimated)

A combination of poor weather and vessel breakdowns meant it was not possible to survey this bed during the 2018 survey programme. For management purposes, the stock on this bed was estimated by adjusting the 2017 survey figures by the mean changes seen on the other surveyed beds during the same period.

**East Breast**

- Area: 19.1 hectares
- Coverage: 27%
- Mean Density: 0.94 kg/0.1m$^2$
- Total Stock: 489 tonnes
- Stock ≥ 45mm: 144 tonnes

The East Breast bed was surveyed on January 8th 2019, during which samples were collected from every fifth “hit”, producing 29 samples from four transects. Figure 26, shows the size frequency of mussel in the population on this bed.

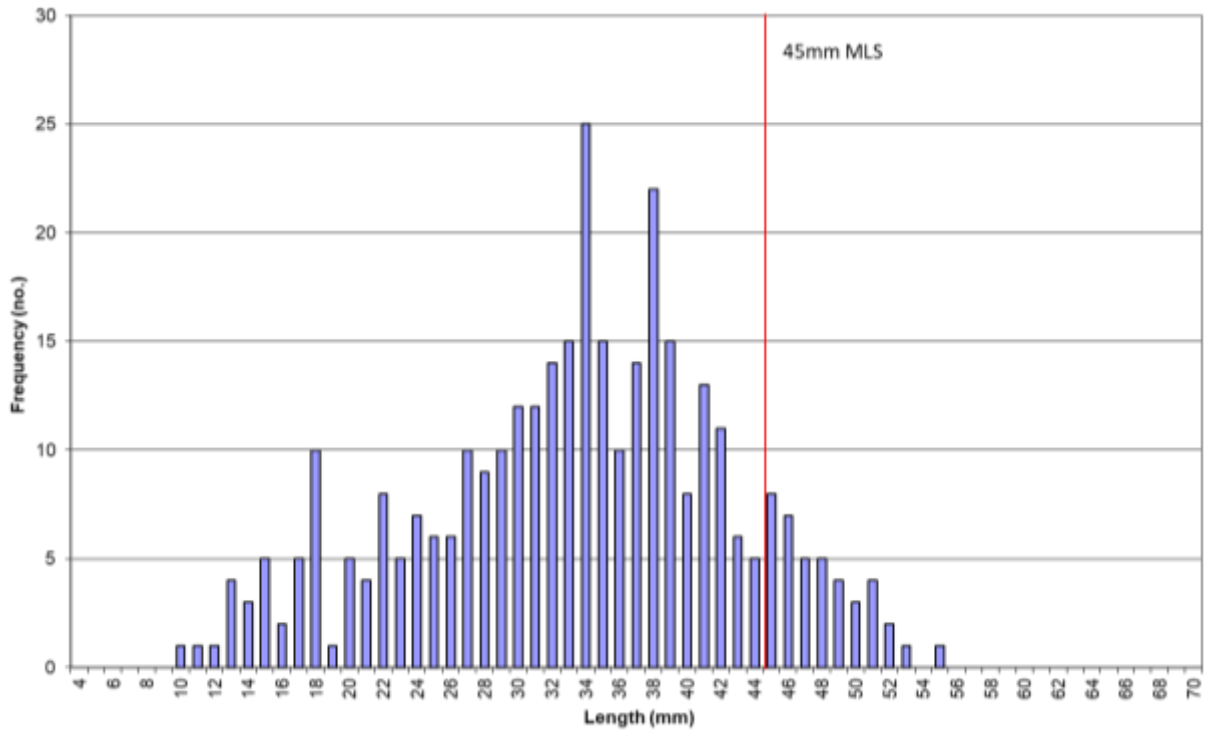


**Figure 26- Mussel size frequency on East Breast – January 2019**

The recent survey found the area of the bed had declined from 25.6 hectares in 2017 to 19.1 hectares. Within this area the coverage of mussels was found to have declined from 29% to 27% and the mean density from 1.02 kg/0.1m$^2$ to 0.94 kg/0.1m$^2$. From these figures, the total biomass of mussels on this bed was calculated to have declined from 764 tonnes to 489 tonnes, while the biomass of harvestable sized mussels had declined from 272 tonnes to 144 tonnes.

**East Scotsman's Sled**

- Area: 55.7 hectares
- Coverage: 22%
- Mean Density: 0.89 kg/0.1m$^2$
- Total Stock: 1,101 tonnes
- Stock ≥ 45mm: 314 tonnes

The Scotsman's Sled bed was surveyed on October 24$^{th}$ during which samples were collected from every fourth "hit", producing 50 samples from seven transects. Figures 27 and 28 show the mussel size distribution over the bed and the mussel size frequency within the population taken from these samples.

Although between surveys the area of the bed had only changed from 55.4 hectares in 2017 to 55.7 hectares, there had been a loss of area to the south of the bed that had been compensated with gains to the north. Within the bed the coverage of mussels had declined from 29% to 22% but the mean density had increased from 0.77 kg/0.1m$^2$ to 0.89 kg/0.1m$^2$. From these figures the biomass of mussels in the bed was calculated to have declined from 1,253 tonnes to 1,101 tonnes and the biomass of mussels ≥45mm from 456 tonnes to 314 tonnes.

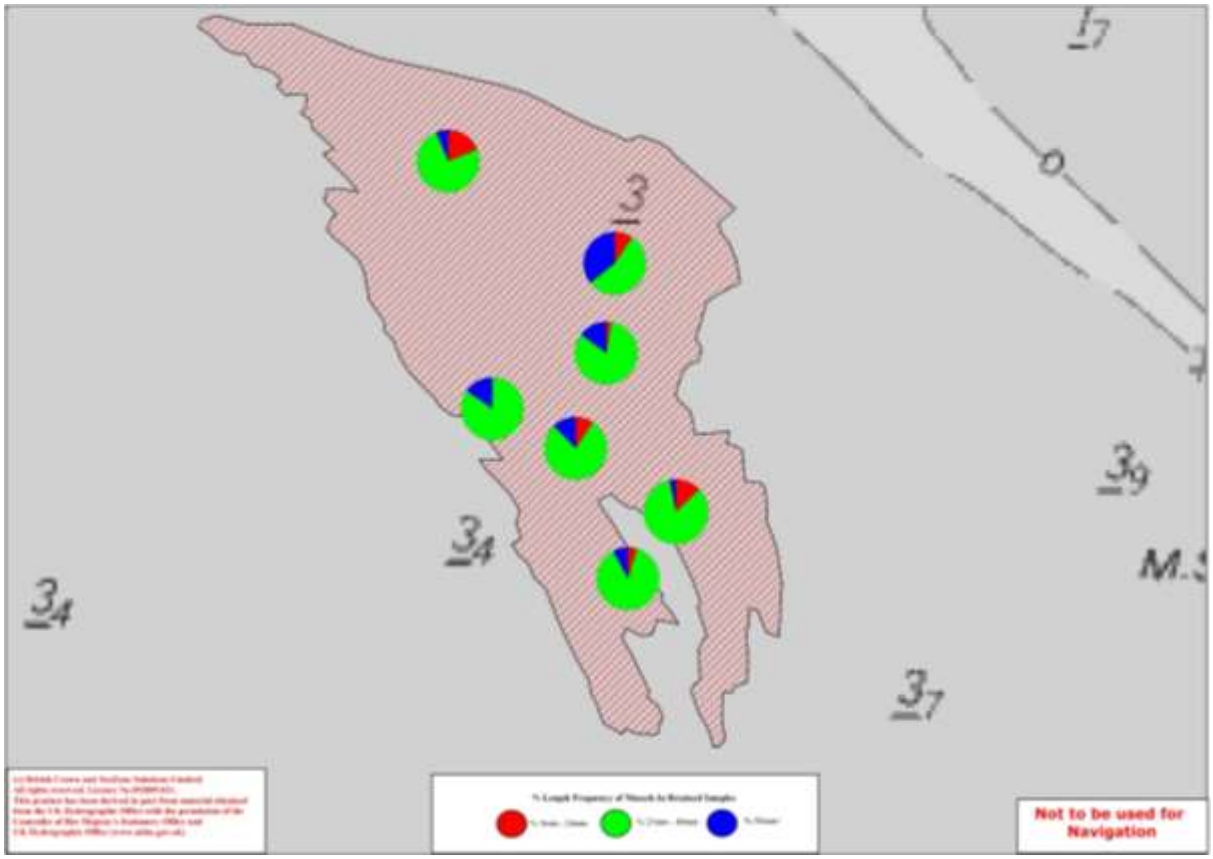


**Figure 27 - Mussel size distribution on the East Scotsman's Sled mussel bed – October 2018**

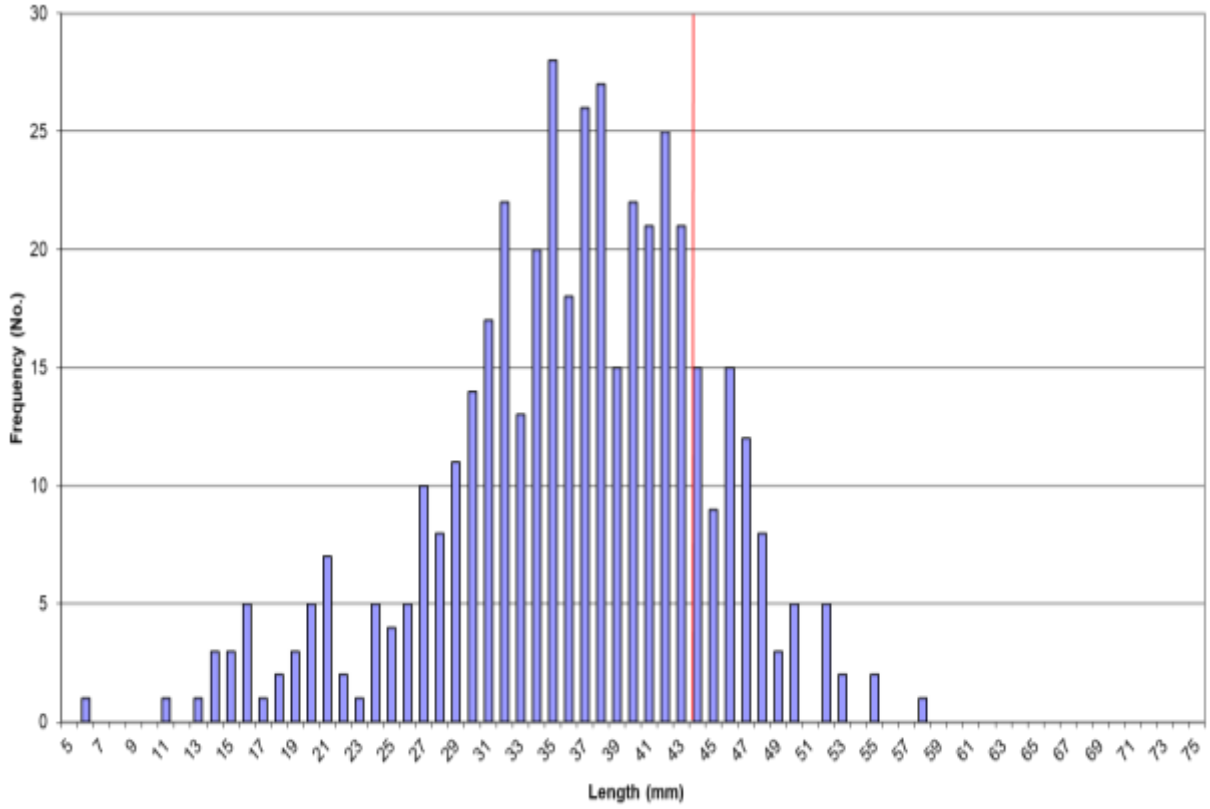


**Figure 28 - Mussel size frequency on East Scotsman's Sled – October 2018**

**Blackshore**

**North**

- Area: 3.1 hectares
- Coverage: 21%
- Mean Density: 1.20 kg/0.1m$^2$
- Total Stock: 78 tonnes
- Stock ≥ 45mm: 41 tonnes

**South**

- Area: 7.9 hectares
- Coverage: 23%
- Mean Density: 0.74 kg/0.1m$^2$
- Total Stock: 133 tonnes
- Stock ≥ 45mm: 30 tonnes

The Blackshore 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. High mortalities of 3 year-old mussels between 2013 and 2015, however, caused the bed to decline to just 50 tonnes. In 2016 the bed benefitted from another good settlement of seed, but when surveyed in 2017 the eastern two-thirds of the bed were found to have washed 350 metres south (figure 29). Although it was thought the southern part of the bed might continue washing towards the River Ouse channel and be lost, the 2018 survey found it had not done so (figure 30).

The 2018 survey was surveyed on October 22$^{nd}$. Samples were collected from every fourth “hit”, producing 27 samples from five transects. Because the bed had split into two parts, the stock on each bed has been recorded separately but their mussel size frequencies have been combined into a single figure (figure 31). The area of the northern part of the bed was found to have declined from 5.1 hectares to 3.1 hectares. Here the coverage of mussels was found to have declined from 39% to 21% but the mean density had increased from 1.09 kg/0.1m$^2$ to 1.20 kg/0.1m$^2$. From these figures the biomass of mussels within this part of the bed was calculated to have declined from 217 tonnes to 78 tonnes. Growth of the mussels meant the biomass of ≥45mm mussels had increased from 8 tonnes to 41 tonnes. The area of the southern part of the bed was found to have declined from 8.5 hectares to 7.9 hectares. Within this area the coverage was found to have declined from 28% to 23% and the mean density from 0.90 kg/0.1m$^2$ to 0.74 kg/0.1m$^2$. The biomass of mussels within this part of the bed was calculated to have declined from 210 tonnes to 133 tonnes. The stock of ≥14mm mussels was calculated to have increased from 5 tonnes to 30 tonnes.

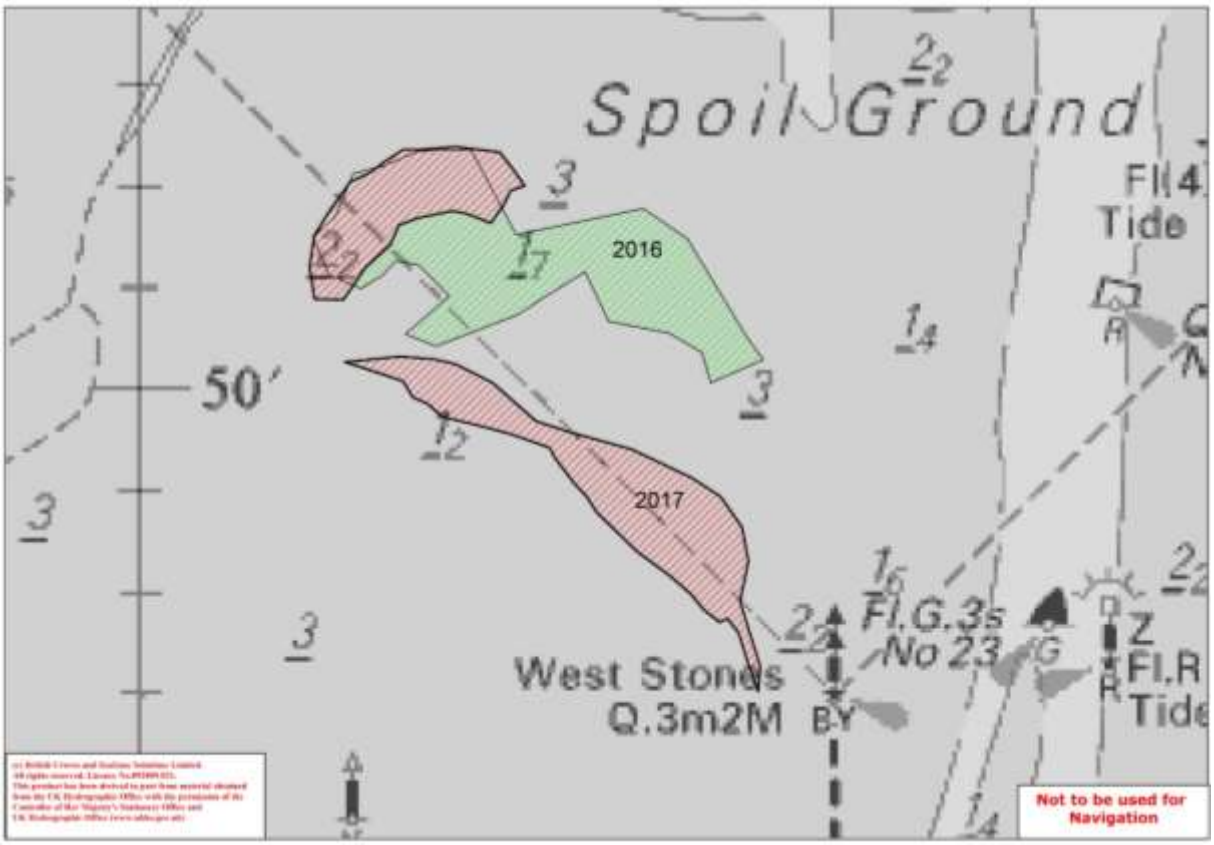


**Figure 29 – Chart showing the change in extent of the Blackshore mussel bed between September 2016 and November 2017**

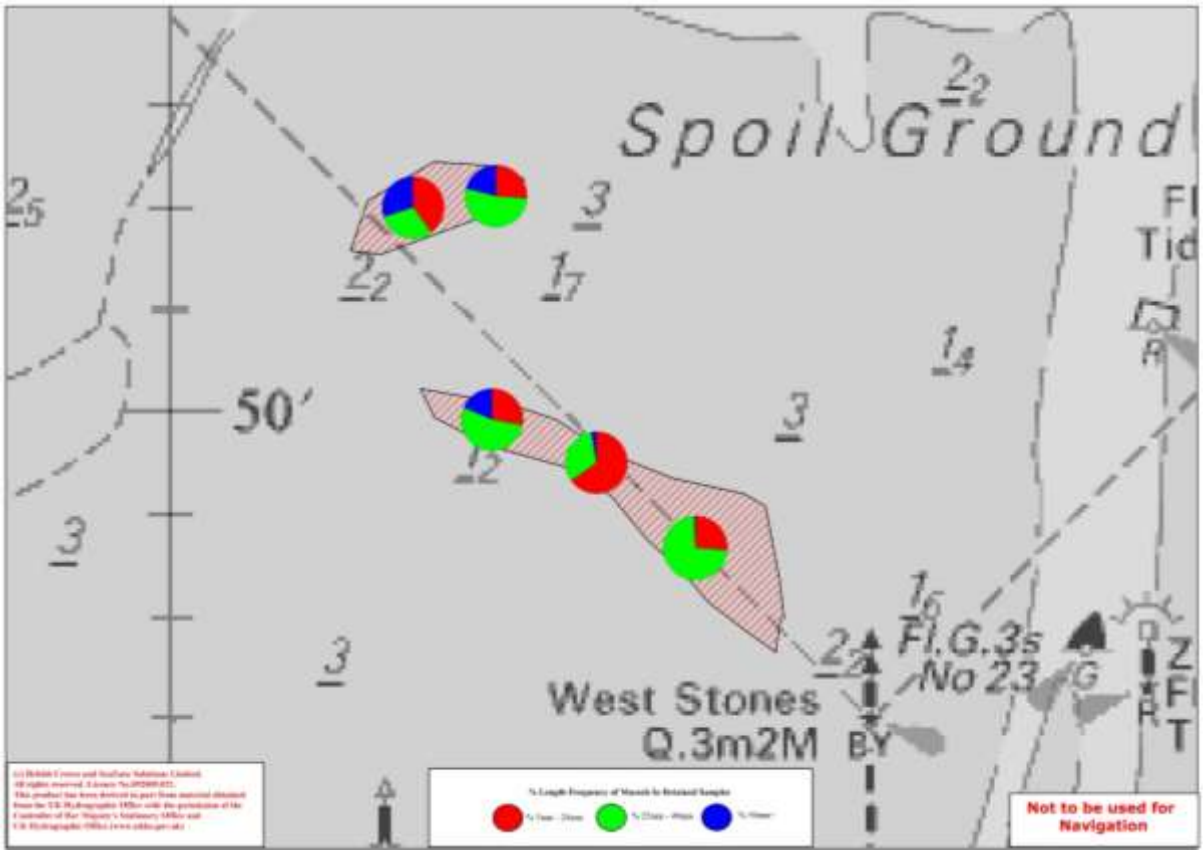


**Figure 30 – Chart showing the extent of the Blackshore mussel bed - October 2018**

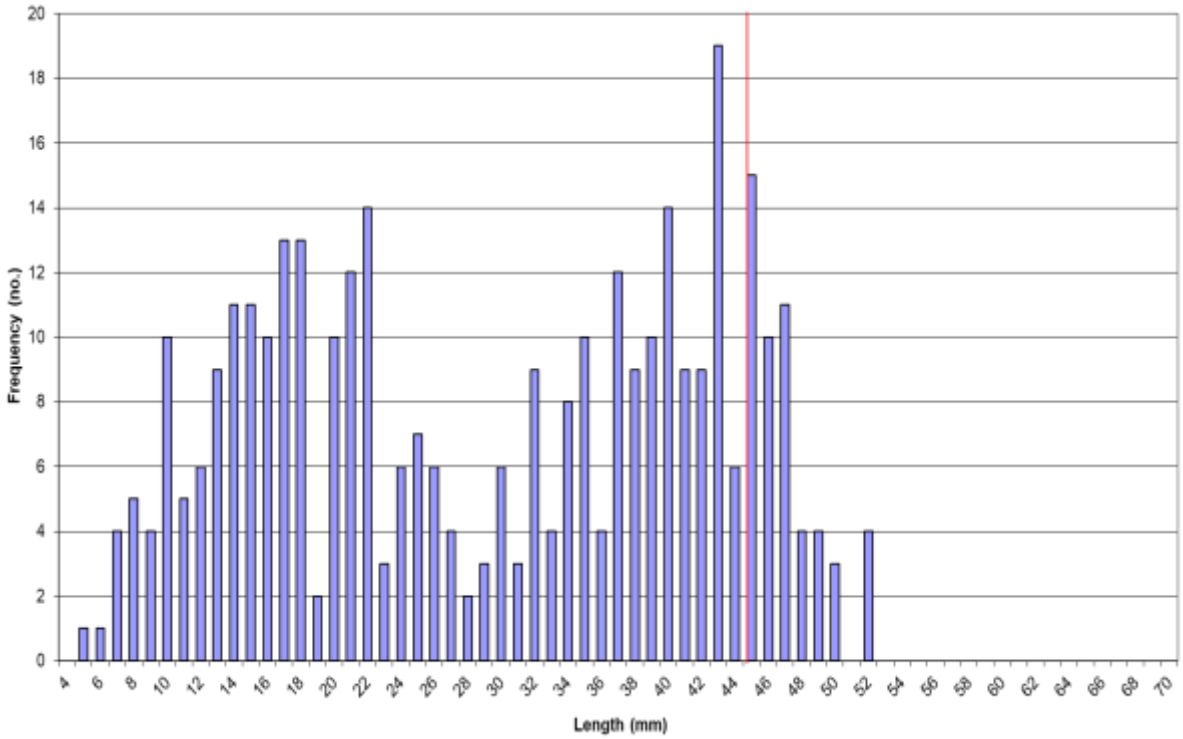


**Figure 31 - Mussel size frequency on Blackshore – October 2018**

**Welland Bank**

- Area: 1.8 hectares
- Coverage: 79%
- Mean Density: 2.38 kg/0.1m$^2$
- Total Stock: 339 tonnes
- Stock ≥ 45mm: 262 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. Because the mussel seed that settles on the wall tends to be sheltered in the crevices between the rocks, this bed tends to recover well from fisheries. As such, these stocks have been managed separately from the other inter-tidal beds and have remained open to the fishery since 2015.

**Figure 32 - 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 inter-tidal 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 33). As the best coverage of mussels on this wall is found at the lower extremities, the survey is generally conducted at low water on the largest possible spring tides. The 2018 survey was conducted on October 11$^{th}$. During the survey, samples were collected from every second “hit”, producing 45 samples from 24 sample stations. Figure 34 shows the mussel size frequency of the population taken from these samples. The survey found the area of mussels on the bank had declined slightly from 1.9 hectares to 1.8 hectares. Within this area the mussel coverage was found to have increased from 70% to 79%, but the mean density had declined from 3.36 kg/0.1m$^2$ to 2.38 kg/0.1m$^2$. From these figures, the total biomass of mussels on the bank was calculated to have

declined from 456 tonnes to 339 tonnes. The biomass of mussels that had reached a size of 45mm had declined from 339 tonnes to 262 tonnes.

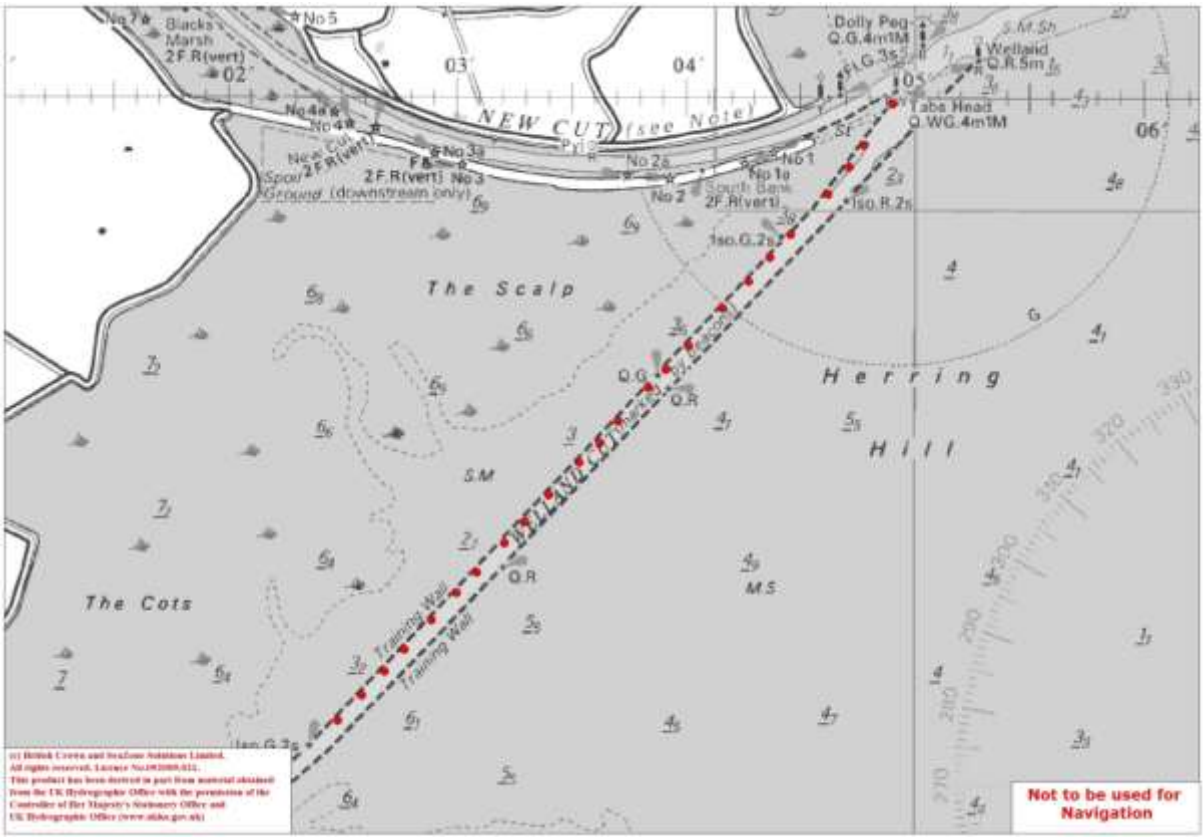


**Figure 33 - Chart showing the positions of sample sites on the Welland Bank – October 2018**

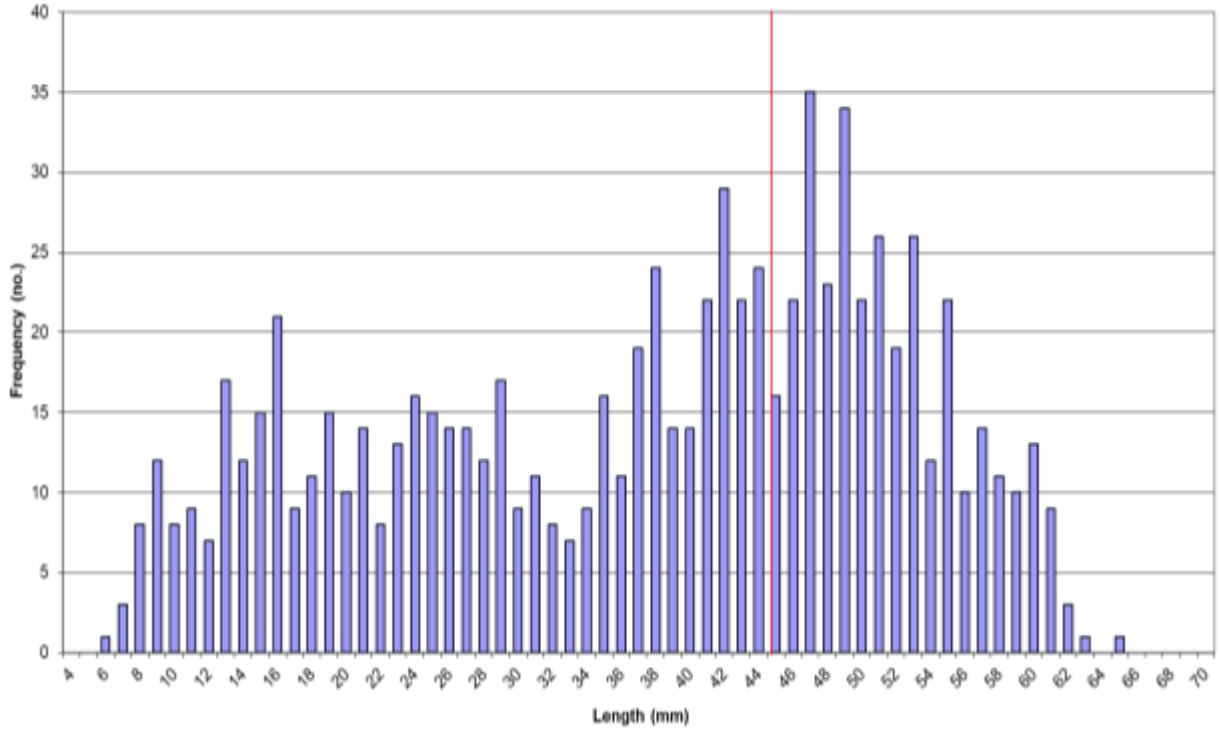


**Figure 34 - Mussel size frequency on Welland Bank – October 2018**

## Discussion

Since 2010 a combination of high mortality (particularly among 2 and 3 year-old mussels) and poor recruitment have caused the gradual decline of all of the inter-tidal mussel beds. Settlement of mussel seed outside of existing beds is an uncommon occurrence in The Wash, but following a good settlement in 2016, mussels settled in patches of ridged out cockles outside of some of the beds. The growth of these young mussels during 2017 helped the stocks to reach their highest biomass since the early 1980s. There was concern following this settlement, however, that the predominance of a single large cohort of vulnerable young mussels would result in high mortalities when they reached 3 years old in 2019. The results from the 2018 surveys, in which most of the beds have suffered losses of 2016 year-class mussels, seem to indicate these fears were justified and further high losses are expected to occur in 2019.

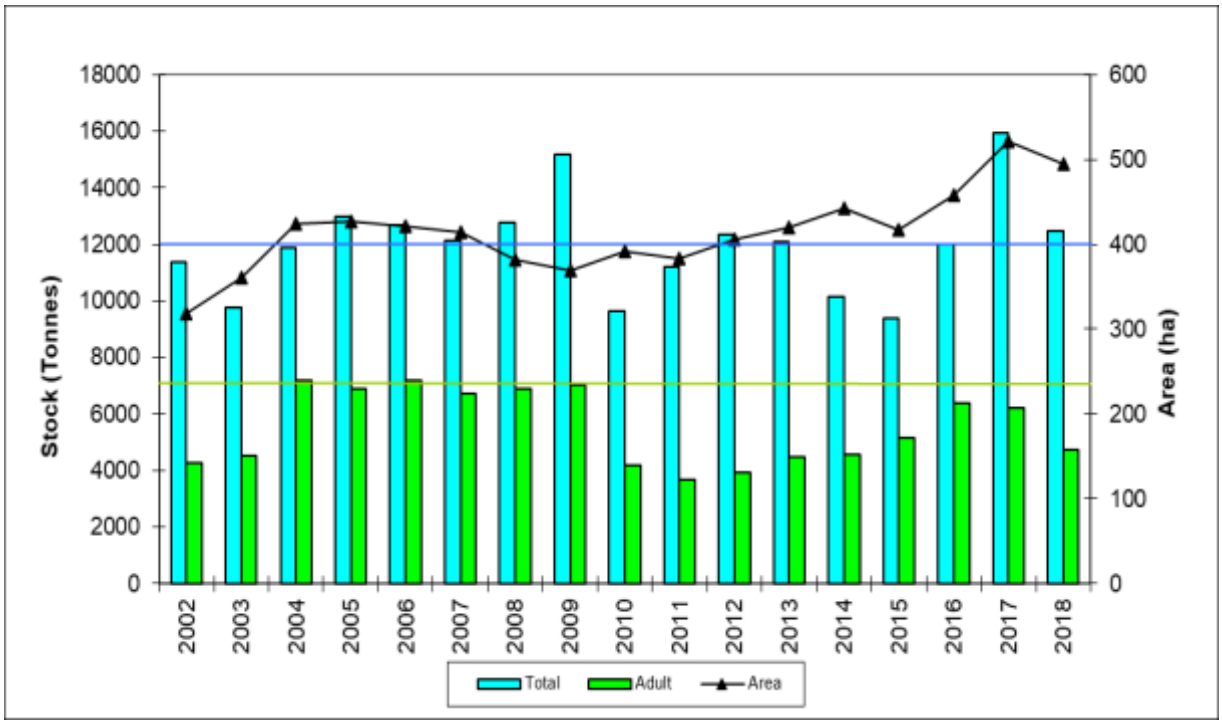


**Figure 35 – Intertidal mussel stock levels in The Wash since 2002 and the Conservation Objective targets**

Figure 35 shows the current levels of stock compared to past survey data from 2002 onwards. While the total stock is still above the Conservation Objective target of 12,000 tonnes, the adult stocks are below their 7,000 tonnes target. Due to the high mortality rates among young mussels since 2010, there has been little recruitment into

the adult population, preventing it from recovering. Those that are currently part of that population are mostly old (pre-2010 year-class) mussels rather than newer recruits. Without significant recruitment into the adult population, as these older mussels gradually age and die, the stock is expected to deplete further.

## References

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**Van Stralen, M.R. & Bol, J.;** 2004. Assessment of survey techniques used by Eastern Sea Fisheries (ESF) for mussel bed surveys in the Wash (UK).