Eastern IFCA

Inshore Fisheries and Conservation Authority

RESEARCH REPORT

2013

R.W. JESSOP

R. STRIGNER

S. THOMPSON

P.R. WELBY

1.0 EXECUTIVE SUMMARY

1.1 Introduction

The Authority's Research and Environment team complements the Enforcement and Administrative teams to deliver evidence-based fisheries management that is sensitive to social, environmental and economic needs. As well as a range of inshore fisheries operating in the district, the district supports a wealth of important natural features that are protected under a suite of UK and EU designations (Site of Special Scientific Interest, Special Protected Area, Special Area of Conservation, Ramsar site). These collectively form a network of Marine Protected Areas that will in the coming years be augmented with the creation of additional Marine Conservation Zones. In addition to continuing to support the Authority's management of the Wash Fishery Order 1992, which oversees the major molluscan fisheries in The Wash, the research team faces a considerable challenge in providing the evidence needed to develop fisheries management measures for the new conservation sites. To achieve these goals the Authority must not only continue the research and monitoring programmes conducted by its predecessor organisation, the Eastern Sea Fisheries Joint Committee, but must develop new skills and deliver a range of projects that will satisfy its new conservation requirements. To this end, the focus of the research team's work during 2013 was:

- To review and, where appropriate, continue with existing Core Research Monitoring projects;
- To advance the Authority's understanding of the features, habitats and species within the district's Marine Protected Areas, and the impacts of fishery activities occurring within them.
- To work in partnership with other organisations and stakeholders to effectively gather and share information;
- To ensure staff are adequately trained to fulfil their work objectives;

When developing the plan of research activities to be conducted during 2013, the Authority polled the community seeking 'bright ideas'. These included research projects that various partners and stakeholders indicated they would like the Authority to conduct alongside the suite of non-discretionary core projects. Table 1.1 lists the core research projects while table 1.2 lists the existing discretionary and suggested "bright ideas" projects.

Table 1.1 - Non-discretionary, core research projects for 2013/14

Activity	**Officer days 2013/2014**
Wash Fishery Order - Spring cockle surveys	90
Wash Fishery Order - Autumn mussel surveys	80
Wash Fishery Order - EHO/DSP Bio-toxin sampling	61
Wash Fishery Order - Water quality monitoring (SWEEP)	29
Wash Fishery Order - Management of Several Fishery lays	15
Habitat mapping (*Sabellaria* reefs and other MPA features)	120
Horseshoe Point cockle surveys	23
Titchwell Marsh mussel surveys	8
Desk Study – Assess current extent of habitat/feature maps in our district	15
Desk Study – Review current scientific literature detailing evidence of gear/feature impacts	15
Desk Study – Review of current survey methodologies and best practice	5
Stakeholder Liaison meetings	40
Technical Advisory Group (TAG) meetings, workshops and work streams	10
MEDIN - Meta-Data Compliance	3
Annual Research Report	60
Total	**574**

Table 1.2 – Discretionary and "Bright Ideas" projects suggested for 2013/14

Activity	**Officer days 2013/2014**
Wash Fishery Order - Autumn cockle surveys	40
Wash Fishery Order - Cockle mortality study for contingency measures	36
Wash Fishery Order - Cockle growth assessment	44
Wash Fishery Order - Cockle dredge environmental impact assessment for muddy sediments	35
Wash Fishery Order - Sub-littoral mussel surveys	29
North Norfolk Coast – Assessment of crab/lobster stocks	50

North Norfolk Coast – Assist Cefas with Practical Indicators in the Exploitation of CRUSTaceans (PIECRUST) surveys	12
Suffolk - Suffolk river surveys (cockles, clams and peacock worm)	35
Suffolk - Holbrook Bay native oyster survey	9
Suffolk - Oyster Restoration Plan for Stour and Orwell	20
Recreational Sea Angling - Revisit flounder project	85
Recreational Sea Angling - Fish monitoring programme	55
Byelaw Review – Mono-filament netting review	24
Byelaw Review - Fisheries Minimum Size review	10
Desk study – Fisheries Nursery Area review	20
Marine mammal observer training	8
Total	**512**

The research department has 1 Senior Research Officer and 3 Research officers. After weekends, public and personal holidays were taken into account, the team had a maximum total of 915 days available during 2013. It was estimated that of these, 20% would be required to fulfil staff development requirements (including inductions, training and appraisals) and necessary administration duties (planning, managing, liaison and reporting). This meant the research department had a total of 732 research officer/days available for conducting the various research projects. From the tables above, it can be seen that a high proportion of the research department's time (574 days) was estimated would be required for completing non-discretionary core research projects. This left only 158 research officer/days available with which to conduct the discretionary and suggested "Bright Ideas" projects, which together would require a total of 512 research officer days. Figures 1.1 depicts how the available time would need to be allocated between the core projects, while figure 1.2 shows how realistically it would not be possible to conduct all of the remaining projects in the remaining time.

Because the time required to complete all of the suggested projects greatly exceeded the resources of the research team, there was a need to prioritise the projects. Given the requirements to meet a full range of demands around the district during 2013, and the amount of time already allocated to core projects in the Wash, it was determined that only one further project could be conducted there. In addition to this project, further work would be chosen that would include studies in Suffolk and North Norfolk, and include a crustacean and a fish monitoring project. These latter projects included an assessment of the district's crab and lobster stocks (incorporating the PIECRUST study), a fish monitoring programme, continued monitoring of the native oyster population at Holbrook Bay and a mono-filament netting review.

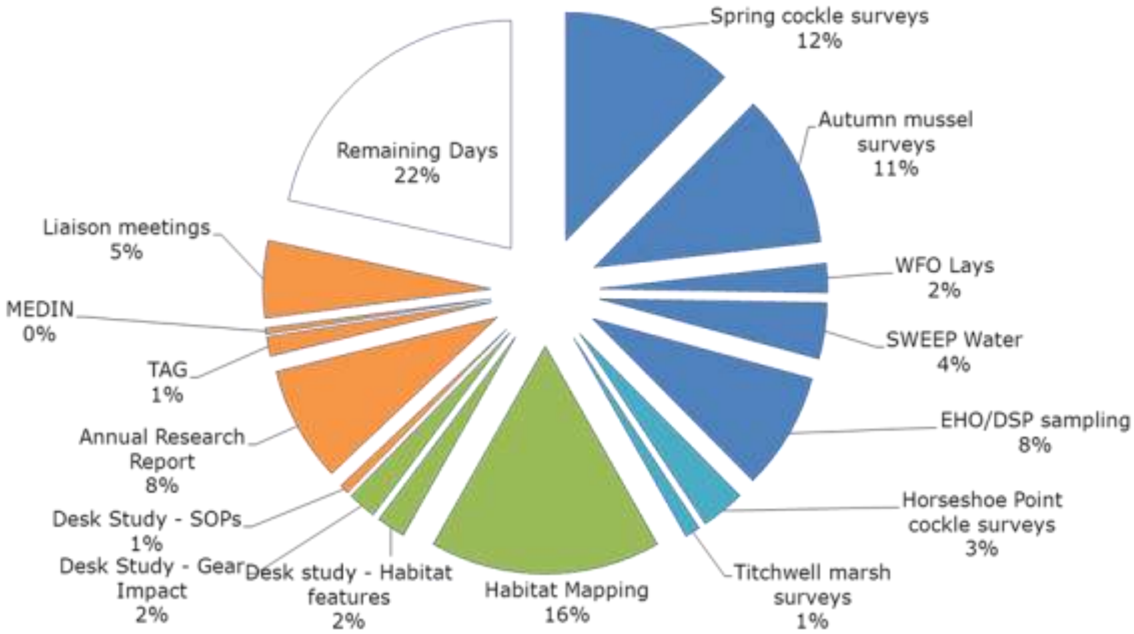


Figure 1.1 – Pie chart showing a breakdown of research officer resources required for the non-discretionary core projects

Project	2013-14
Autumn Cockle surveys	40
Cockle Mortality study	36
Cockle growth assessment	44
Cockle dredge Impact assessment	35
Sub-littoral mussel surveys	29
Crab/lobster biosampling	50
PIECRUST surveys	12
Suffolk River surveys	35
Holbrook Bay Native Oyster survey	9
Oyster Restoration Plan	20
Flounder research	85
Byelaw review - Monofilament nets	24
Juvenile Fish monitoring	55
Byelaw review - Fish MLS	10
Fisheries Nursery Area review	20
Marine Mammal observation	8
Total	**512**

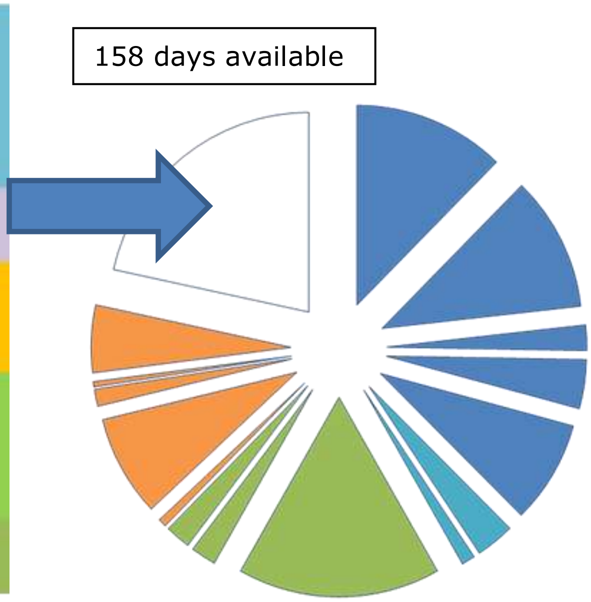


Figure 1.2 – Depiction of remaining research officer resources available for discretionary and "Bright Ideas" projects

Choosing which discretionary project would be conducted in the Wash was particularly difficult. In the past ESFJC had regularly conducted acoustic surveys to identify sub-littoral mussel seed. Although this type of work had almost become “expected” of the Authority, most of the Wash fishermen were instead divided over two of the other projects; a cockle mortality study or a cockle growth study. The former study would monitor “atypical” mortality rates with the potential to increase the fishable quotas of cockles in areas were the cockles were found to be dying. The cockle growth study was to determine how much the cockles grew between the spring surveys being conducted and the commencement of the fishery a few months later, again with a desire from the industry to increase quotas appropriately. Although a mortality study had been successfully conducted in 2012, allowing a contingency fishery to be opened on the Wrangle sand, the overall preference from the industry was for the cockle growth study.

This report details the main research activities that were conducted by the Authority during 2013.

Mussel surveys

Surveys conducted on the Wash inter-tidal beds found the mussel stocks appeared to be relatively stable, having decreased very slightly from 12,228 tonnes in 2012 to 12,100 tonnes. Although these figures suggested stability, and the Conservation Objective target for total mussel biomass has been achieved, overall the beds were in poor condition. The biomass of adult mussels had failed to meet the Conservation Objective target of 7,000 tonnes and several of the beds appeared to be in a state of continued decline having failed to attract any settlement for several years. The ideal substrate for seed to settle on is a raised matrix of live mussels and dead shells bound together with byssus threads. On several of the beds, the mussel densities have declined below levels at which they can support these raised matrices, reducing the probability of further successful settlements.

On the North Norfolk coast on the lower shoreline of Titchwell Marsh there is a small bed of mussels attached to an outcropping of exposed Neolithic peat. Being exposed to strong winter tidal action, this bed is ephemeral in nature, regularly attracting good settlements of seed that are subsequently washed away. A survey conducted in February found the mussel biomass on this bed to be 110 tonnes. Although this was found to have increased to 129 tonnes when surveyed again in August, the population structure indicated some of the mussels had been lost following the February survey and replaced with the new settlement.

Cockle surveys

The spring cockle surveys in the Wash found that while the total cockle biomass had declined slightly from 21,106 tonnes to 20,932 tonnes, the biomass of cockles that had attained a size of ≥14mm width had increased from 7,107 tonnes to 11,159 tonnes. This was mainly due to a high proportion of the dominant 2010 year-class cohort reaching 14mm between surveys. Having shown sharp declines between 2008 and 2011, the past two surveys have shown some signs of recovery and stability. This has been facilitated by the recruitment and growth of a strong 2010 year-class cohort which boosted the total cockle biomass in 2012 and the adult biomass in 2013. With the exception of those stocks which died on Wrangle in 2012, most of this cohort has not yet been affected by the atypical mortalities that have been responsible for the declines. Their size and age structure suggests they could be vulnerable to high losses during the summer of 2013, however, which would precipitate a further decline by 2014. The survey also found high densities of 2011 year-class cockles to be present on the Dills and Daseley's sands. Although these were just under commercial size at the time of the surveys, the industry predominantly targeted these stocks during the summer fishery.

Cockle surveys conducted at Horseshoe Point since 2010 have found the cockle stocks to be suffering the similar atypical mortality effects as those in the Wash. The cockles on this bed grow faster than those in the Wash, and possibly as a result of this, the mortalities have been seen to occur sooner. Although the bed has benefited from regular settlements of spat each summer, the majority are tending to die before their second summer, precluding the opportunity for a fishery.

Cockle growth study

The project looking at the impact of cockle growth detected measurable levels of growth had occurred in the two month study period. Over all age groups there had been an 18.2% increase in mean cockle weight, with the younger, smaller cockles increasing in weight at faster rates than the larger cockles. If this figure was applied to the cockle biomass of 20,932 tonnes at the time of the spring surveys, the stock would have grown to 24,760 tonnes by the start of the fishery. Because some of the <14mm width cockles had attained 14mm width during the study period, the biomass of this population would have increased at a faster rate of 26.5%, from 11,159 tonnes to 14,117 tonnes. These figures, however, do not account for any mortalities that may have occurred during the study period. Although cockle stocks at this time of the year tend not to be subject to the large-scale mortalities associated with losses from winter storms or warm weather phenomena like "ridging-out" events or "atypical" mortality, bird predation and other natural losses would have occurred. The methodology was designed to collect information about mortality rates in addition to growth, but even though two replicates were taken from each sample station, localised variability in cockle densities were too high for mortality estimations to be made. If the TAC for the fishery was calculated from figures that took into account growth but not mortality, it could easily lead to over-exploitation of the stocks. This might not only endanger the sustainability of the stocks but could also have a detrimental impact on the conservation status of the site.

Crustacean stock assessment

The Crustacean research programme was reinitiated this year and this report represents the first efforts at utilising data from MSAR (Monthly Shellfish Activity Returns) forms in analysing the fishery. This data has allowed effort and landings to be quantified for the entire district, by port and by fishing grounds leading the identification of the main areas of activity in the district for this type of fishing. The North Norfolk coast has been identified as the most productive with ~95% of mean annual landings originating from this area. Edible crab is by far the most important species landed in terms of weight but the value of the crab fishery is only slightly higher than for lobster due in most part to the higher market value of the latter species. Fisheries assessment has been carried out on the most important fishing grounds in the area using surplus yield models to provide indicative estimates of MSY (maximum sustainable yield) and optimum fishing effort. Initial indications are that none of the fisheries in the area are operating at unsustainable levels but that some may be approaching threshold levels. A need for more appropriate analysis methods has been identified, along with the need for a programme of biosampling at sea and point of landing to support the MSAR data.

Finfish Project

The finfish project audited the main finfish species and fisheries within our district. Data from several sources were used for this study, including EIFCA and MMO landings records, Environment Agency survey data and records of fish caught on screens from the Sizewell nuclear power station. This information was summarised into species summary sheets for each of the main finfish species within our district.

Habitat Mapping

The Authority continued to map *Sabellaria spinulosa* reefs in the district. Unlike earlier surveys that had used RoxAnn AGDS equipment and intensive ground truthing for mapping these features, this year’s surveys were conducted using an Edgetech 4200 side scan sonar.

Suffolk Rivers

Since 1997 the Authority (and its predecessor, ESFJC) have conducted regular surveys in the rivers Stour and Orwell. These have included monitoring the cockle and Manila clam populations along the inter-tidal banks of the rivers, colonies of peacock worm in both rivers, a population of native oysters in the Holbrook Bay area of the River Stour and a population of mussels at North Mistley. Due to high workloads and competition from other projects, this year the surveys in these rivers were limited to monitoring the native oyster and mussel stocks. Since the first oyster survey in 2004, the stocks have steadily declined to a level only a ninth the size of the original survey. The reason for this decline is not currently unknown, but could be due to a change in the substrate which has become muddier during this period. Four small patches of mussel were surveyed at North Mistley. These mainly supported populations of old, barnacle encrusted mussels with little evidence of any recent settlements.

Water Quality

The Study of the Wash Embayment Environment and Productivity (SWEEP) was continued throughout 2013. Although no short term high resolution studies were conducted this year, long term monitoring was in place as usual. Unfortunately, the project faced a number of challenges this year including sonde malfunctions, sonde damage and staff changeovers. These resulted in significant gaps in data, especially with regards to the spot monitoring. The buoy sonde provided a reliable picture of the year's water quality parameter movements and patterns, and results were compared with weather data.

Bacteriological and Biotoxin sampling

Bacteriological and biotoxin sampling was continued in 2013 for the Wash area on behalf of the Food Standards Agency (FSA) for the purpose of determining bed classifications for commercial shellfish harvesting areas. In the Wash this consisted of mussels *M. edulis* and cockles *C. edule*. Sampling sites remained the same in 2013 as they were in 2012, and all beds were classified as class B, the majority of which achieved long-term status. 2013 saw the Welland Wall site being upgraded from class C to class B, marking an improvement in water quality.

2.0 WASH MUSSEL STOCKS

2.1 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.

2.2 Method

The intertidal mussel surveys in the Wash are conducted during the daytime low periods of spring tides. These tides allow vessel to 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 2.1).

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.

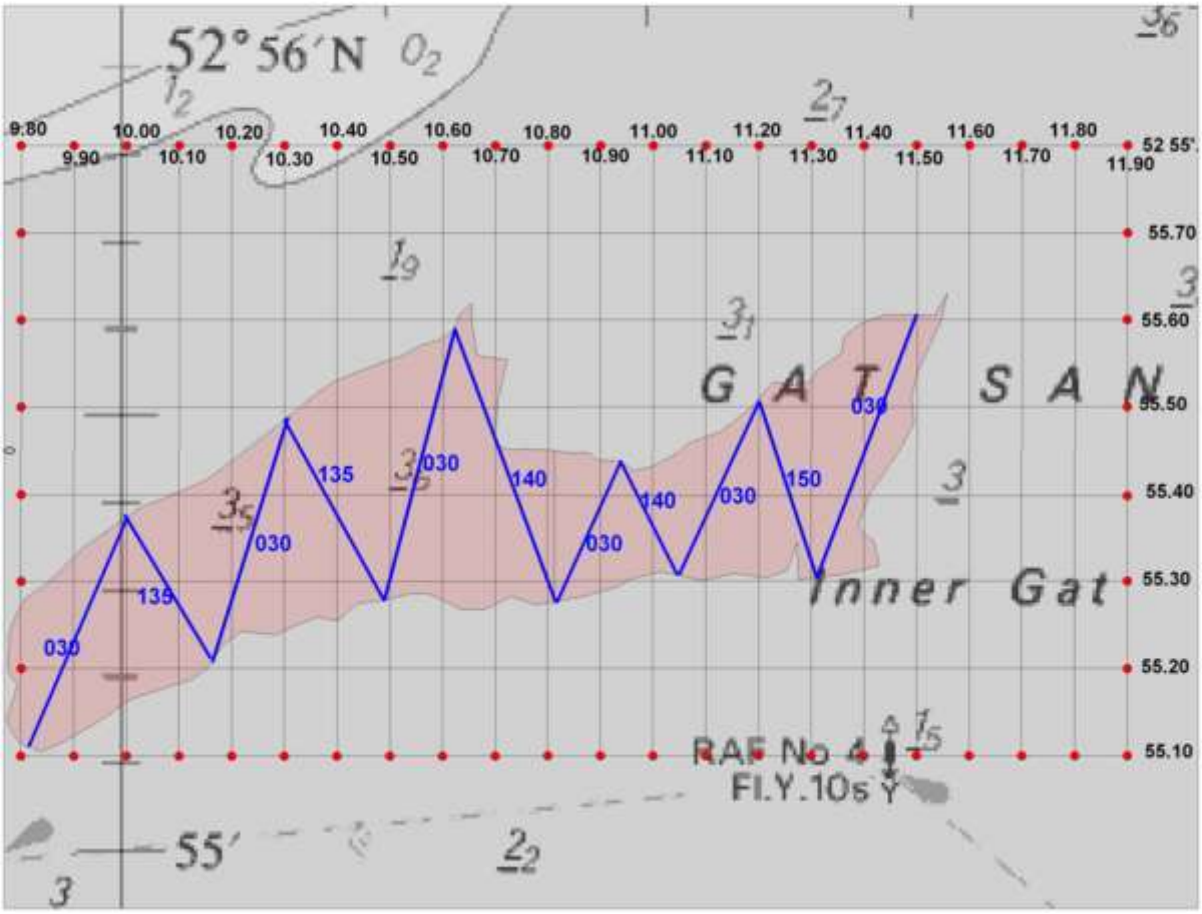


Figure 2.1 – Chart showing the area of a mussel bed, the transect lines to be surveyed, their bearings and an overlaid grid showing the lat/long positions

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.

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.

2.3 Results

The 2013 surveys were conducted between September 21st and November 19th, during which 19 areas of mussel bed, plus the Welland Bank, were surveyed. Following advice from the industry regarding the potential location of another bed, a further survey was subsequently conducted in the area of Daseley's North West Run (Teetotal Run) on December 6th. Insufficient mussels were found at this site to warrant inclusion in the dataset. Figure 2.2 shows the location of the beds surveyed.

The total biomass of mussels on the regulated beds was found to be 12,100 tonnes, a slight decline from the 12,338 tonnes recorded the previous year. Although there had been a light dredge fishery during October that had contributed towards this decline, the main losses were attributed to high mortalities of 3 year-old mussels on the Daseley's and Blackshore beds. These caused the total loss of the Daseley's bed and a 45% reduction on the Blackshore bed. Growth of mussels and a light recruitment had helped some of the beds increase in biomass over the year, but several of the beds were found to be in poor condition following several successive years of decline. These beds, which include the Gat, East Mare Tail, Shellridge, Main End and Pandora, are predominantly composed of ageing populations of large, barnacle-encrusted mussels growing amid dead shells. Having attracted little recruitment in recent years to offset natural mortality, some of these beds now only support scattered clumps of mussel amid old scars of dead shell and are interspersed with large bare patches. No longer having sufficient mussel density with which to form the raised structures best suited for attracting seed, some of these beds are in danger of being permanently lost. Figure 2.3 shows the recent changes in stock biomass that have occurred during the year.

4,487 tonnes were found to have attained the Minimum Landing Size (MLS) of 45mm length. This is an improvement on the 3,942 recorded in 2012 but is still well below the Conservation Objective target of 7,000 tonnes for mussels of this size. Since the decline of this group in 2010, recovery has been slow.

There had been a light settlement of spat on some of the beds.

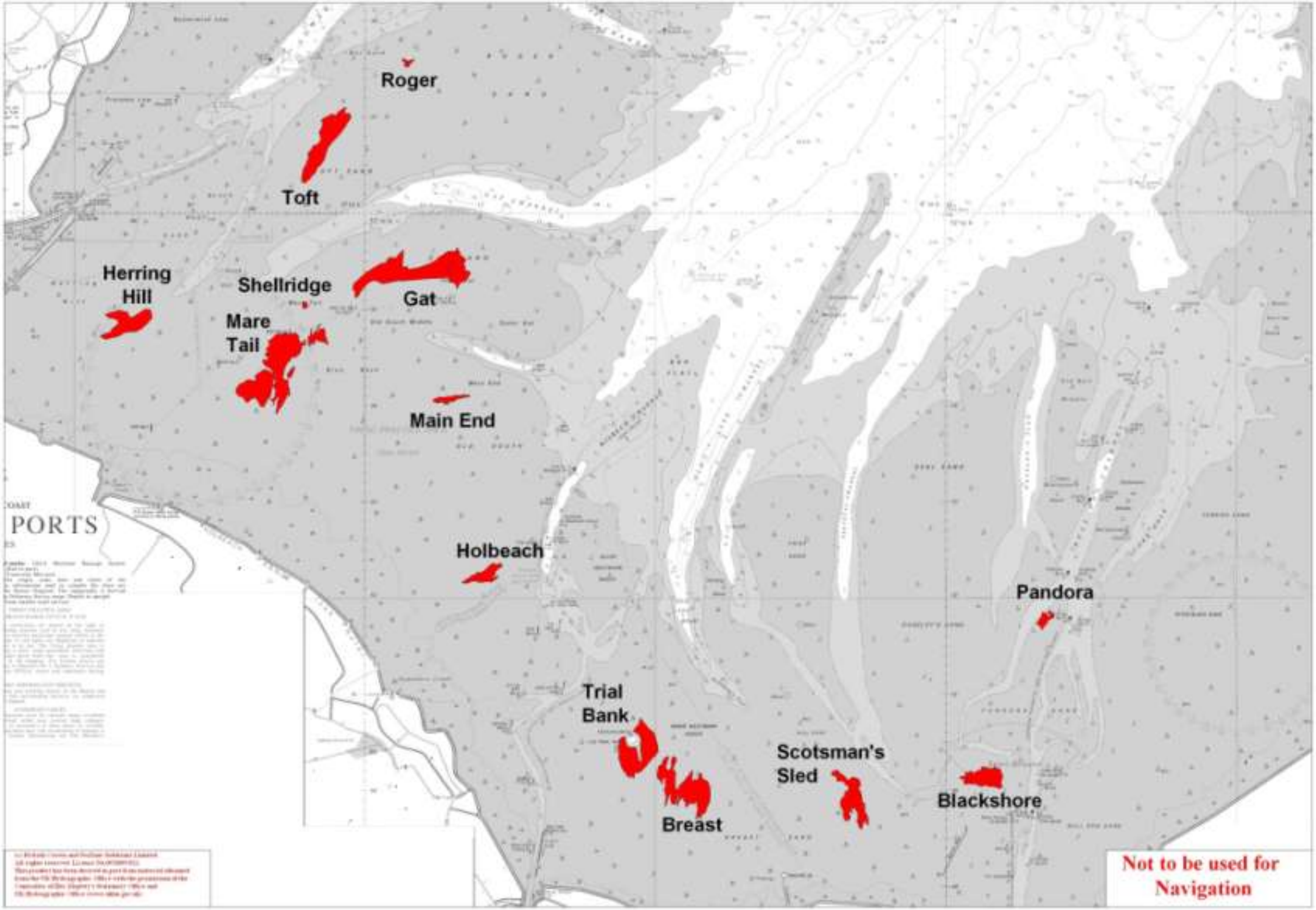


Figure 2.2 Distribution of intertidal mussel beds surveyed during 2013

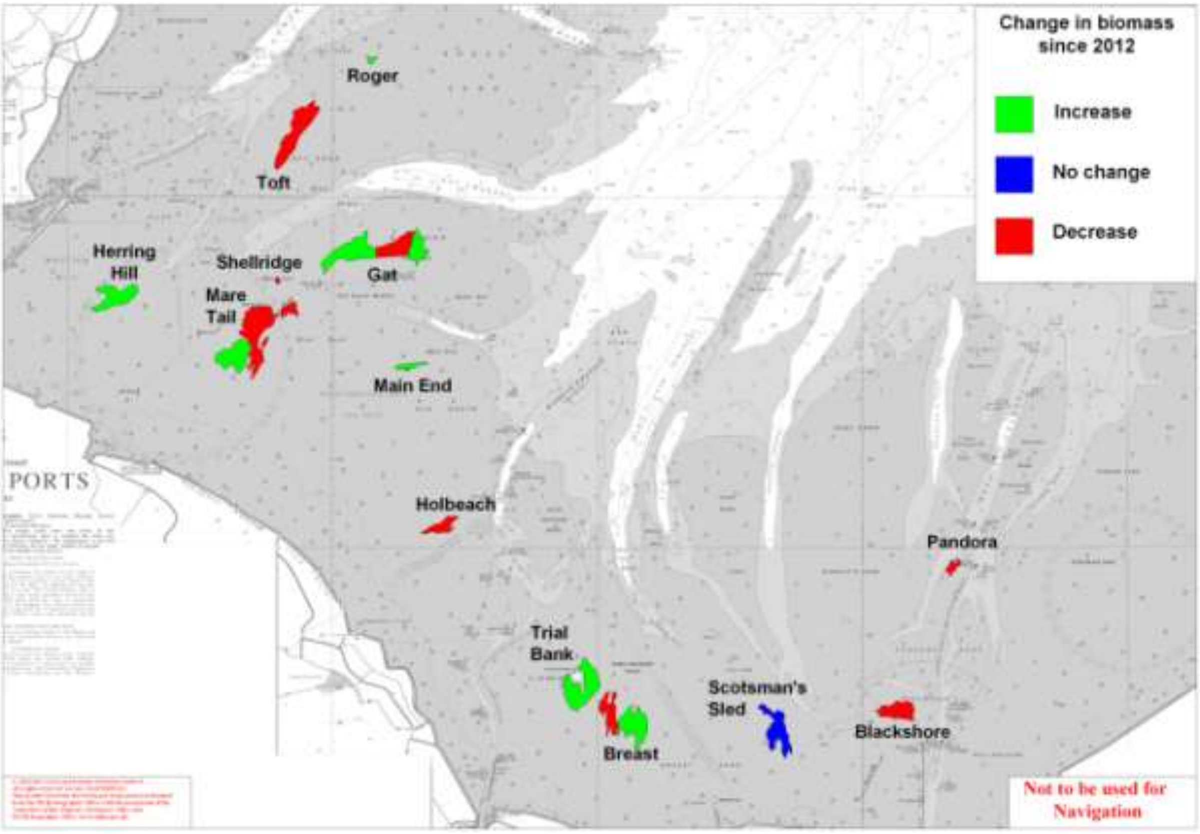


Figure 2.3 Chart showing changes to stock biomass on the intertidal mussel beds since 2012

2.3.1 Mare Tail Beds

There are four discrete areas of mussel bed present on the Mare Tail sand, which for survey and management purposes are referred to as the North, South, and East Mare Tail beds and the Shellridge (figure 2.4). 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. Although the mussels from these beds are not of sufficient quality to directly harvest, they have traditionally provided the industry with a source of seed for relaying.

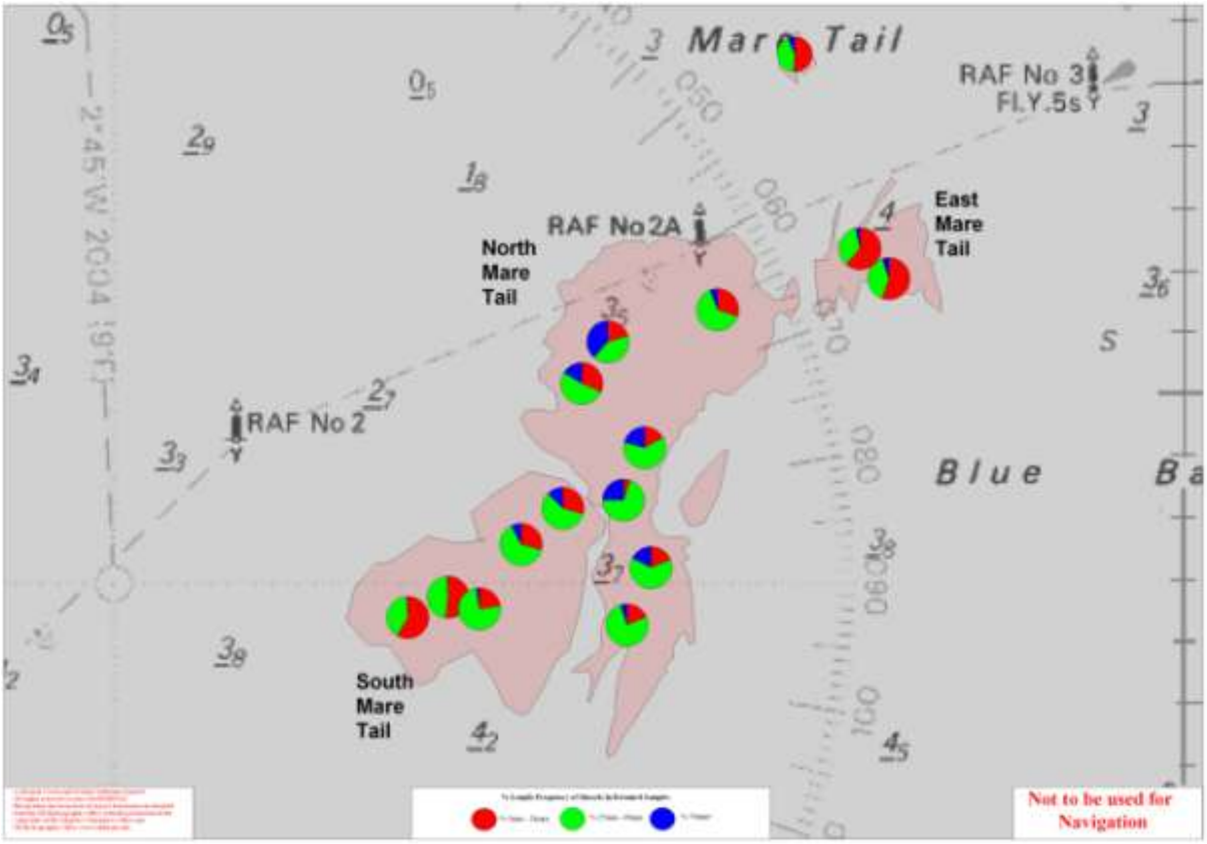


Figure 2.4 Mussel size distributions on the Mare Tail mussel beds – September 2013

2.3.1.1 North Mare Tail

- Area: 54.2 hectares
- Coverage: 36%
- Mean Density: 1.24 kg/0.1m^2
- Total Stock: 2,398 tonnes
- Stock ≥ 45mm: 900 tonnes

The North Mare Tail bed was opened to the dredge relaying fishery in October 2013 during which light fishing activity occurred to the northern part of the bed. The survey on this bed, which had been delayed until the end of the fishery, was conducted on November 9th. During this survey, samples were collected from every fifth "hit", producing 70 samples from seven transects. Figure 2.5 shows the mussel size frequency within the population taken from these samples.

The area of the bed was found to have decreased during the year from 63.3 hectares to 54.2 hectares, mainly as the result of an area of low density mussels that had been included in the previous survey being excluded from the current survey. Within the bed the coverage had decreased from 38% to 36%, possibly as a result of the fishery, while growth had helped the mean density of the mussel patches increase from 1.10 kg/0.1m^2 to 1.24 kg/0.1m^2. From these figures the total biomass of mussels on the bed was calculated to be 2,398 tonnes compared to 2,644 tonnes recorded the previous year. Of these, 900 tonnes had attained the minimum landing size of 45mm, a good improvement to the 613 tonnes recorded in 2012. As a consequence of disparate fishing efforts on this bed, which have tended to focus on the northern parts of the bed, the mussel coverage is now significantly lower in the northern parts of the bed than the southern parts.

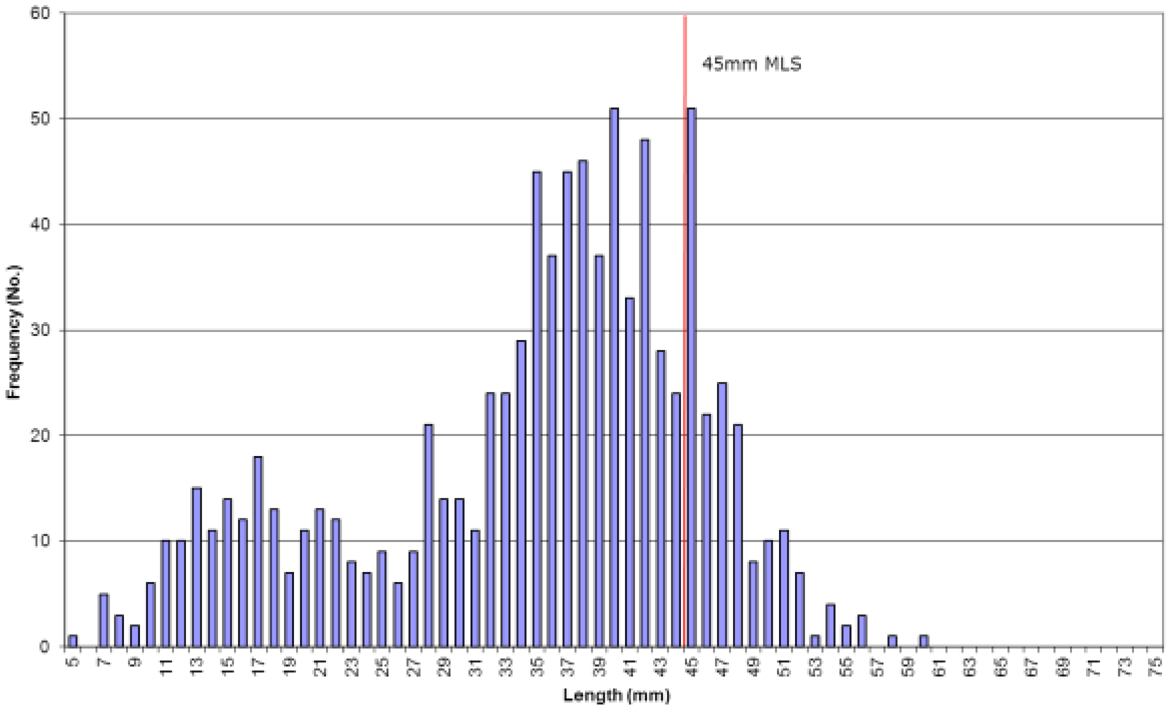


Figure 2.5 Mussel size frequency on North Mare Tail - September 2013

2.3.1.2 South Mare Tail

- Area: 30.9 hectares
- Coverage: 36%
- Mean Density: 0.81 kg/0.1m^2
- Total Stock: 890 tonnes
- Stock $\geq$ 45mm: 121 tonnes

The South Mare Tail bed was surveyed on September 22nd 2013. Samples were taken from every fourth "hit", producing 64 samples from five transects. Figure 2.6 shows the mussel size frequency within the population taken from these samples.

The area of this bed was found to have increased slightly from 29.8 hectares to 30.9 hectares. Within this area a light settlement of seed had helped the coverage increase from 27% to 36% and the mean density from 0.76 kg/0.1m^2 to 0.81 kg/0.1m^2. From these figures the biomass of mussels within the bed was calculated to be 890 tonnes, compared to 615 tonnes the previous year. Of these 121 tonnes were found to have attained the 45mm MLS compared to 37 tonnes in 2012.

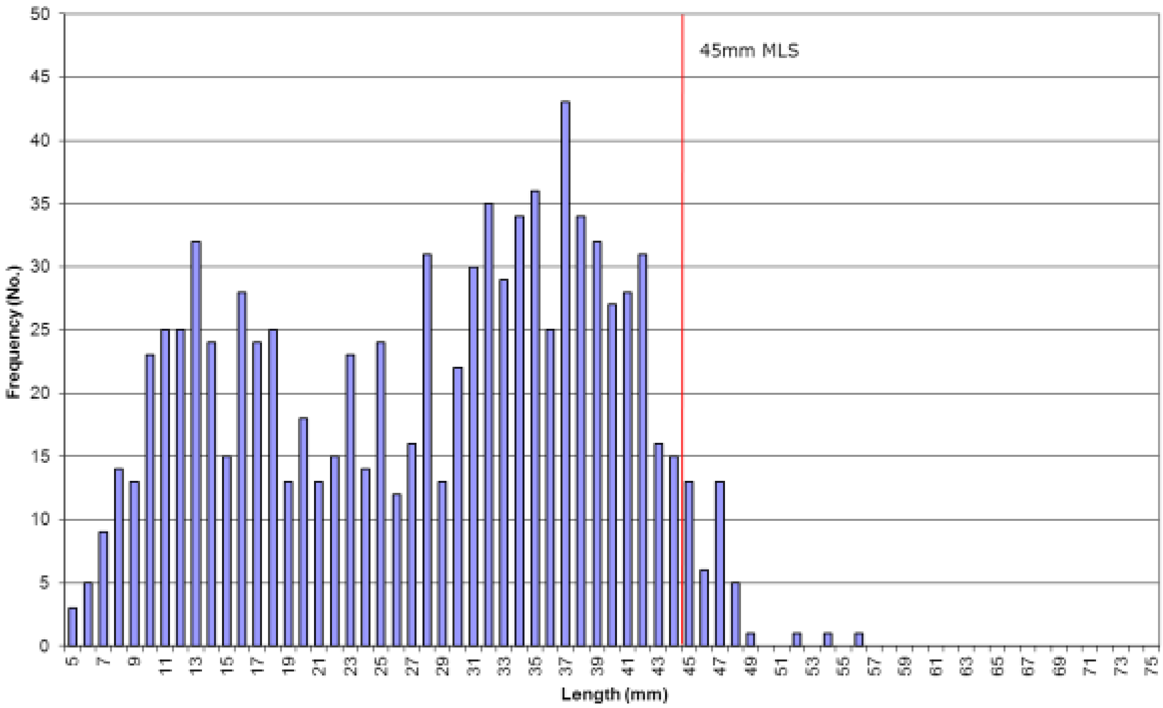


Figure 2.6 Mussel size frequency on South Mare Tail - September 2012

2.3.1.3 East Mare Tail

- Area: 7.2 hectares
- Coverage: 23%
- Mean Density: 0.33 kg/0.1m^2
- Total Stock: 54 tonnes
- Stock ≥ 45mm: 11 tonnes

The East Mare Tail bed was surveyed on October 6th 2013. Samples were collected from every third "hit", resulting in 20 samples being taken from two transects.

The area of this bed was found to have increased from 5.5 hectares to 7.2 hectares, but both the coverage and mean density within it had decreased from 29% to 23% and from

0.64 kg/0.1m^2 to 0.33 kg/0.1m^2. From these figures the total biomass of mussels in this bed was calculated to be 54 tonnes, a significant decline from the 102 tonnes recorded the previous year. The stock of mussels that had attained marketable size was found to have declined during the same period from 43 tonnes to 11 tonnes.

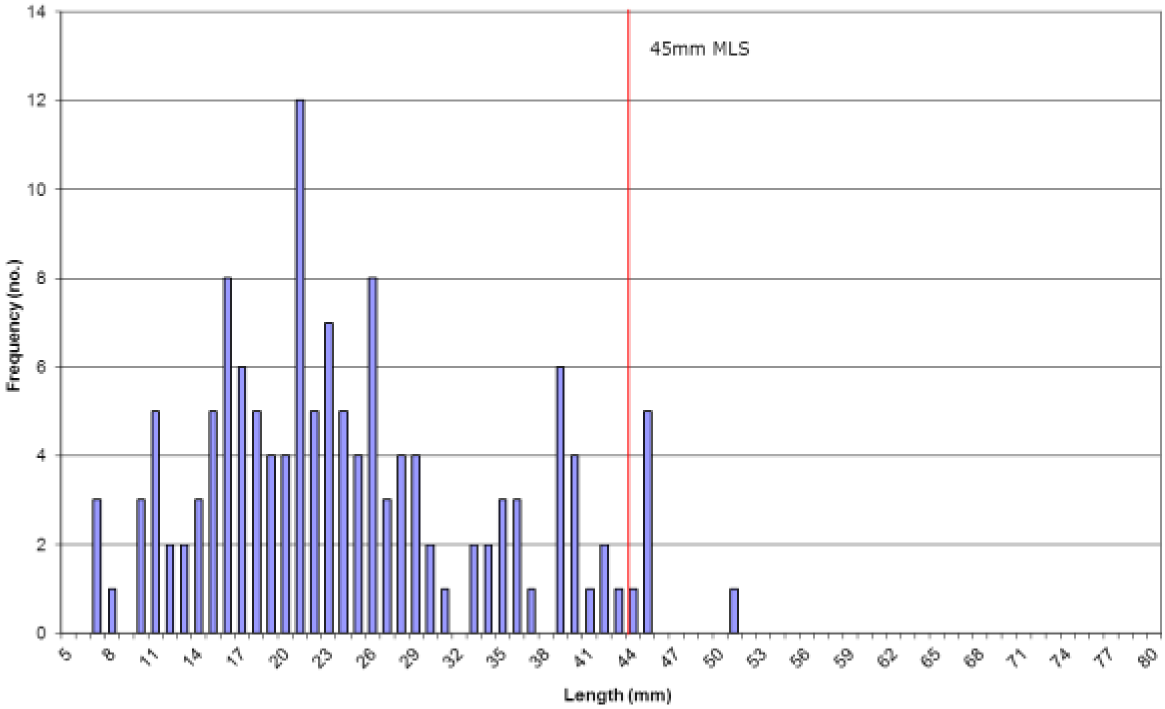


Figure 2.7 Mussel size frequency on East Mare Tail – September 2013

Figure 2.7 shows the size frequency of the mussels found in the samples from this bed. The predominance of smaller mussels seen in this figure would suggest the bed has benefitted from a good settlement of seed in the past year. This is not the case, however, and the predominance of smaller mussels seen in the chart is actually due to the declining number of large mussels in comparison. The decline of mussel stocks on this bed is highlighted in figure 2.8, which shows the mussel biomass found on the bed since 2002. Although there have been regular fluctuations in the stock levels over that time, which are possibly an artefact of the level of survey accuracy, the overall trend is downwards

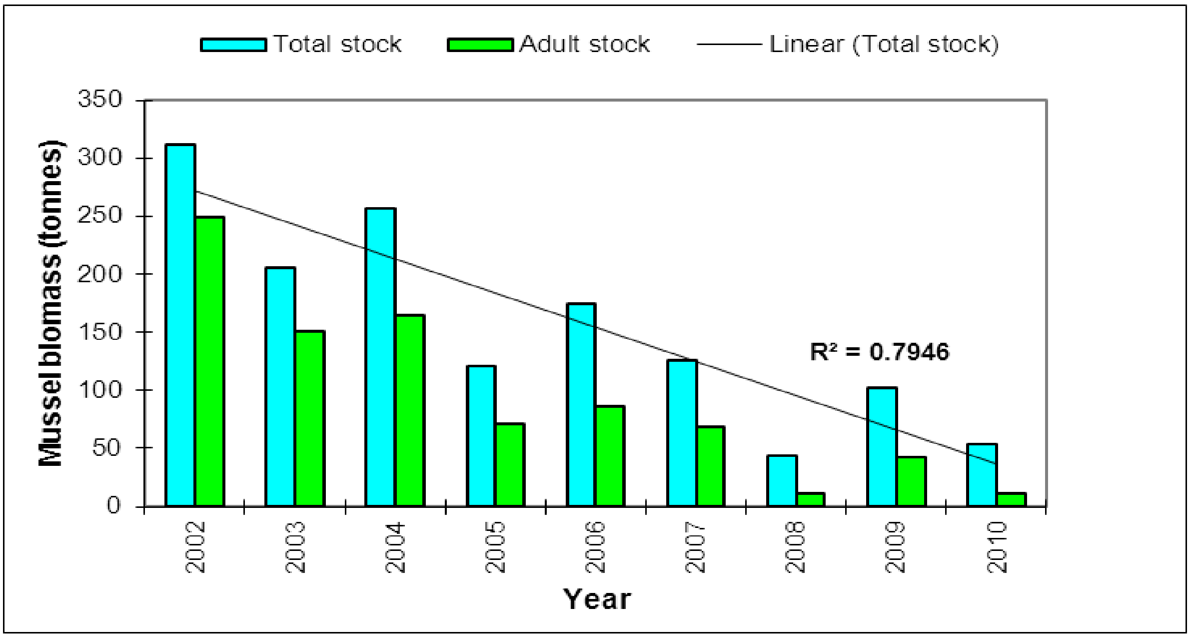


Figure 2.8 Biomass of mussels on East Mare Tail bed between 2004 and 2012

2.3.1.4 Shellridge

- Area: 1.0 hectares
- Coverage: 17%
- Mean Density: 0.38kg/0.1m^2
- Total Stock: 6 tonnes
- Stock $\geq$ 45mm: 1 tonnes

The Shellridge bed was surveyed on October 6th 2013, during which samples were taken from every second "hit", producing 8 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 recent recruitment has caused the bed to decline severely in recent years. Only a very small patch of the original bed now remains, covering an area of 1.0 hectares. Within this area the mussels were found to have a coverage of 17% and a mean density of 0.38kg/0.1m^2. From these figures the biomass of mussels on this bed was calculated to be 6 tonnes, a slight decline from the 8 tonnes recorded the previous year. 1 tonne of these were found to have reached a size of 45mm length.

2.3.2 Gat Sand

Following the crash of the mussel stocks in the 1990s, the Gat was 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 into important biogenic reef features. As such, these beds have been considered to be of particular importance by conservationists. 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 the biogenic reef features. Although fisheries on these beds have been closely managed, since 2010 they have suffered from high mussel mortality rates. Coupled with recent poor recruitment, this has resulted in a significant decline to the Gat beds in recent years. This decline can be seen in figure 2.9, which shows the biomass of mussels estimated to be present on the Gat beds since 2002.

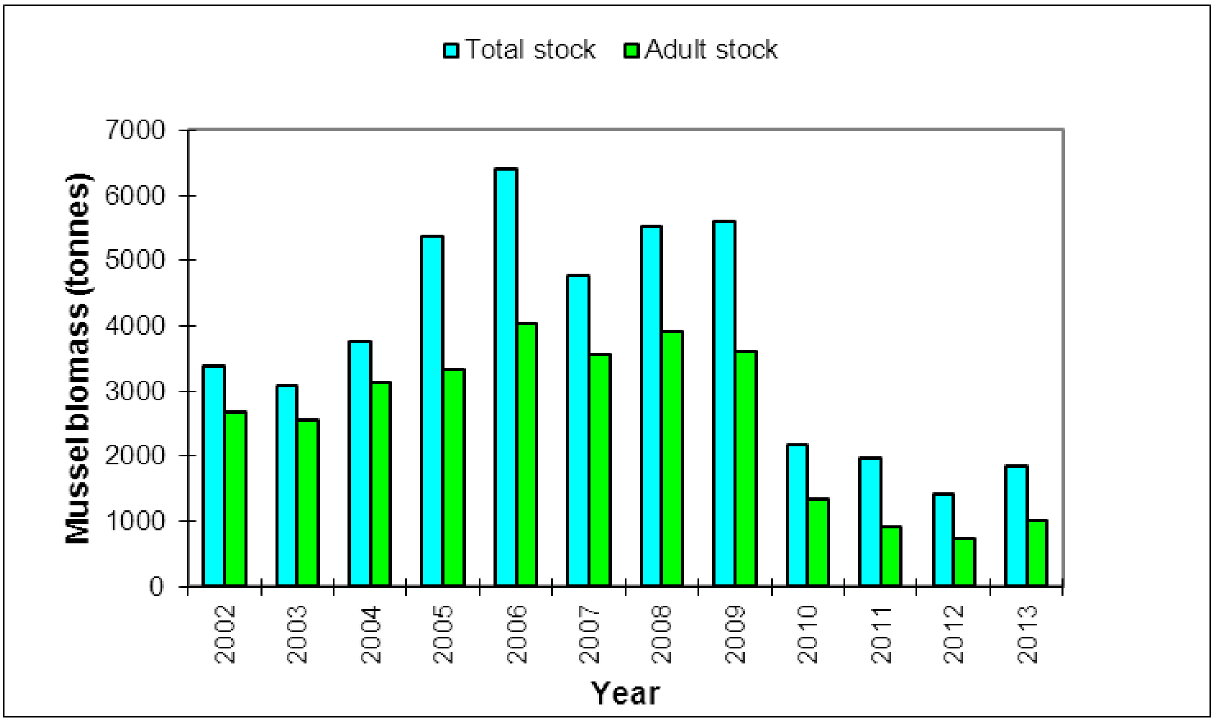


Figure 2.9 Biomass of mussels estimated to be present on the Gat beds between 2002 and 2013

Figure 2.10 shows the extent of the Gat beds and the mussel size distribution across the beds.

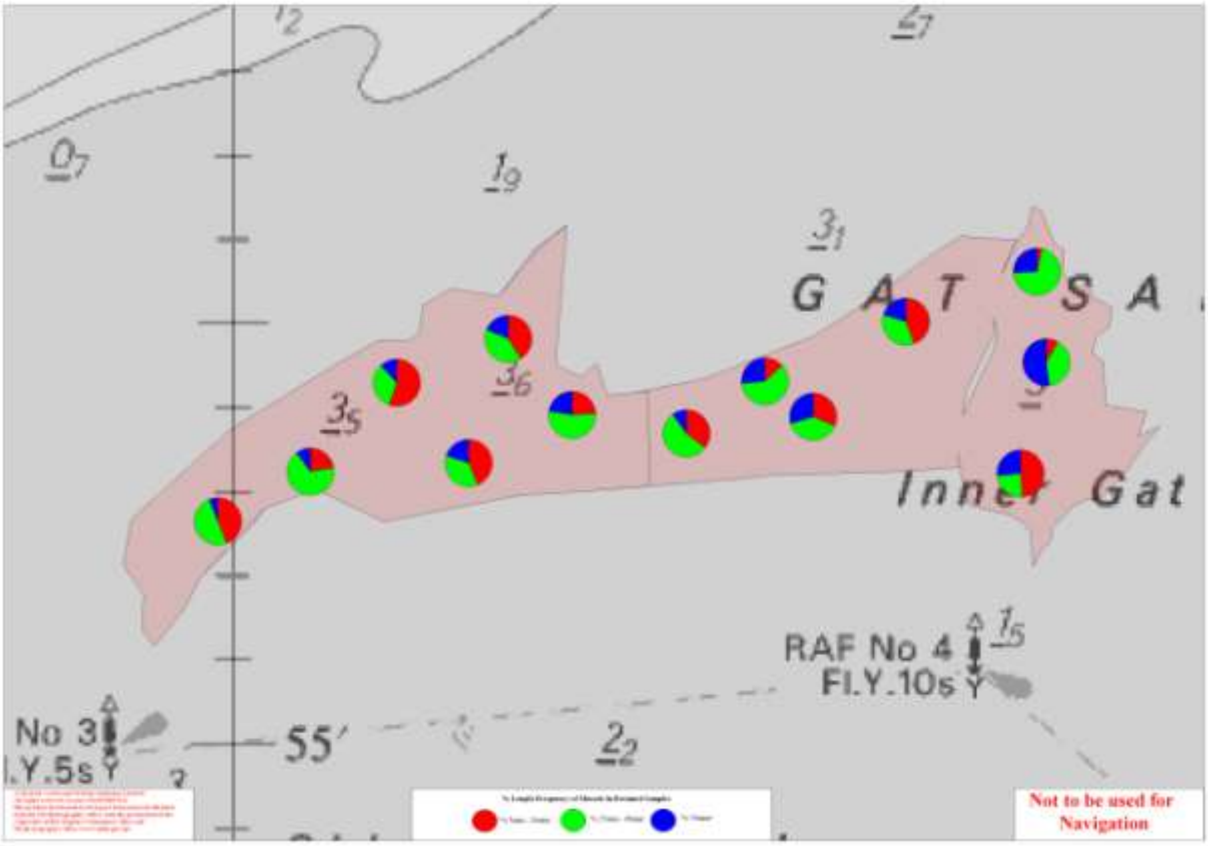


Figure 2.10 Mussel size distributions on the Gat mussel beds – September 2013

2.3.2.1 West Gat

- Area: 38.4 hectares
- Coverage: 39%
- Mean Density: 0.73kg/0.1m^2
- Total Stock: 1,110 tonnes
- Stock ≥ 45mm: 563 tonnes

The West Gat bed was surveyed on September 24th 2013. Samples were taken from every fifth "hit", producing 70 samples from six transects. Figure 2.11 shows the mussel size frequency within the population taken from these samples.

The area of the bed was found to have increased from 34.5 hectares in 2012 to 38.4 hectares. Most of this increase was due to the inclusion of scattered clumps of mussels around the edge of the bed that had not been included within the area in 2012. Within the bed the coverage was found to have increased from 30% to 39%, and the mean density from 0.52kg/0.1m^2 to 0.73kg/0.1m^2. From these figures the total mussel biomass on this bed was calculated to be 1,110 tonnes, a good increase on the 539 tonnes recorded the previous year. During the same period the biomass of mussels that had attained the MLS of 45mm length had increased from 203 tonnes to 563 tonnes. Although the figures suggest there has been a good recovery on this bed, it does still appear to be in poor condition with many large bare patches and areas of dead shell developing. Some of this increase may be an artefact of the survey methodology, in which transects are sampled through areas in the bed with differing mussel patchiness.

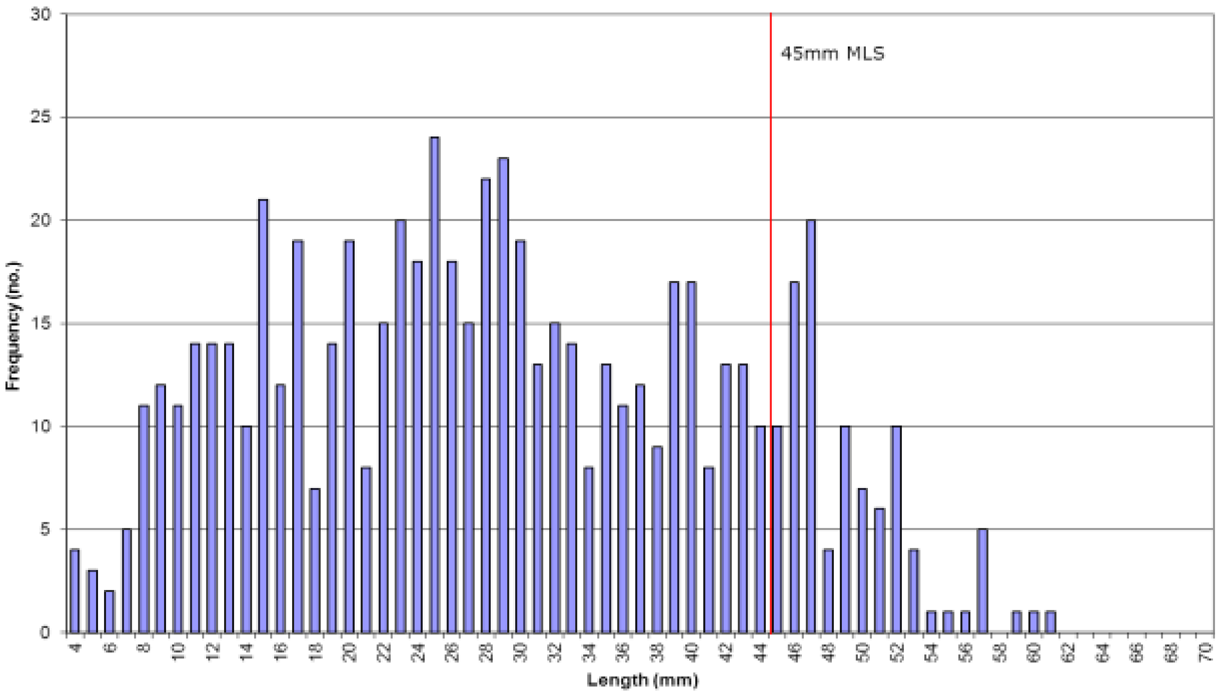


Figure 2.11 Mussel size frequency on West Gat - September 2013

2.3.2.2 Mid Gat

- Area: 24.6 hectares
- Coverage: 31%
- Mean Density: 0.51kg/0.1m^2
- Total Stock: 388 tonnes
- Stock ≥ 45mm: 215 tonnes

The Mid Gat was surveyed on October 4th 2013. Samples were collected from every fourth "hit", producing 45 samples from four transects. Figure 2.12 shows the mussel size frequency within the population taken from these samples.

The survey found the area of the bed had declined slightly from 25.4 hectares to 24.6 hectares. Within this area the coverage was found to have increased from 27% to 31%

but the mean density had declined from 0.84kg/0.1m2 to 0.51kg/0.1m^2. From these results the mussel biomass on this bed was estimated to decreased from 566 tonnes in 2012 to 388 tonnes. Of these, 215 tonnes had attained 45mm MLS, a decline from 333 tonnes.

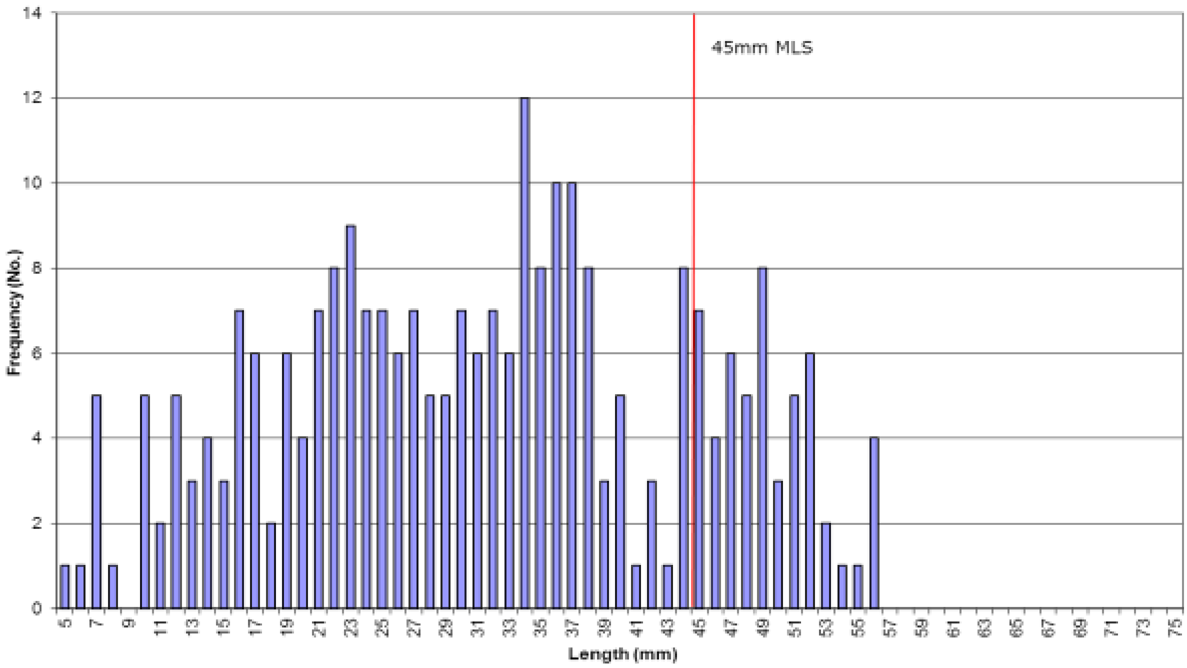


Figure 2.12 Mussel size frequency on Mid Gat - October 2013

2.3.2.3 East Gat

- Area: 17.0 hectares
- Coverage: 32%
- Mean Density: 0.61kg/0.1m^2
- Total Stock: 337 tonnes
- Stock ≥ 45mm: 237 tonnes

The East Gat was surveyed on September 23rd 2013. Samples were taken from every fourth "hit", producing 36 samples from three transects. Figure 2.13 shows the mussel size frequency within the population taken from these samples.

The area of the bed was found to have increased slightly from 16.1 hectares in 2012 to 17.0 hectares. While the coverage within the bed was found to have decreased slightly from 34% to 32%, the mean density within the mussel patches was found to have increased from 0.56kg/0.1m^2 to 0.61kg/0.1m^2. From these figures the biomass on the bed was estimated to have increased from 308 tonnes in 2012 to 337 tonnes. The population of marketable sized mussels was found to have increased from 206 tonnes to 237 tonnes.

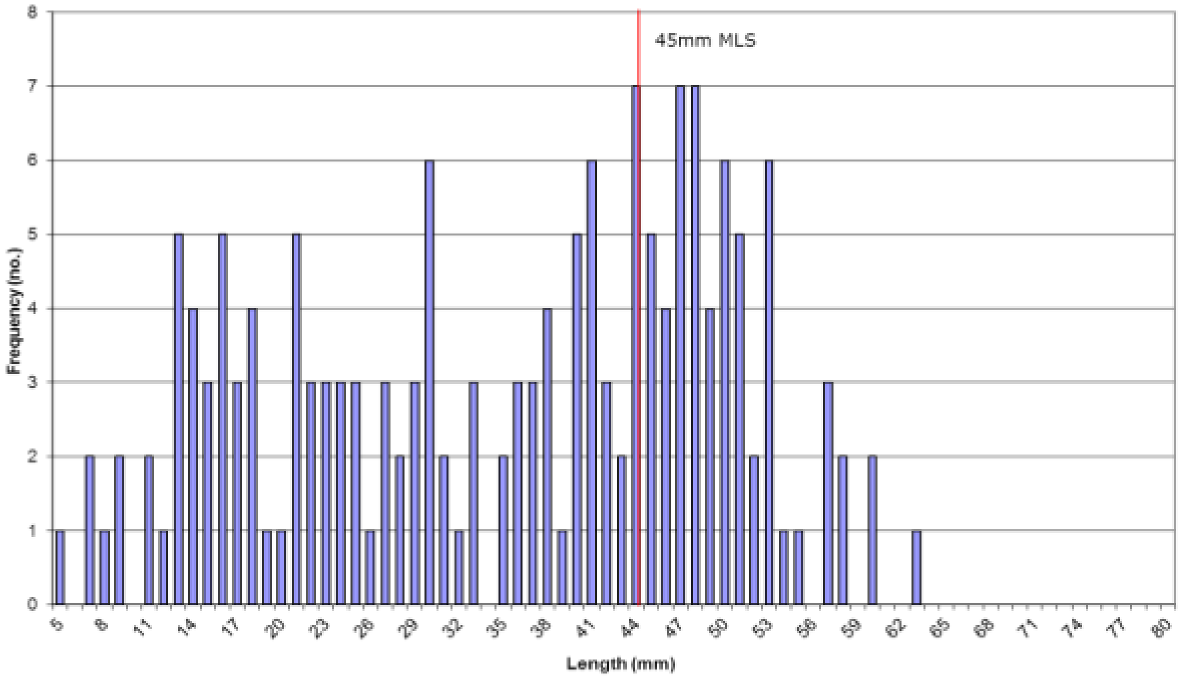


Figure 2.13 Mussel size frequency on East Gat - September 2013

2.3.3 Tofts

- Area: 43.9 hectares
- Coverage: 33%
- Mean Density: 1.39 kg/0.1m^2
- Total Stock: 2,005 tonnes
- Stock ≥ 45mm: 1,468 tonnes

Because of the size of this bed, the perimeter of the Tofts bed was surveyed on October 9th 2013 and transects on October 16th. Samples were taken from every sixth "hit", producing 93 samples from twelve transects. Figure 2.14 shows the mussel size distribution over the bed while figure 2.15 shows the size frequency within the population.

The area of this bed was found to have decreased slightly from 44.5 hectares to 43.9 hectares, mainly due to determining the precise edge of the bed close to the several fishery lay, TO6. Within this area the coverage was found to be the same as the previous year at 33%, but the mean density had decreased from 1.58 kg/0.1m^2 to 1.39

kg/0.1m^2. From these figures the total biomass of mussels on the bed was estimated to have declined from 2,234 tonnes to 2,005 tonnes.

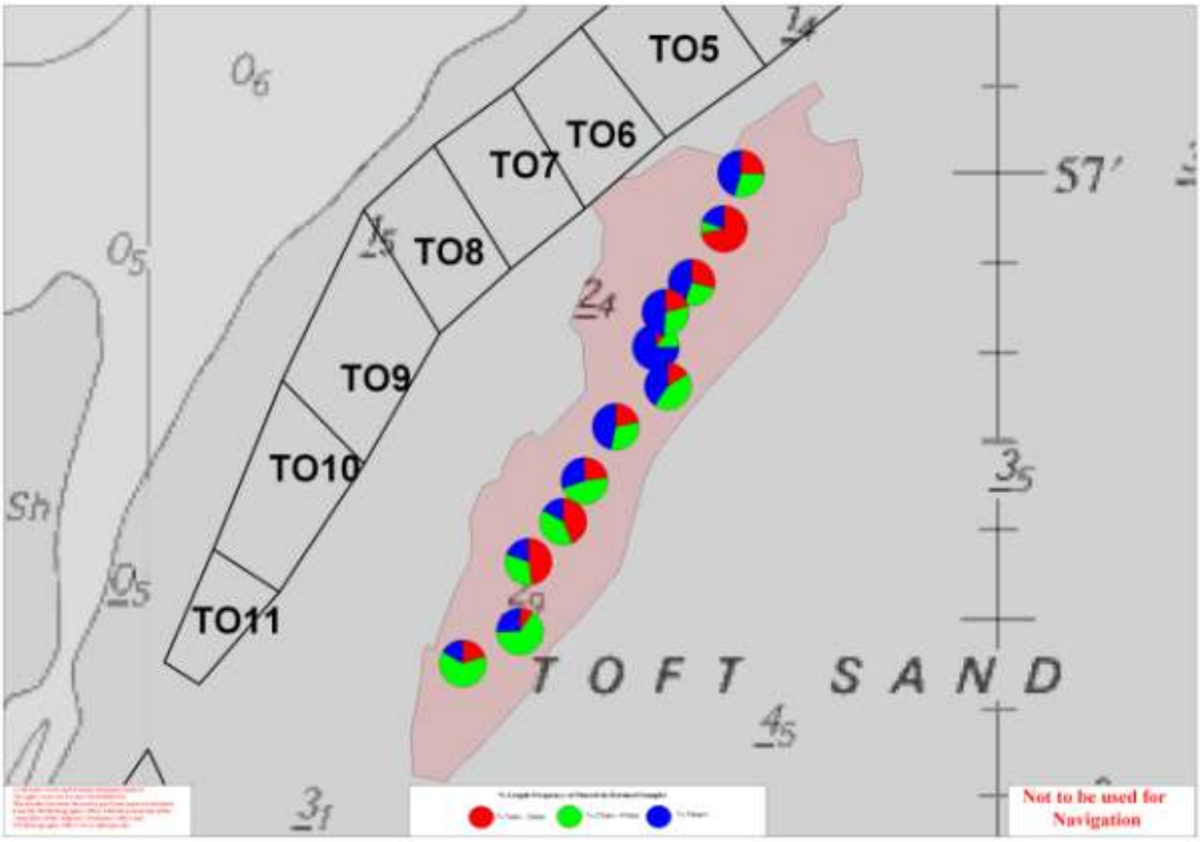


Figure 2.14 Mussel size distributions on the Toft mussel bed – October 2013

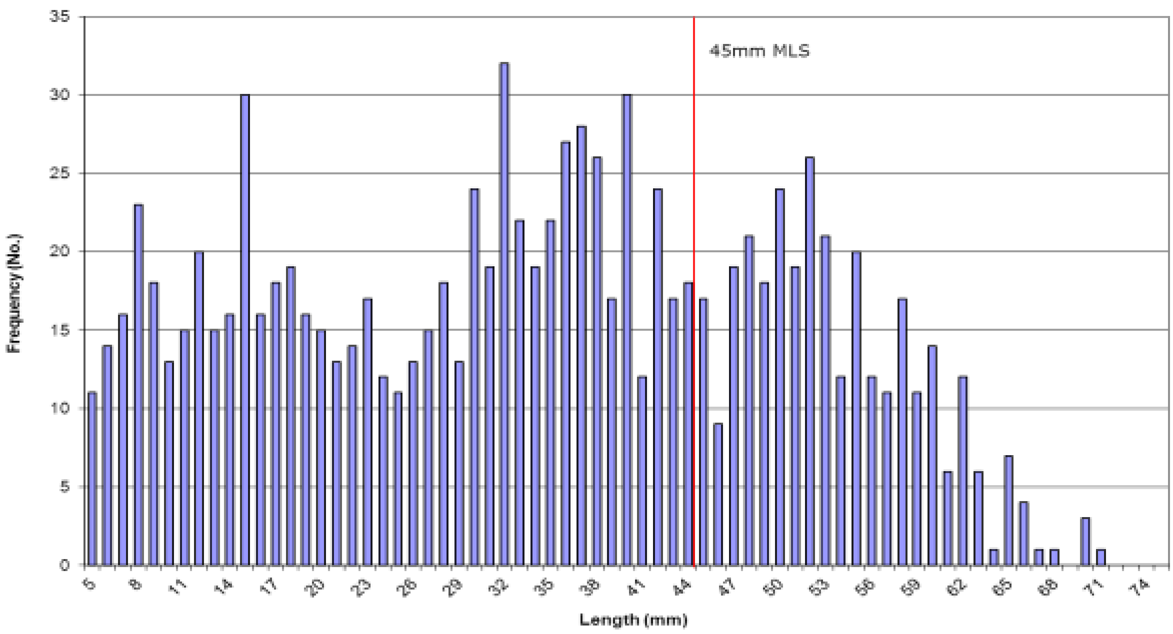


Figure 2.15 Mussel size frequency on the Tofts - October 2013

2.3.4 Roger

- Area: 1.7 hectares
- Coverage: 45%
- Mean Density: 0.84 kg/0.1m^2
- Total Stock: 64 tonnes
- Stock ≥ 45mm: 43 tonnes

This small bed was surveyed on 9th October 2013. Samples were collected from every third "hit", producing 13 samples from a single transect. Figure 2.16 shows the mussel size distribution on this bed while figure 2.17 shows the size frequency within the population.

The area of the bed was found to have increased in size from 1.3 hectares in 2012 to 1.7 hectares. Within this area the coverage was found to have increased from 37% to 45% while there was little change with the mean density, from 0.83 kg/0.1m^2 to 0.84 kg/0.1m^2. From these figures the total biomass on the bed was calculated to be 64 tonnes, an improvement on the 41 tonnes recorded the previous survey. 43 tonnes were calculated to have attained marketable size compared to 32 tonnes in 2012.

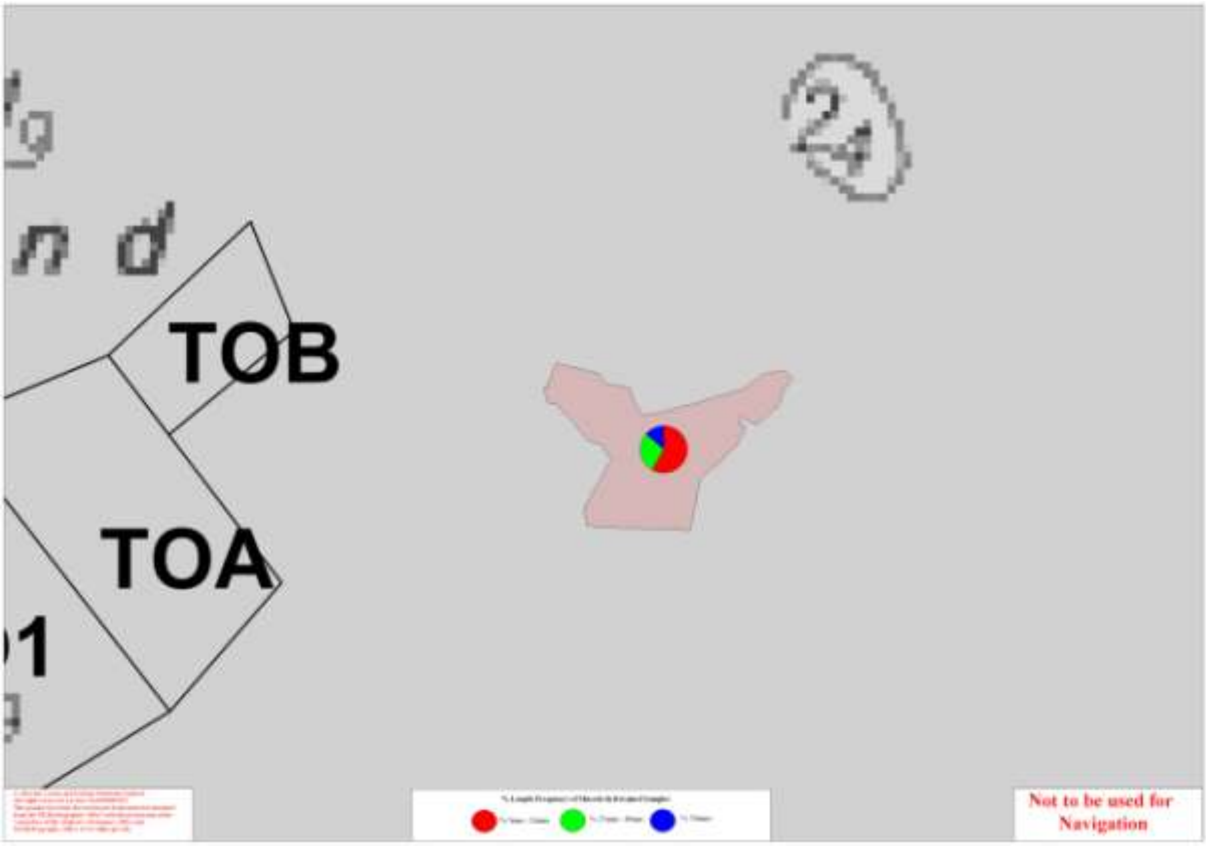


Figure 2.16 Mussel size distribution on the Roger mussel bed – October 2013

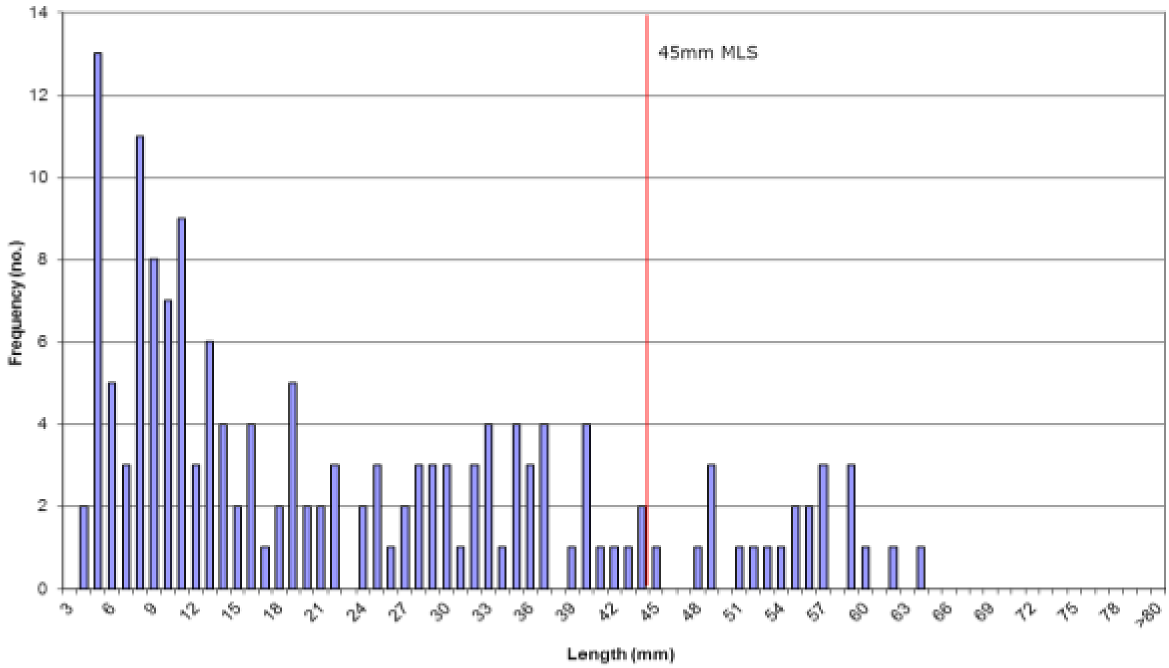


Figure 2.17 Mussel size frequency on the Roger - October 2013

2.3.5 Herring Hill

- Area: 28.3 hectares
- Coverage: 32%
- Mean Density: 0.97 kg/0.1m^2
- Total Stock: 881 tonnes
- Stock ≥ 45mm: 24 tonnes

The Herring Hill bed was surveyed on October 17th 2013. Samples were taken from every fifth "hit", producing 68 samples from seven transects. Figure 2.18 shows the mussel size distribution across the bed while figure 2.19 shows the size frequency of the population taken from these samples.

The survey found the area of the bed had increased from 25.4 hectares to 28.3 hectares. This was mainly due to the growth and spread of a good settlement of spat that had occurred on this bed during 2011. The spread of these mussels over a wider area had caused the coverage within the bed to decrease from 38% to 32%, but their growth had enabled the mean patch density to increase from 0.71 kg/0.1m^2 to 0.97 kg/0.1m^2. From these figures the total mussel biomass on the bed was calculated to have increased from

693 tonnes in 2012 to 881 tonnes. Due to the elevation of this bed, growth tends to be slow. As a consequence of this, only 24 tonnes had attained a size of 45mm MLS.

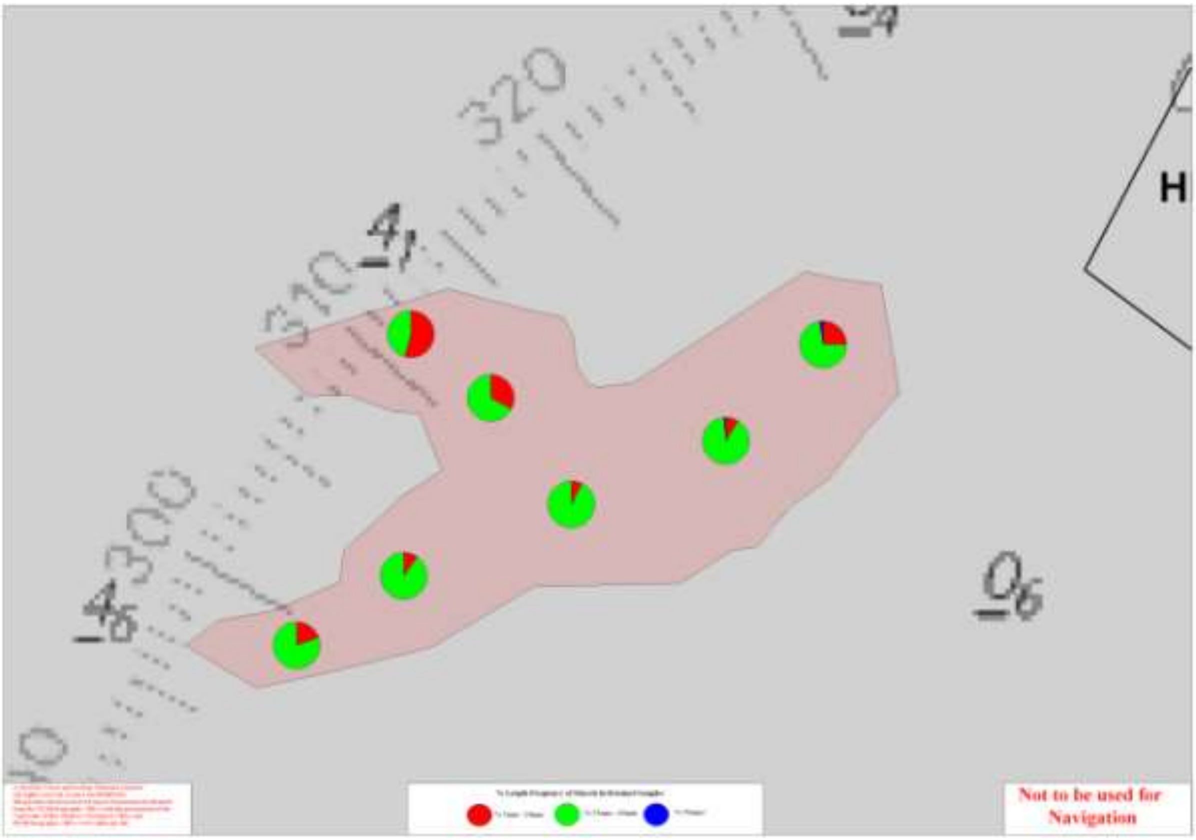


Figure 2.18 Mussel size distribution on the Herring Hill mussel bed – October 2013

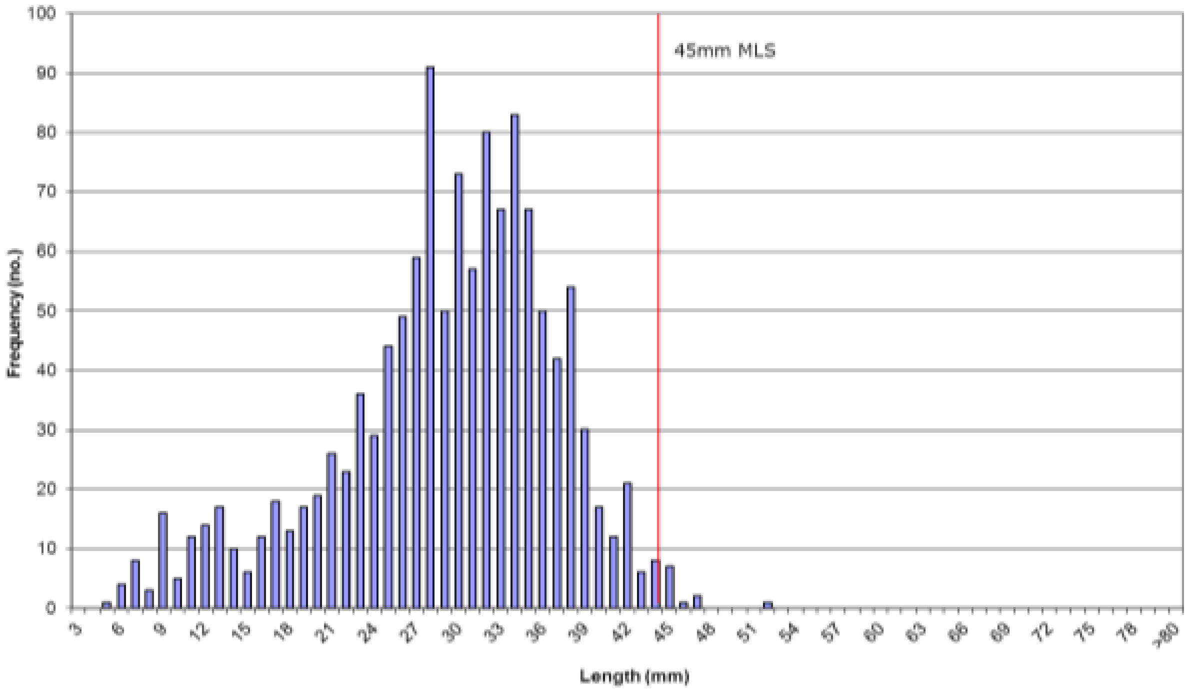


Figure 2.19 Mussel size frequency on Herring Hill - October 2013

2.3.6 Main End

- Area: 5.7 hectares
- Coverage: 21%
- Mean Density: 0.81 kg/0.1m^2
- Total Stock: 95 tonnes
- Stock ≥ 45mm: 76 tonnes

The Main End bed was surveyed on October 5th 2013. Samples were collected from every third "hit", producing 21 samples from two transects. Figures 2.20 and 2.21 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 5.2 hectares in 2012 to 5.7 hectares. Within this area the coverage of the bed was found to have decreased from 29% to 21%. Most of this decline appeared to have occurred to those mussels in the western half of the bed. During the same period the mean density was found to have increased from 0.58 kg/0.1m^2 to the 0.81 kg/0.1m^2. From these figures the total mussel biomass in the bed was calculated to be 76 tonnes, a slight decline from the 88 tonnes recorded the previous year. Of these, 76 tonnes were of marketable size, similar to the 75 tonnes recorded the previous year.

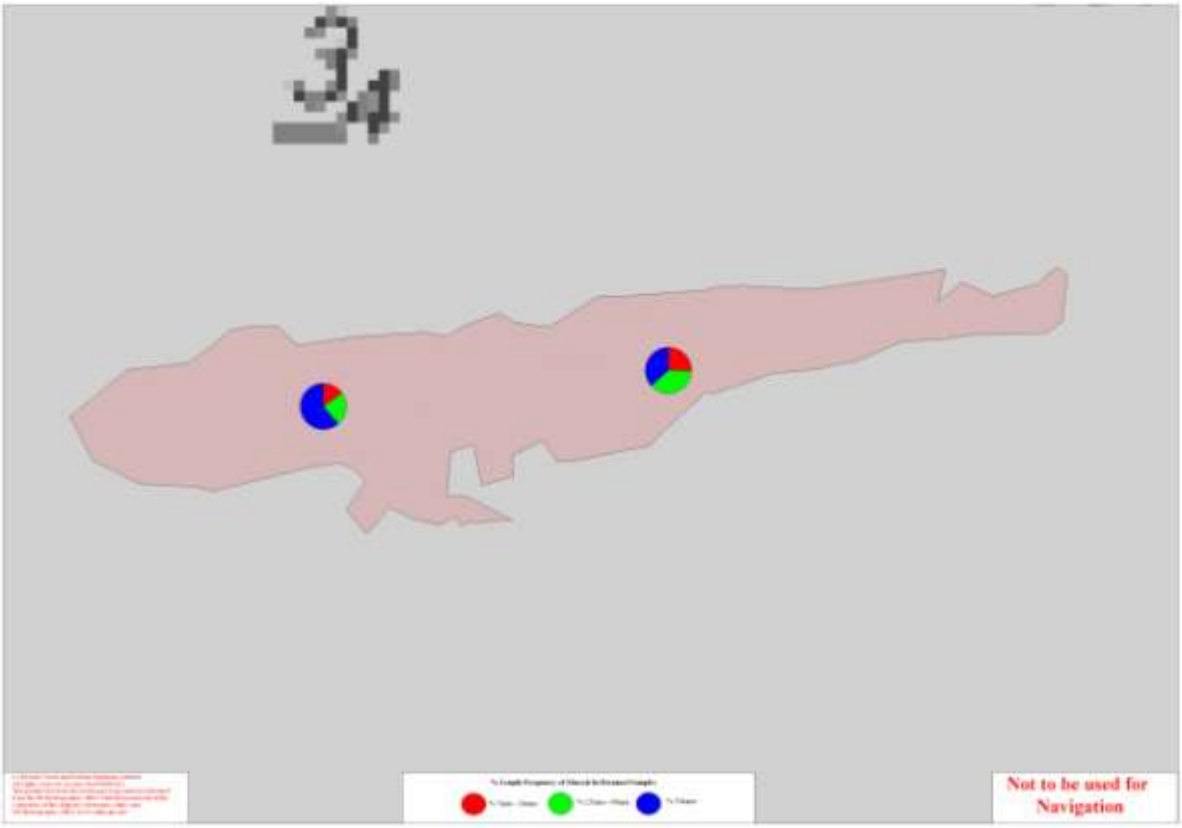


Figure 2.20 Mussel size distribution on the Main End mussel bed – October 2013

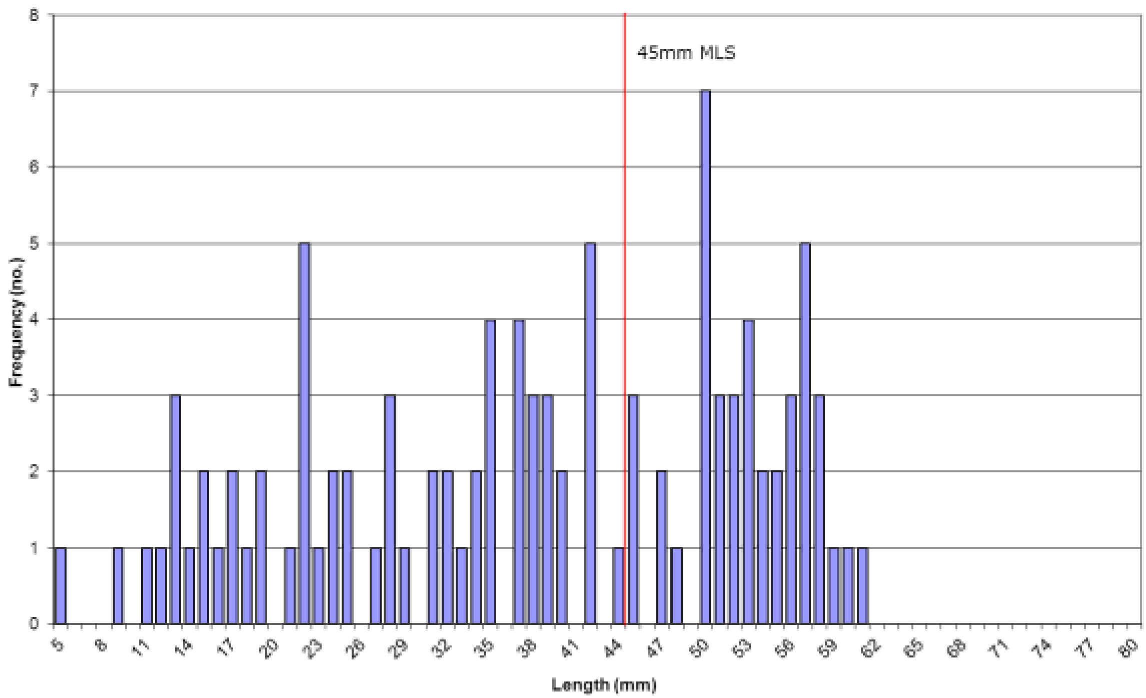


Figure 2.21 Mussel size frequency on Main End - October 2013

2.3.7 Holbeach

- Area: 12.6 hectares
- Coverage: 45%
- Mean Density: 0.89 kg/0.1m^2
- Total Stock: 502 tonnes
- Stock ≥ 45mm: 124 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. Unlike the nearby Main End bed, which was established during the same spatfall, this bed has benefited from good settlements of spat in recent years which have kept the bed rejuvenated. Because this bed was opened to the dredge relaying fishery in October 2013, the survey was delayed until November 17th after the fishery had closed.

Samples were collected from every fifth "hit", generating 67 samples from five transects. Figures 2.22 and 2.23 show the size distribution of mussels across the bed and the mussel size frequency within the population.

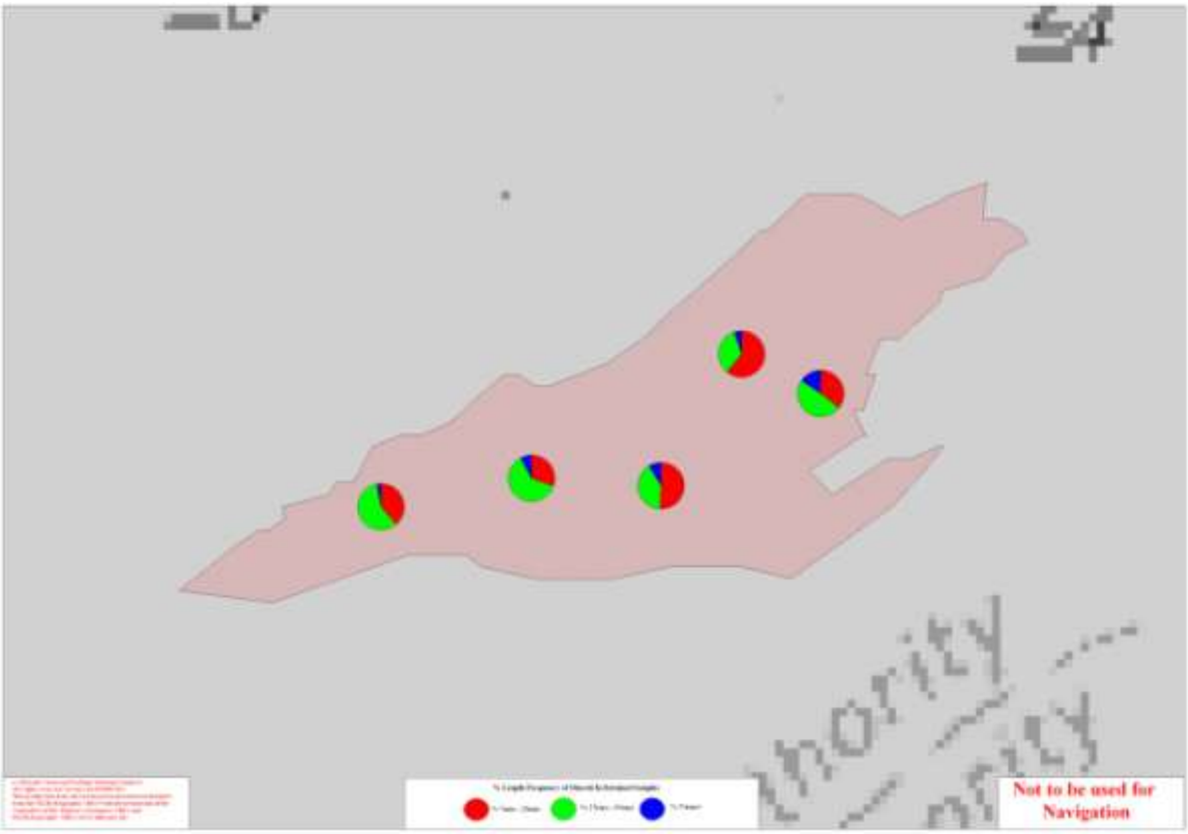


Figure 2.22 Mussel size distribution on the Holbeach mussel bed – November 2013

The area of the bed was found to have increased from 11.8 hectares in 2012 to 12.6 hectares. Within this area there was evidence of recent moderate dredging activity. In addition to removing mussels, this had also caused some of the mussels from clumps to scatter. While this activity had only reduced the coverage from 47% to 45%, the patches had become much thinner with a reduction in mean density from 1.34 kg/0.1m^2 to 0.89 kg/0.1m^2. From these figures the mussel biomass on the bed was calculated to have declined from 741 tonnes in 2012 to 502 tonnes. Growth had enabled the biomass of marketable sized mussels to increase during the same period from 50 tonnes to 124 tonnes. As can be seen from the bimodal distribution in figure 2.23, there had been a reasonable settlement of spat on this bed during 2013.

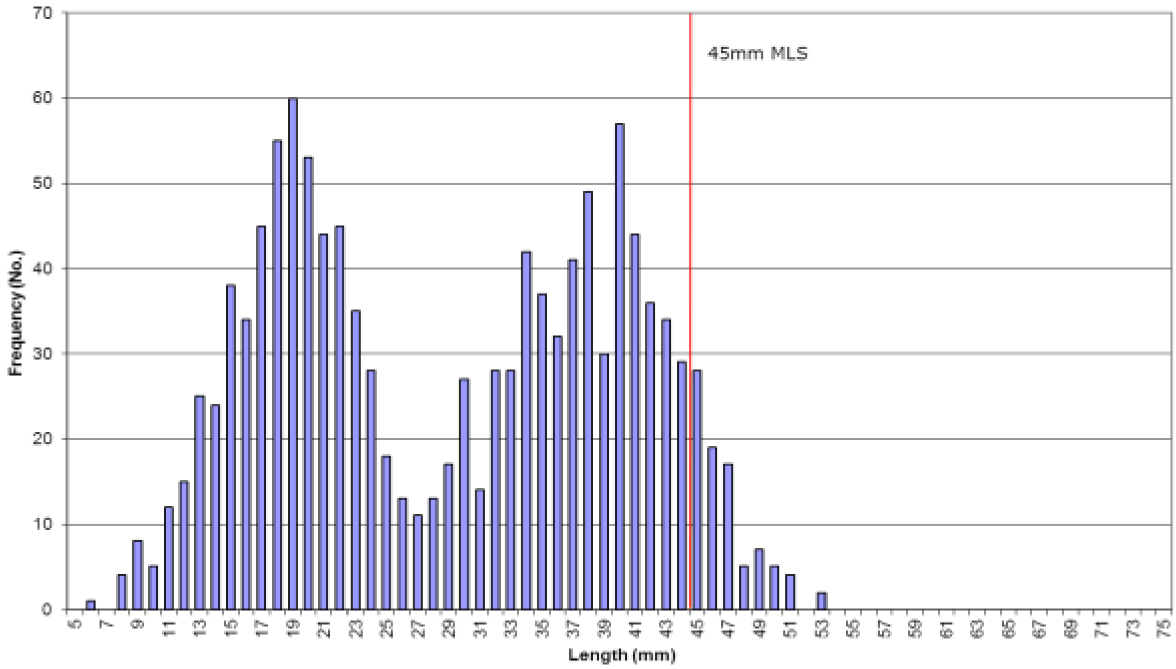


Figure 2.23 Mussel size frequency on Holbeach - November 2013

2.3.8 Trial Bank

- Area: 44.0 hectares
- Coverage: 26%
- Mean Density: 0.88 kg/0.1m^2
- Total Stock: 1,014 tonnes
- Stock $\geq$ 45mm: 117 tonnes

The Trial Bank mussel bed was surveyed on September 25th 2013. Samples were collected from every fifth "hit", producing 54 samples from seven transects. Figures 2.24

and 2.25 show the size distribution of mussels across the bed and the mussel size frequency within the population taken from these samples.

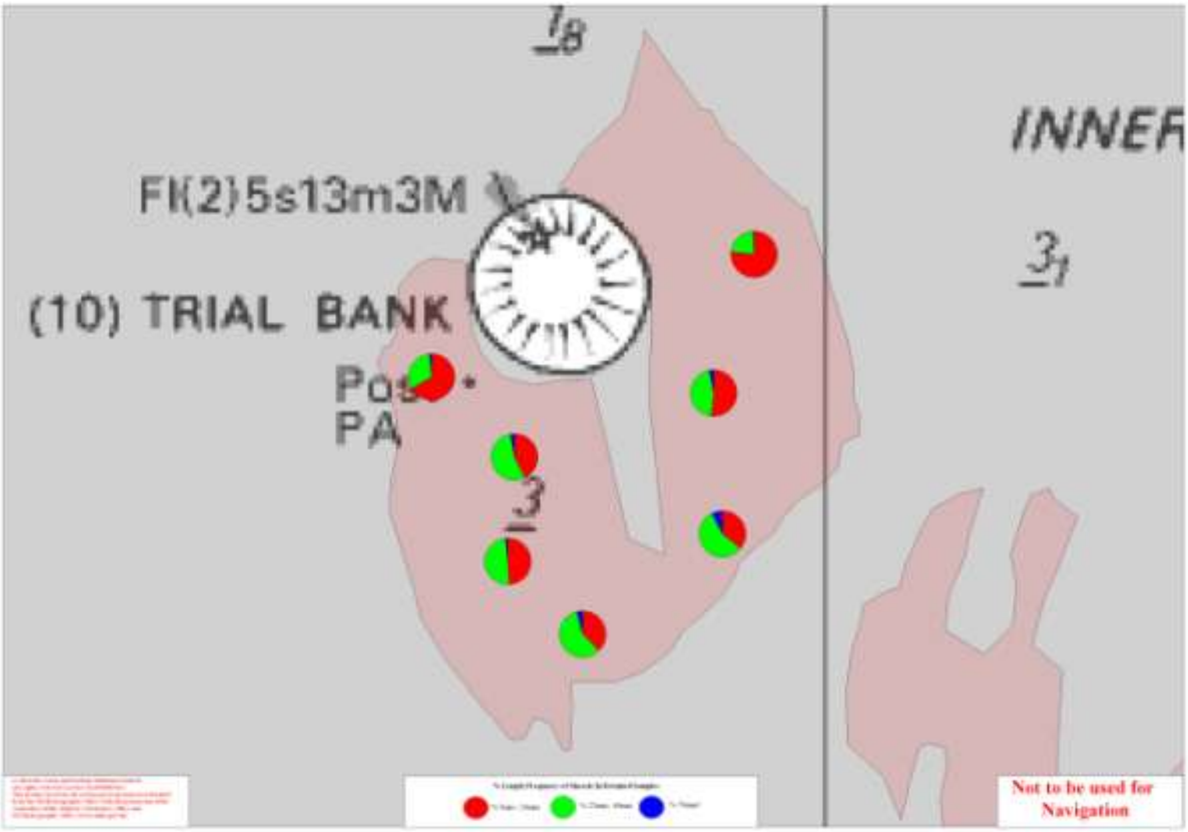


Figure 2.24 Mussel size distribution on the Trial Bank mussel bed – September 2013

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. The 2013 survey found there had been a moderate settlement of spat, which combined with growth of existing mussels, had helped the bed recover slightly. The area was found to have increased from 39.3 hectares to 44.0 hectares. Within this area some of the mussels from formerly undisturbed patches had scattered into some of the bare patches that had developed during the fishery. This resulted in the coverage increasing from 12% to 26%, but the mean density in the patches declining from 1.21 kg/0.1m^2 to 0.88 kg/0.1m^2. Overall the mussel density was found to have increased from 585 tonnes to 1,014 tonnes. The biomass of marketable sized mussels had increased from 81 tonnes to 117 tonnes.

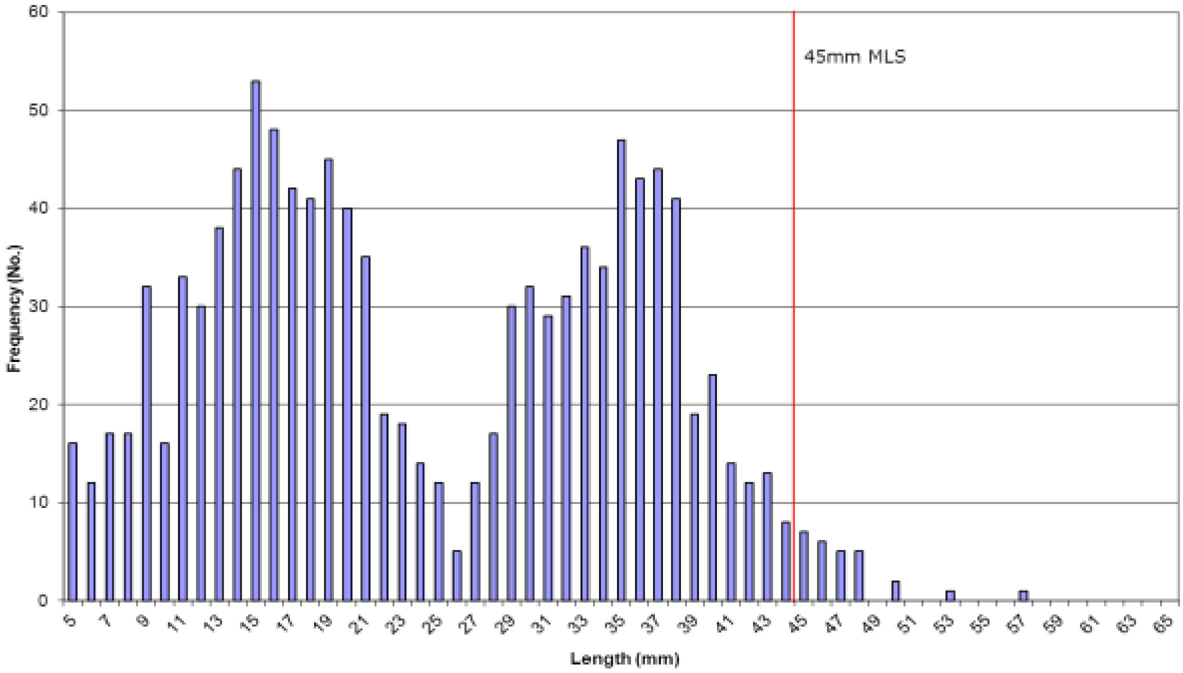


Figure 2.25 Mussel size frequency on Trial Bank - September 2013

2.3.9 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 Centre bed until only a run that had originally delineated the western edge of the Centre bed separated them. Since then, disparate fishing effort on these beds resulted in the Centre 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 Centre 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 2.26 shows the mussel size distribution over these beds following the 2013 surveys.

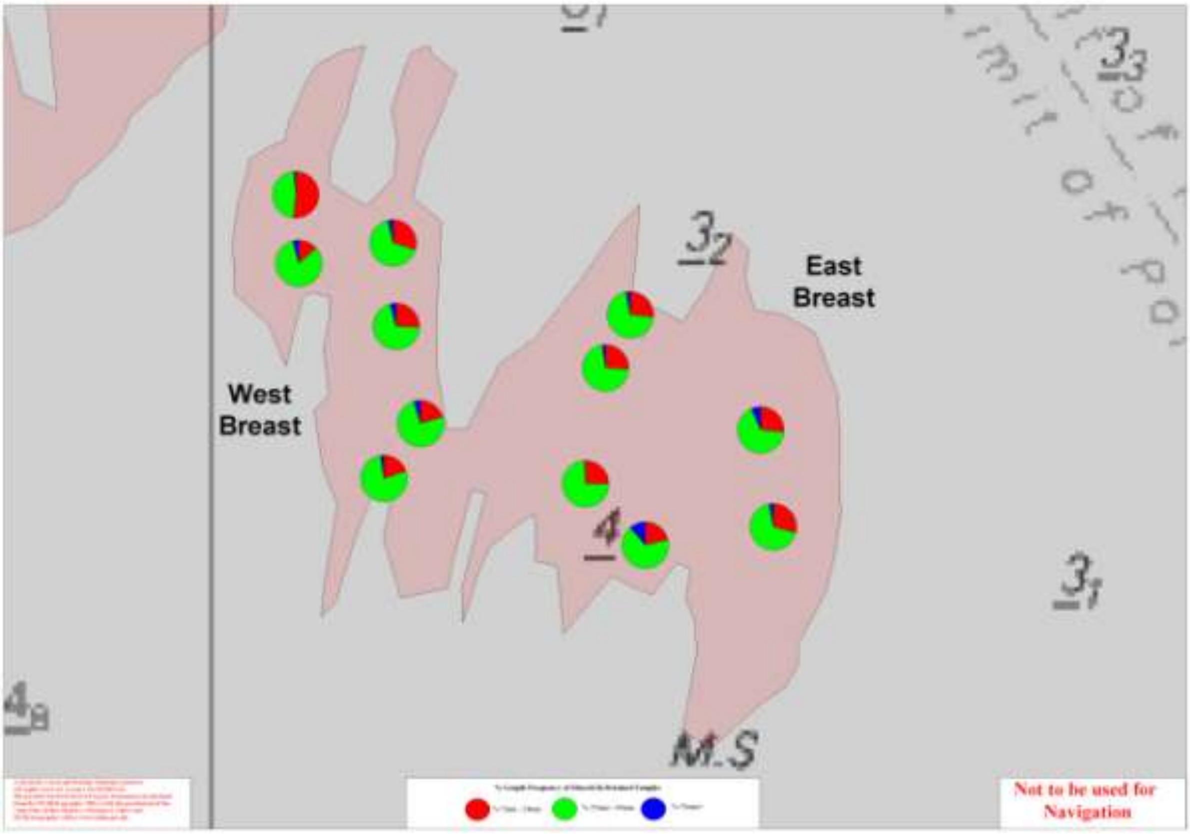


Figure 2.26 Mussel size distribution on the Breast mussel beds – November 2013

2.3.9.1 West Breast

- Area: 19.7 hectares
- Coverage: 21%
- Mean Density: 0.76kg/0.1m^2
- Total Stock: 316 tonnes
- Stock ≥ 45mm: 32 tonnes

The West Breast bed was surveyed on November 7th 2013. Samples were collected from every fourth "hit", producing 43 samples from six transects. Figure 2.27 shows the mussel size frequency within the population taken from these samples.

The area of the West bed was found to have increased from 17.5 hectares in 2012 to 19.7 hectares. Although there had been a light settlement of spat within the bed, the density of mussels appeared to have declined from the previous year. This was evidenced in the coverage that had decreased from 32% to 21% and the mean density that had declined from 1.03 kg/0.1m^2 to 0.76 kg/0.1m^2. From these figures the total biomass of mussels on this bed was calculated to have decreased from 585 tonnes to

316 tonnes. The biomass of mussels that had reached marketable size had also declined from 51 tonnes to 32 tonnes.

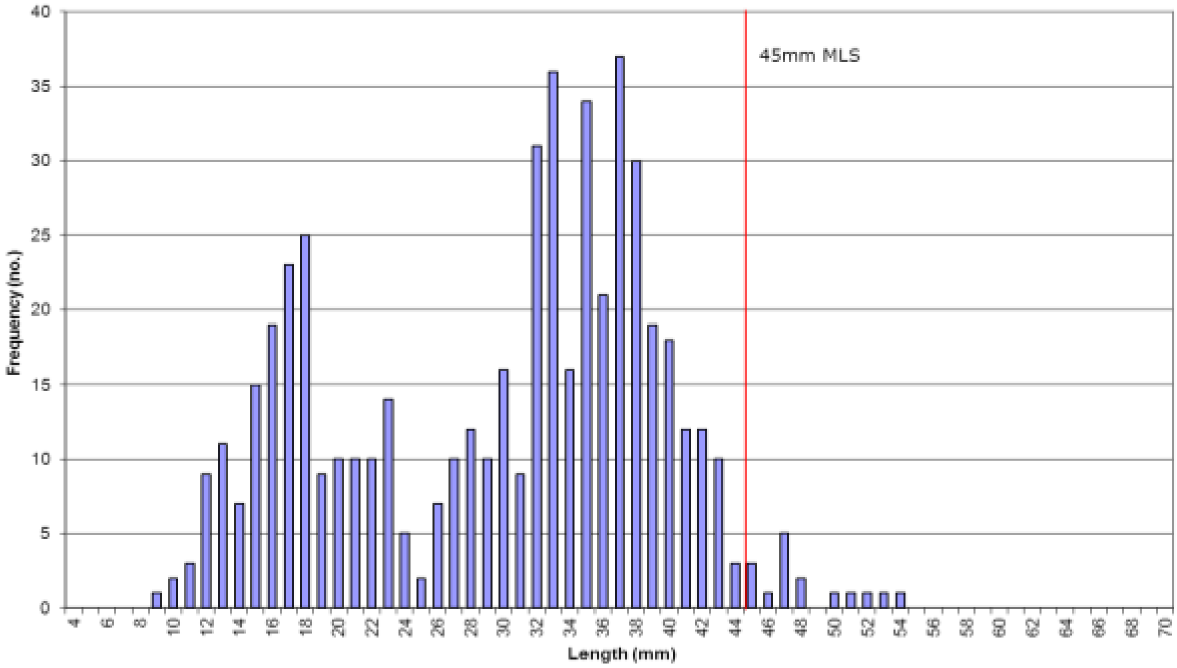


Figure 2.27 Mussel size frequency on West Breast – November 2013

2.3.9.2 East Breast

- Area: 31.9 hectares
- Coverage: 30%
- Mean Density: 1.20 kg/0.1m^2
- Total Stock: 1,154 tonnes
- Stock ≥ 45mm: 143 tonnes
- Stock ≥ 45mm: 99 tonnes

The East Breast bed had been opened to the dredged relaying fishery in October 2013 so the surveys were delayed until November 7th, after the fishery had closed. Samples were collected from every fifth "hit", producing 50 samples from six transects. Figure 2.28 shows the mussel size frequency within the population taken from these samples.

The survey found evidence of recent fishing activity within and to the north of this bed. Disturbance only appeared light, however. The area of the bed was found to have increased in area from 27.4 hectares in 2012 to 31.9 hectares. Within this area the coverage had increased slightly from 29% to 30% but the mean density had declined from 1.33 kg/0.1m^2 to 1.20 kg/0.1m^2. From these figures the total biomass of mussels on this bed was calculated to have increased from 1,066 tonnes to 1,154 tonnes. This was mainly attributed to growth and a light settlement of spat more than compensating for fishery losses. During the same period the biomass of mussels that had attained marketable size had increased from 99 tonnes to 143 tonnes.

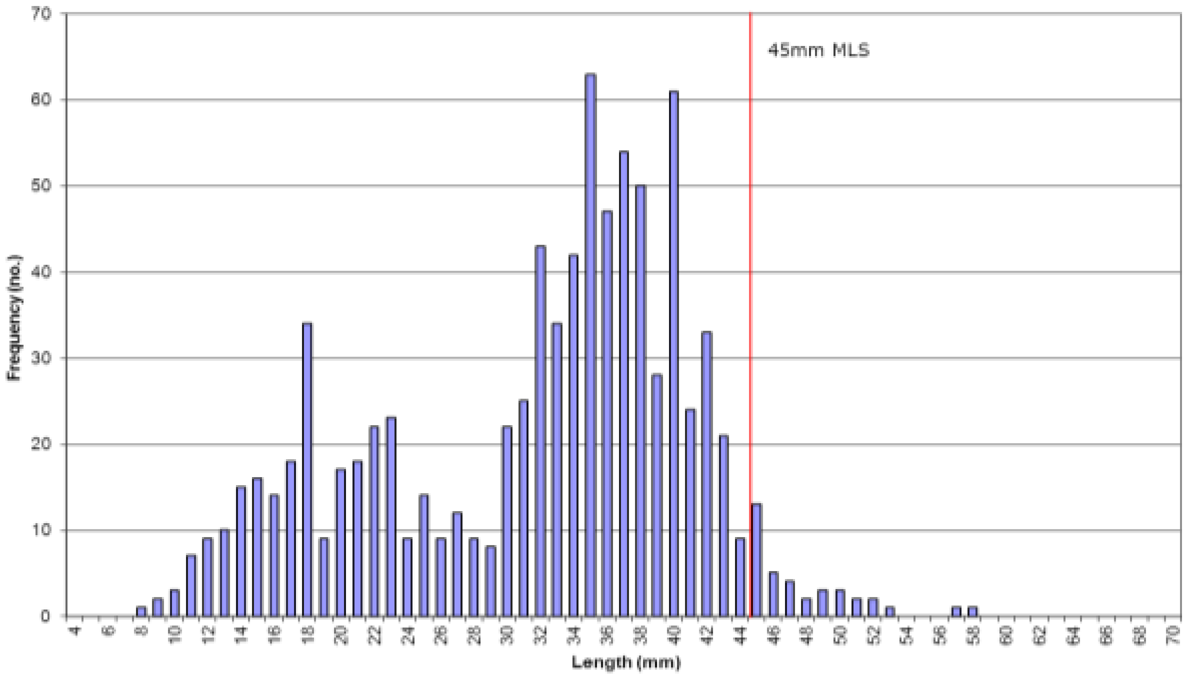
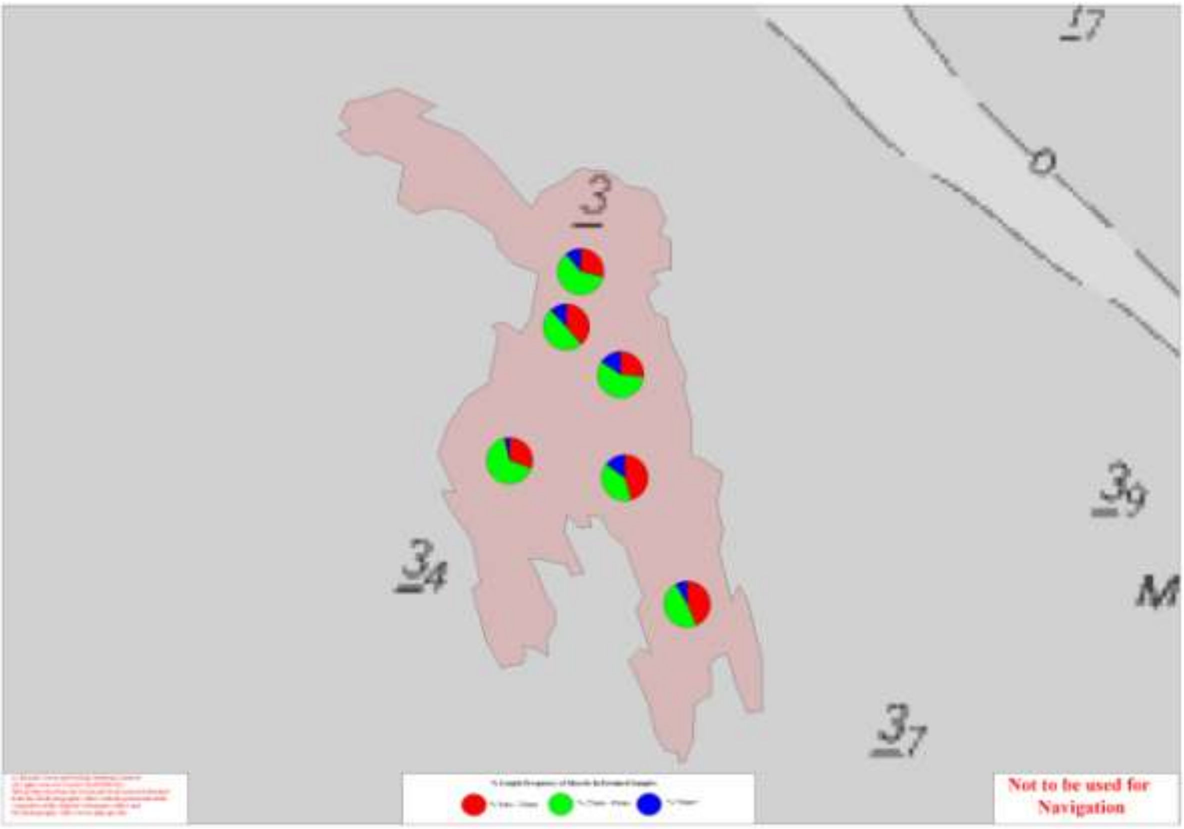


Figure 2.28 Mussel size frequency on East Breast – November 2013

2.3.10 East Scotsman's Sled

- Area: 31.0 hectares
- Coverage: 21%
- Mean Density: 0.55 kg/0.1m^2
- Total Stock: 365 tonnes
- Stock ≥ 45mm: 106 tonnes

The Scotsman's Sled bed was surveyed on October 15th 2013. Samples were collected from every fourth "hit", producing 43 samples from six transects. Figures 2.29 and 2.30 show the mussel size distribution over the bed and the mussel size frequency within the population taken from these samples.



2.29 Mussel size distribution on the East Scotsman's Sled mussel bed – October 2013

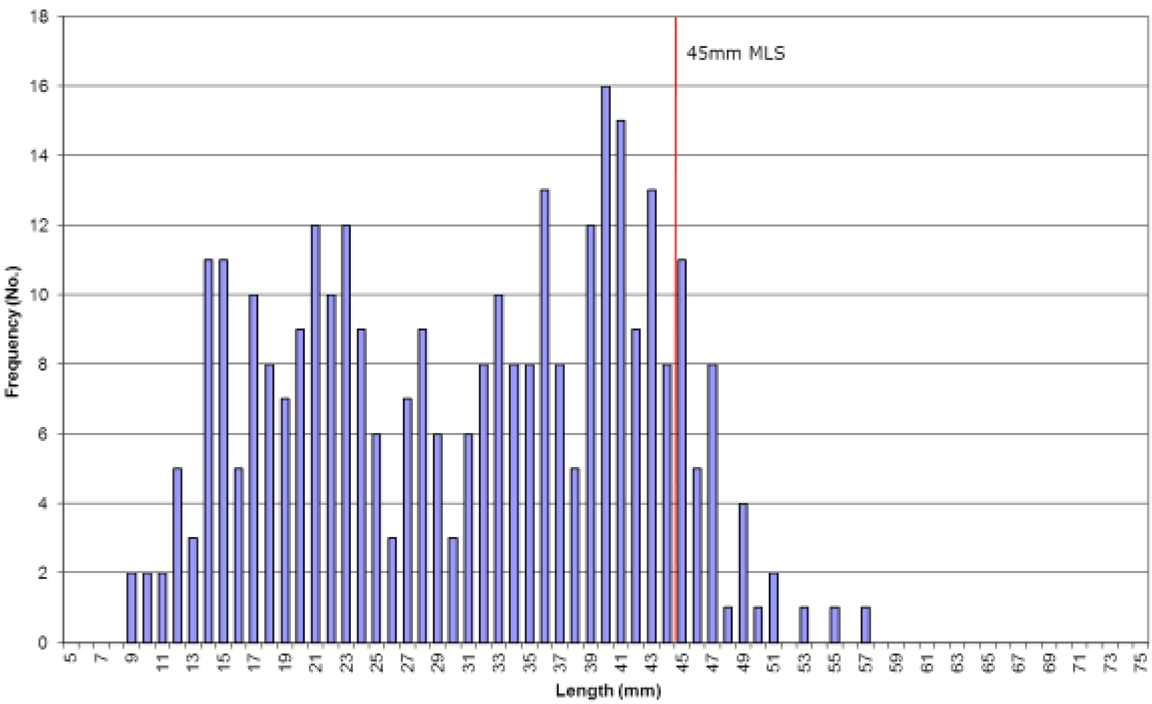


Figure 2.30 Mussel size frequency on East Scotsman's Sled - October 2013

The survey found a light density of mussel spat had settled among cockle shells in an area along the north-western edge of the bed. This area had formally supported mussels until they were removed during a dredge fishery in 2004. This is the first sign since then of any recovery following that fishery. With the inclusion of this area, the bed was found to have increased in size from 25.4 hectares in 2012 to 31.0 hectares. Within the bed the coverage was found to have increased from 16% to 21% but the mean density had declined from 0.91 kg/0.1m^2 to 0.55 kg/0.1m^2. From these figures the total stock was calculated to be 365 tonnes, similar to the 369 tonnes recorded the previous year.

2.3.10 Pandora

- Area: 5.2 hectares
- Coverage: 26%
- Mean Density: 0.99 kg/0.1m^2
- Total Stock: 135 tonnes
- Stock $\geq$ 45mm: 119 tonnes

The Pandora bed was surveyed on November 19th 2013. Samples were collected from every second "hit", producing 27 samples from a single transect. Figure 2.31 shows the mussel size distribution within the bed while figure 2.32 shows the mussel size frequency within the population taken from the samples.

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 small scattered clumps situated in ridges of mussel and clam shells. The survey found the area of the bed had declined from 7.2 hectares in 2012 to 5.2 hectares. The weather conditions at the time of the recent survey prevented the tide from ebbing as far as expected, however, so some of this decline could be due to the lower parts of the bed remaining unexposed. Within the bed the coverage was found to have declined from 36% to 26% and the mean density from 1.08 kg/0.1m^2 to 0.99 kg/0.1m^2. From these figures the total mussel biomass on the bed was calculated to have halved from 279 tonnes in 2012 to 135 tonnes. Of these, 119 tonnes were found to have attained a size of 45mm.

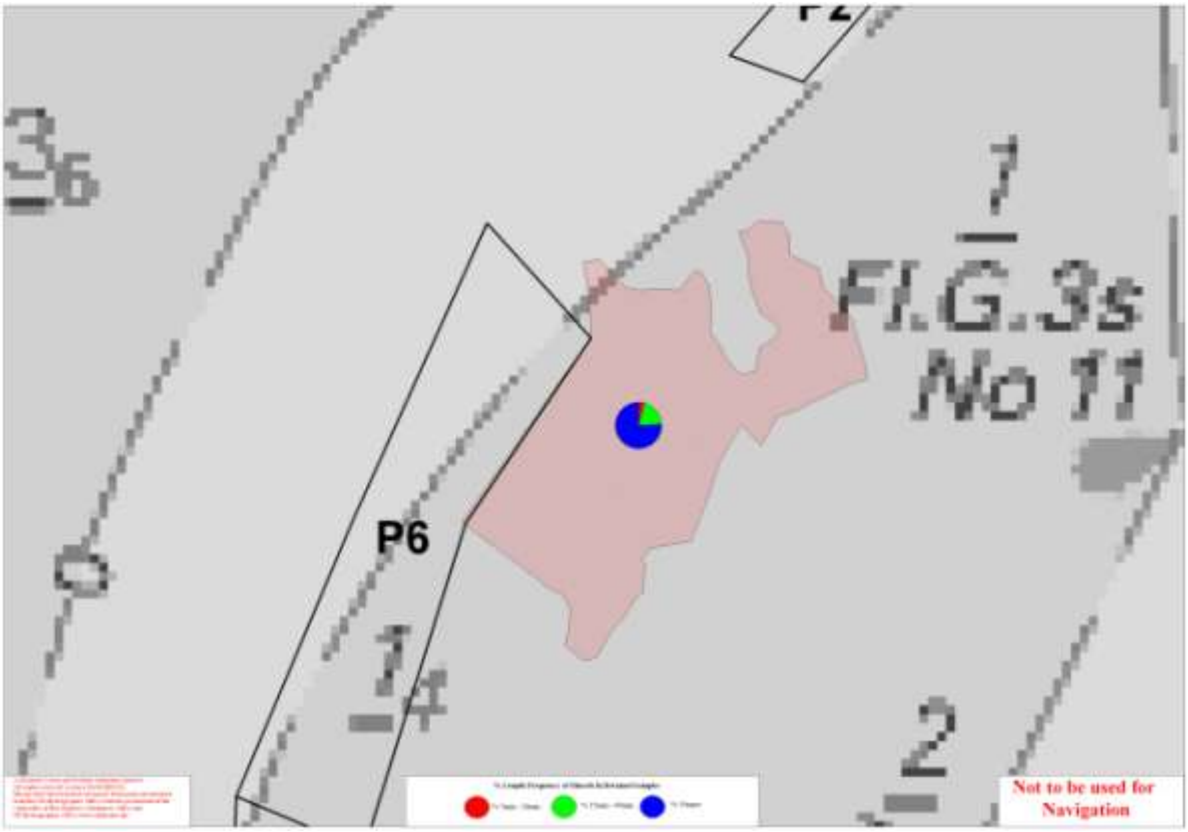


Figure 2.31 Mussel size distribution on the Pandora mussel bed – November 2013

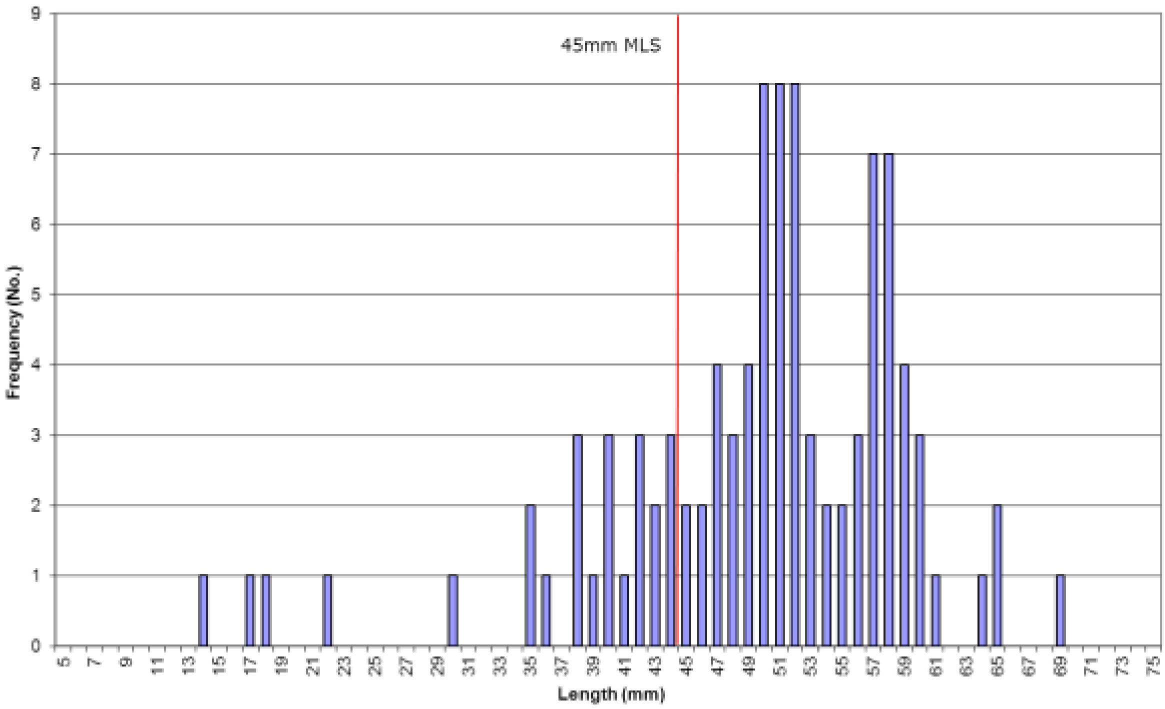


Figure 2.32 Mussel size frequency on Pandora - November 2013

2.3.11 Daseley's

Figure 2.33 shows two areas on the Daseley's sand that were visited during the 2013 surveys. Between 2009 and 2012 Area 1 had supported a small bed of mussels that had a total biomass of 23 tonnes in 2012. When visited on October 18th 2013 these mussels were found to have died. Samples were collected from the few remaining mussels that were found to still be alive and sent to CEFAS for analysis. No cause for the mortality could be identified.

Following advice from a member of the industry that there could have been mussel settlement at Area 2 in the North-west Run (Teetotal Run), the area was visited on December 6th 2013. This area had supported a small bed of mussels until 2002 when they had disappeared. When visited in 2013 the area was found to contain numerous mussel shells in the bottom of a shallow run but insufficient numbers of live mussels to warrant a full survey. The size of these mussels suggested they could be surviving remnants of the original bed.

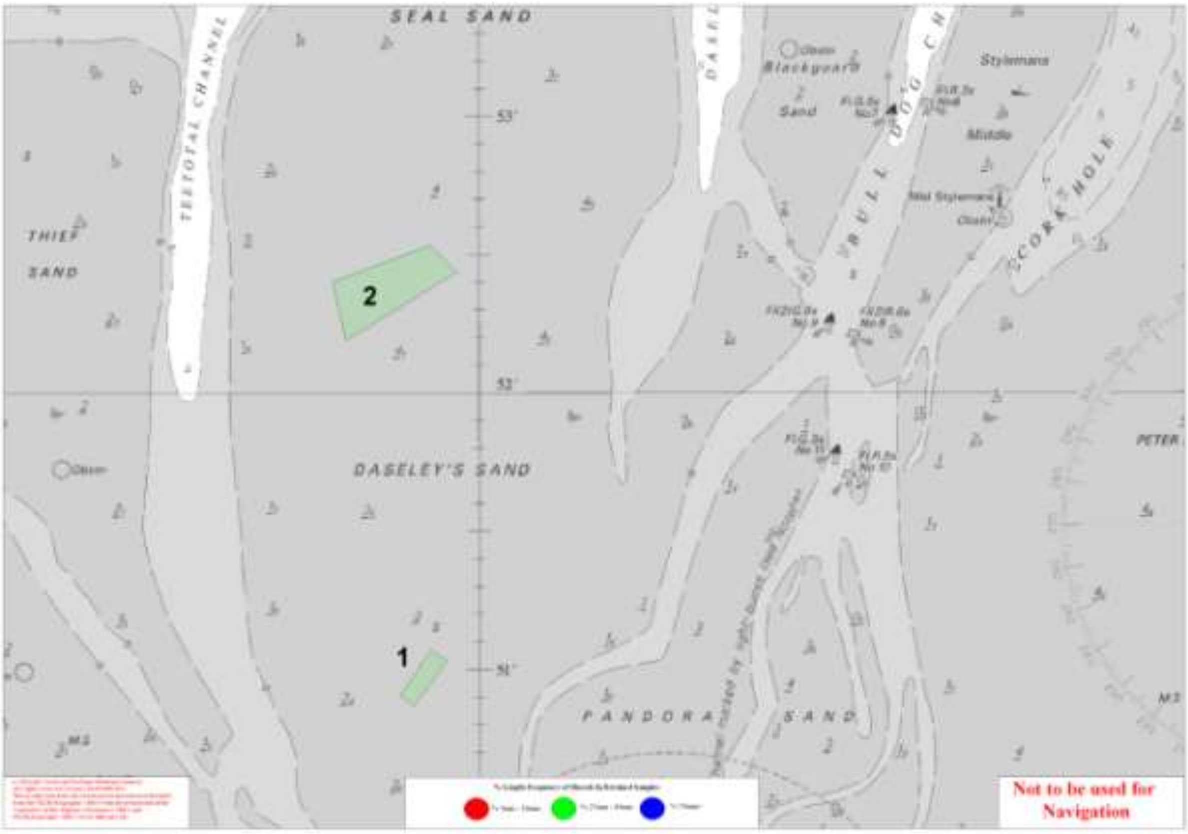


Figure 2.33 Mussel size distribution on the Daseley's mussel bed – November 2012

2.3.12 Blackshore

- Area: 23.2 hectares
- Coverage: 26%
- Mean Density: 0.68 kg/0.1m^2
- Total Stock: 386 tonnes
- Stock $\geq$ 45mm: 187 tonnes

The Blackshore bed was opened to a dredged relaying fishery in October 2013, so the survey was delayed until November 18th when the fishery had ended. During the survey samples were collected from every fourth "hit", producing 38 samples from four transects. Figures 2.34 and 2.35 show the mussel size distribution within the bed and the mussel size frequency of the population taken from these samples.

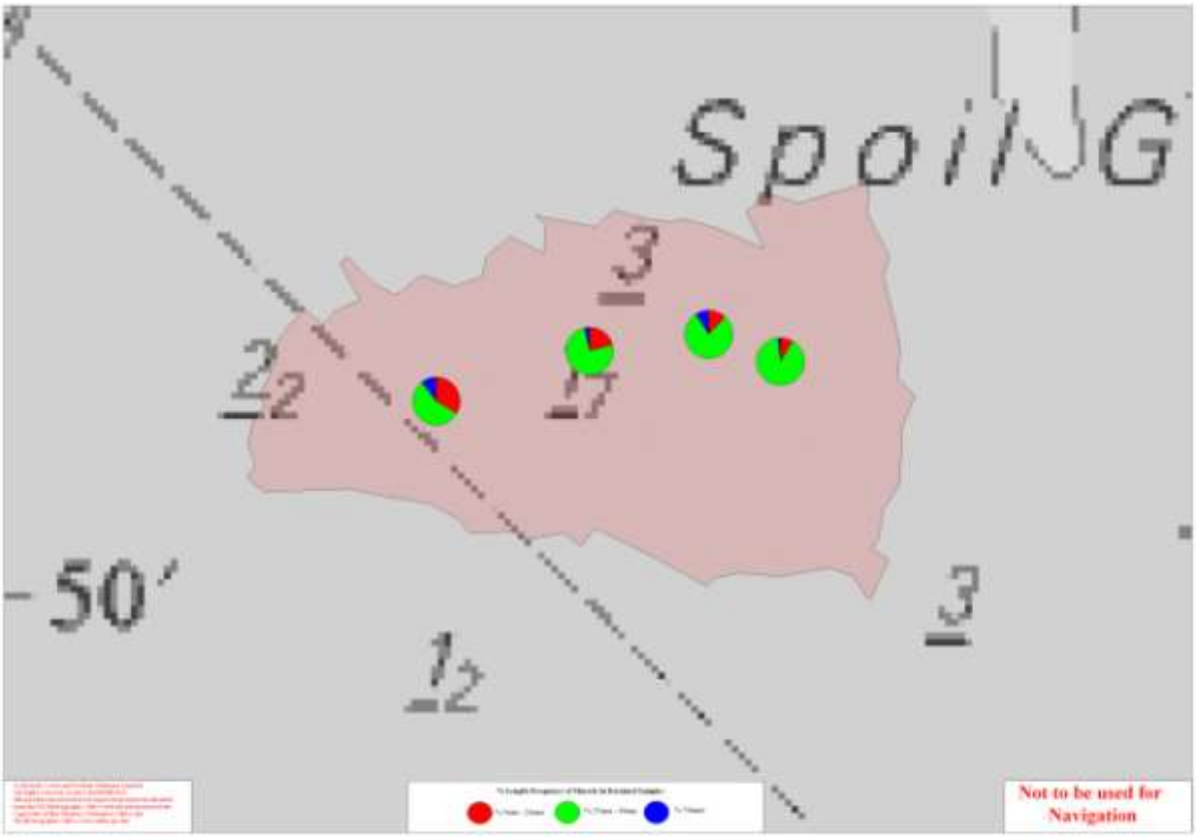


Figure 2.34 Mussel size distribution on the Blackshore mussel bed – November 2013

This bed was first established in 2010 and grew quickly in size and biomass following subsequent settlements of seed. It was opened during both the 2012 and 2013 fisheries but did not appear to have attracted much fishing effort. The 2013 survey found there had been significant mortalities among the 3 year-old mussels on this bed. These losses resulted in the area of the bed declining from 23.2 hectares to 23.2 hectares, the coverage from 30% to 26% and the mean density from 1.21 kg/0.1m^2 to 0.68 kg/0.1m^2. From these figures the total mussel biomass was calculated to have declined from 852 tonnes in 2012 to 386 tonnes. The majority of this decline can be attributed to natural mortality rather than fishery disturbance. Although the total biomass had declined, the age structure of the mussels in the bed meant the biomass of marketable sized mussels had increased from 150 tonnes to 187 tonnes.

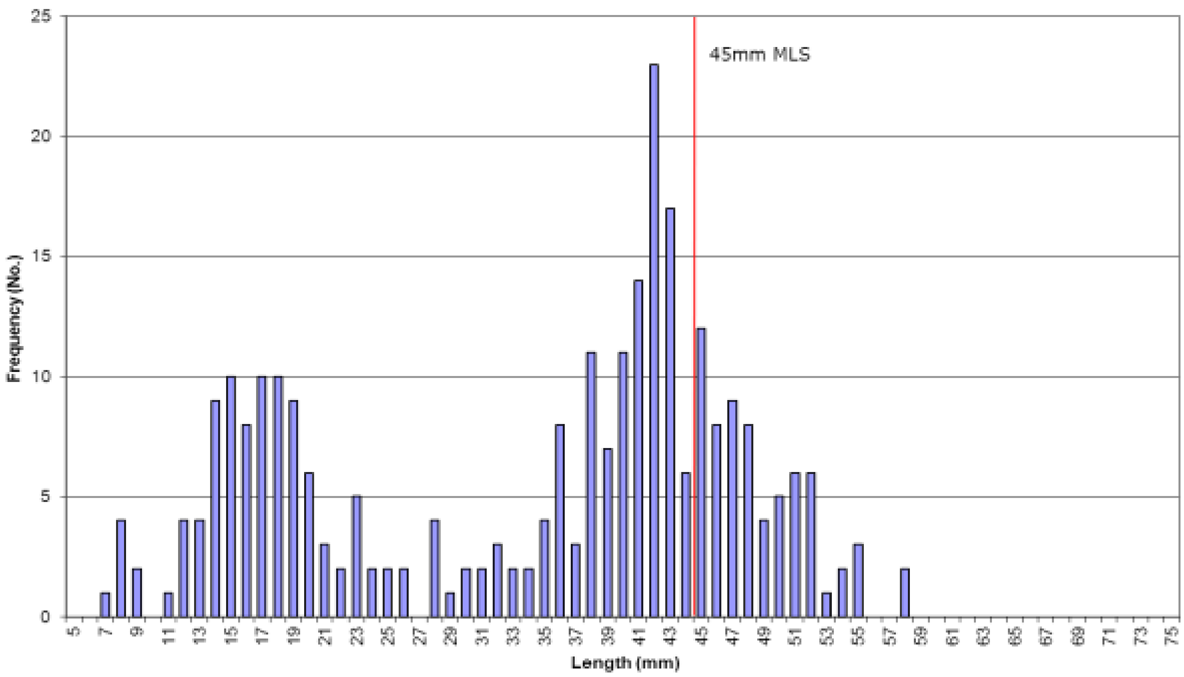


Figure 2.35 Mussel size frequency on Blackshore - November 2013

2.3.13 Welland Bank

- Area: 2.3 hectares
- Coverage: 69%
- Mean Density: 2.12 kg/0.1m^2
- Total Stock: 328 tonnes
- Stock ≥ 45mm: 214 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 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 2.37). 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.

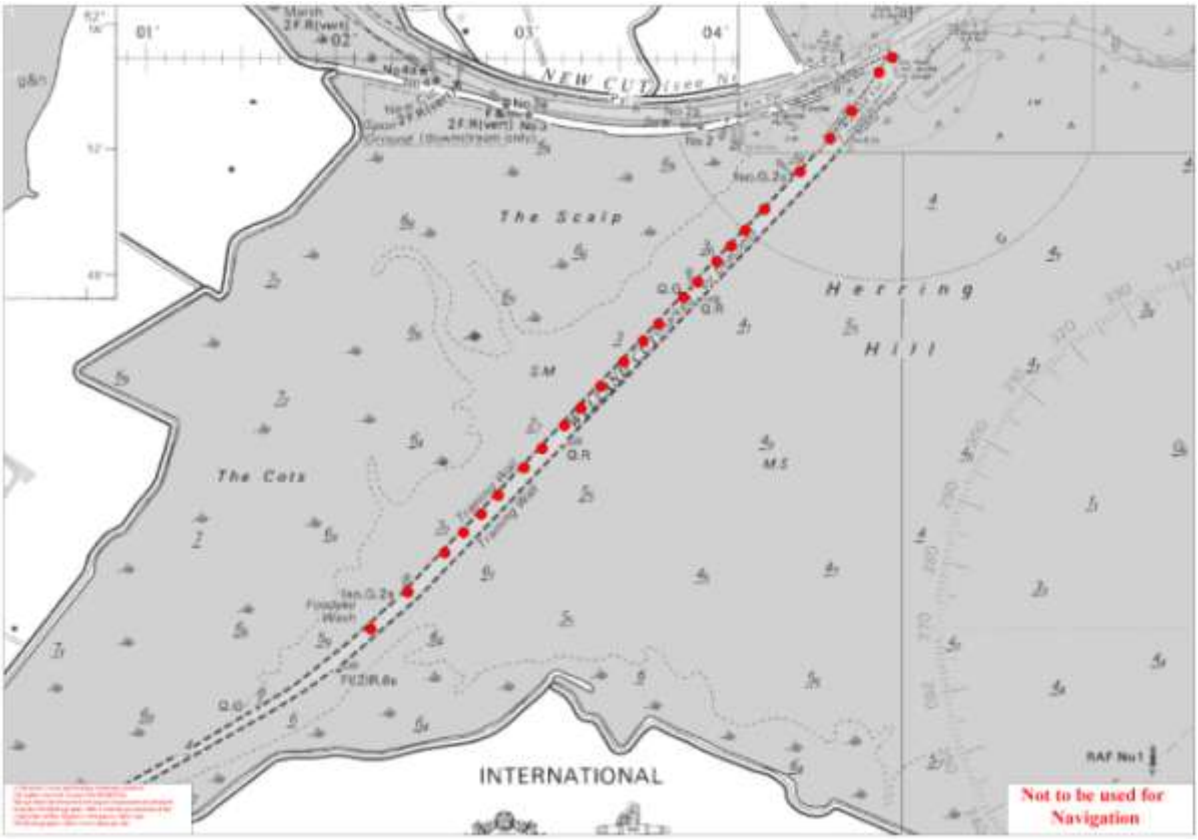


Figure 2.37 Chart showing the positions of sample sites on the Welland Bank – September 2013

The Welland Bank survey was conducted on September 21st 2013. Samples were collected from every second “hit”, producing 45 samples from 25 sample stations. Figure 2.38 shows the mussel size frequency of the population taken from these samples.

The area occupied by mussels was found to be 2.3 hectares, similar to the 2.2 hectares recorded in 2012. Within this band the coverage of mussels was found to have declined from 83% to 69% and the mean density from 2.19 kg/0.1m^2 to 2.12 kg/0.1m^2. From these figures the total biomass of mussels on the bank was calculated to have declined from 369 tonnes to 328 tonnes. Of these 214 tonnes had reached marketable size compared to 232 tonnes the previous year.

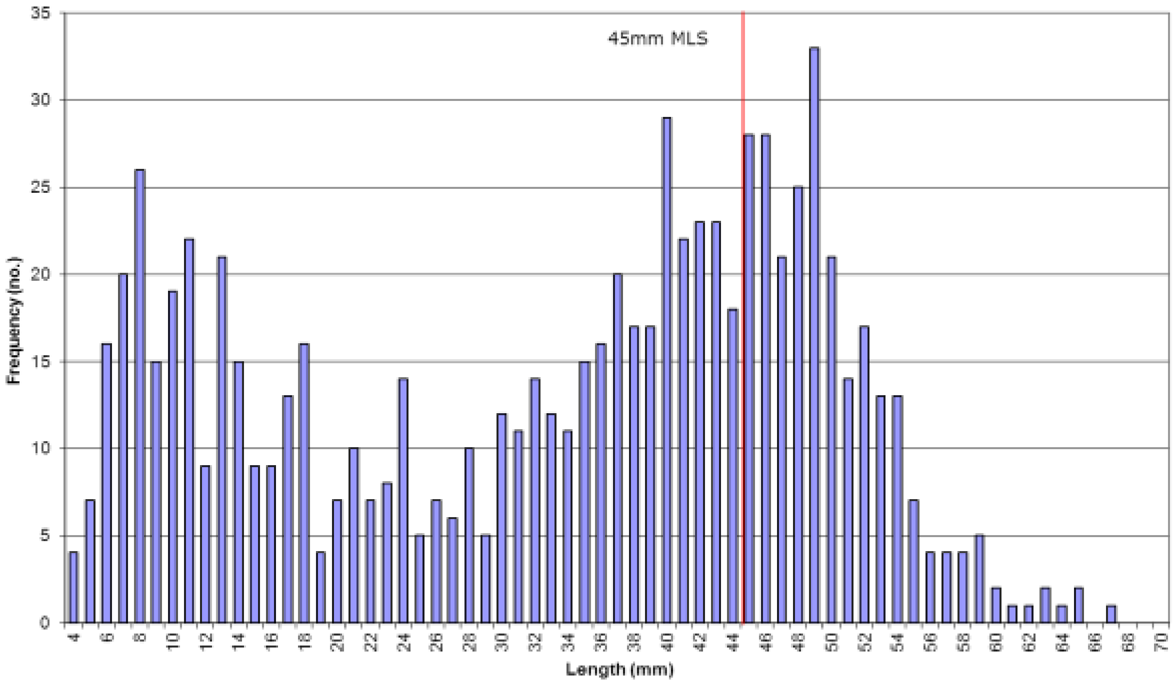


Figure 2.38 Mussel size frequency on Welland Bank – September 2013

Table 2.1 - Summary of The Wash intertidal mussel stocks following the 2013 autumn mussel surveys									
	2013							2012	
BED	**AREA (ha)**	**COVERAGE (%)**	**DENSITY ($kg/0.1m^2$)**	**TOTAL STOCK (Tonnes)**	**STOCK ≥45MM (Tonnes)**	**% ≥45MM**	**Tonnes/ ha**	**TOTAL STOCK (Tonnes)**	**% CHANGE**
Mare Tail North	54.2	36	1.24	2398	900	37.5	44.2	2644	-9.3
Mare Tail South	30.9	36	0.81	890	121	13.6	28.8	615	44.7
Mare Tail East	7.2	23	0.33	54	11	20.4	7.5	102	-47.1
Shellridge	1	17	0.38	6	1	16.7	6.0	8	-25.0
Toft	43.9	33	1.39	2005	1468	73.2	45.7	2234	-10.3
Roger	1.7	45	0.84	64	43	67.2	37.6	41	56.1
Gat, West	38.4	39	0.73	1110	563	50.7	28.9	539	105.9
Gat, Mid	24.6	31	0.51	388	215	55.4	15.8	566	-31.4
Gat, East	17	32	0.61	337	237	70.3	19.8	308	9.4
Main End	5.7	21	0.81	95	76	80.0	16.7	88	8.0
Holbeach	12.6	45	0.89	502	124	24.7	39.8	741	-32.3
Herring Hill	28.3	32	0.97	881	24	2.7	31.1	693	27.1
Trial Bank	44	26	0.88	1014	117	11.5	23.0	585	73.3
Breast, West	19.7	21	0.76	316	32	10.1	16.0	585	-46.0
Breast, East	31.9	30	1.20	1154	143	12.4	36.2	1066	8.3
Scotsman's Sled, East	31	21	0.55	365	106	29.0	11.8	369	-1.1
Daseley's	0	0	0	0	0	0.0	0.0	23	-100.0
Blackshore	22.1	26	0.68	386	187	48.4	17.5	852	-54.7
Pandora	5.2	26	0.99	135	119	88.1	26.0	279	-51.6
TOTAL	**419.42**			**12100**	**4487**	**37.1**	**28.8**	**12338**	-1.9
Welland Bank	2.3	69	2.12	328	214	65.2	264.2	369	-11.1

2.4 Discussion

Figure 2.39 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. The results from the 2013 surveys show that the total mussel biomass on the intertidal beds has decreased slightly from 12,228 tonnes in 2012 to 12,100 tonnes.

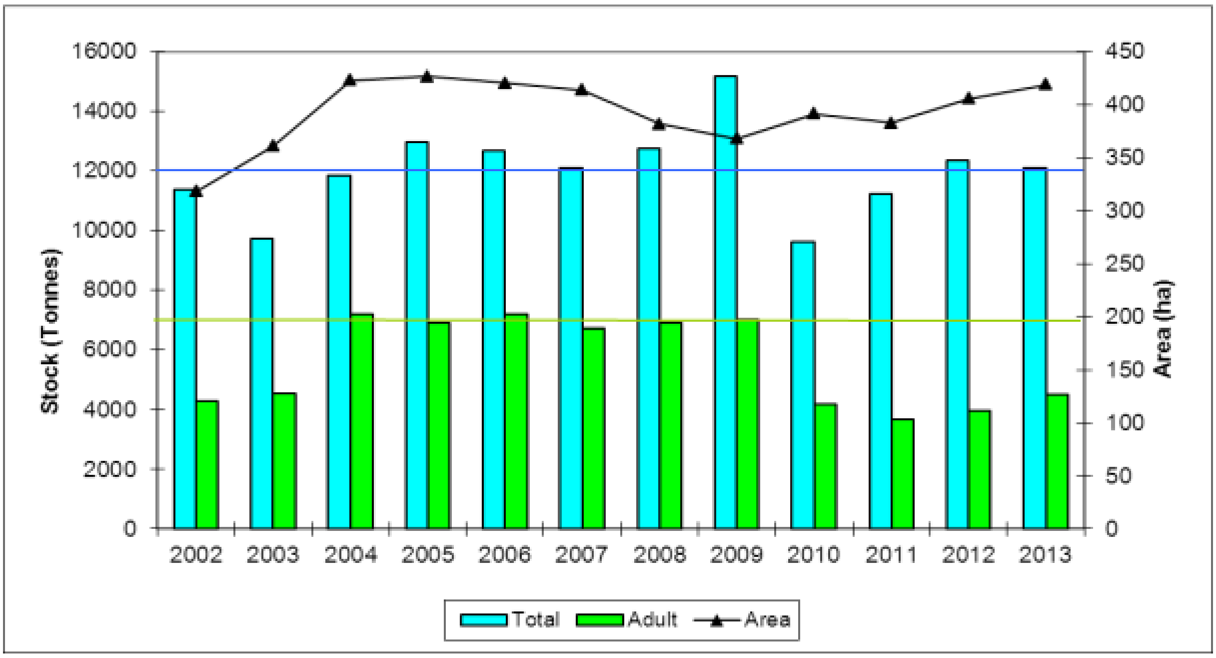


Figure 2.39 Chart showing the annual stocks of mussels present on the intertidal beds in the Wash compared to their Conservation Objective targets.

The population structure following the 2012 surveys had suggested there were sufficient juvenile mussels in the population for the total biomass of the stocks to increase by approximately 1,000 tonnes during the year. Based on this, a dredge fishery for seed had been opened in October 2013 with a Total Allowable Catch (TAC) of 800 tonnes. The timing of this fishery was not ideal as seed is usually relayed in April/May when the mussels are looser on the ground. Further, with only limited time available between the end of the cockle fishery and the deadline for completing the remaining mussel surveys, it was only opened for two weeks. During this period, only about 250 tonnes of the TAC were taken. This proved fortuitous, because the remaining surveys found there had been significant mortalities among 3 year-old mussels on some of the beds. These caused the total loss of the Daseley’s bed and a 45% reduction on the Blackshore bed. Coupled with these natural losses, had the full TAC for the fishery been taken, the stocks would have fallen well below the Conservation Objective target.

Although the Conservation Objective target for total mussel biomass has been achieved, overall the beds are in poor condition. Since the crash in 2010, the stocks of adult mussels (those ≥45mm length) have failed to achieve their Conservation Objective target of 7,000 tonnes. The recovery of this population is slow, having been impaired by the die-offs of large numbers of 3 year-old mussels in recent years. Samples of mussels of this age that had survived on the Daseley's bed were sent to Cefas for analysis, but their tests failed to find a causal agent. The Authority will be working closely with Cefas in 2014 to study these die-offs further. Fishery pressure has also slowed the recovery. Having failed in recent years to exploit any sub-littoral beds of seed for their lays, the industry has relied more on the inter-tidal beds for their seed requirements. Although these fisheries have mainly targeted juvenile stocks, it has impacted the beds by reducing how many juveniles remain to recruit to adult size.

The lack of seed recruitment is also of concern. While some beds have benefited from recent settlements and appear healthy, others have not received significant settlements for several years. Such beds now support declining populations of ageing, barnacle-encrusted mussels, frequently surviving in small clumps amid dead shell. It has been observed that the majority of new settlement in the Wash is 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. Their importance for attracting and protecting seed would explain why some of the beds are continuing to attract seed and remain in good condition while others appear to be in terminal decline. If this is the case, the industry's reliance on the remaining healthy beds will eventually lead to their decline, too, if their densities fall below levels able to support the raised matrices that are facilitating the settlement of seed. The Authority plans to conduct work during 2014, exploring ways of encouraging seed to settle on some of the beds that have declined.

2.5 TITCHWELL MARSH MUSSEL BED

2.5.1 Introduction

Titchwell Marsh is a popular nature reserve owned and managed by the Royal Society for the Protection of Birds (RSPB). Located between the villages of Titchwell and Thornham, the reserve has a variety of habitats including reed beds, marshland, fresh and brackish water lagoons and sandy beaches. Together these provide feeding, roosting, breeding, overwintering and staging sites for a number of nationally and internationally important birds. The area plays host to important saltmarsh plant communities and supports important assemblages of several rare moths and beetles. In order to protect these habitats and dependant species, the area is designated as a Special Protected Area (SPA), a Special Area of Conservation (SAC), A Site of Special Scientific Interest (SSSI) and a Ramsar site. It is also a part of the North Norfolk Coast Area of Outstanding Natural Beauty (AONB) and Biosphere Reserve.

Figure 2.5.1 Satellite image showing location of Titchwell Marsh nature reserve and mussel bed, Google maps, 2012.

Situated on the beach is a small area of exposed Neolithic peat upon which mussels regularly settle (figure 2.5.1). When local fishermen approached Eastern Sea Fisheries Joint Committee (ESFJC) in 2009 requesting permission to fish these mussels it was initially unclear who would be responsible for managing a fishery within a nature reserve maintained by the RSPB. Consultation with the Crown Estate landowners, however, confirmed that because the Joint Committee would need to relax Byelaw 4, minimum size of mussels, and authorise the fishing activity under Byelaw 2(b), allowing the removal of mussels for the purpose of stocking, the responsibility for the management and enforcement of the fishery was that of the Joint Committee. Since then the Joint Committee (and its successor, Eastern Inshore Fisheries and Conservation Authority (Eastern-IFCA)) have conducted a number of stock assessment surveys on this bed.

In 2009, when the first survey was conducted at this site the total biomass was recorded at 420 tonnes. The exposed location of the bed makes the mussels on it vulnerable to winter storms, however, and subsequent surveys have shown a history of loss and recovery as mussels are lost in winter and new settlements occur in summer. These fluctuation can be severe, with the stocks falling as low as 10 tonnes in March 2010 and 72 tonnes in March 2012, with recoveries back to 146 tonnes in September 2010 and 194 tonnes in October 2012. Irrespective of recoveries, none of the surveys have shown stocks as high as those recorded during the initial survey in 2009.

2.5.2 Method

As part of the on-going survey program the Titchwell mussel bed was surveyed on the 13th February and the13th August 2013. The methodology used for these surveys was identical to that used to survey intertidal mussel beds in the Wash (See section 2.2).

2.5.3 Results

2.5.3.1 Titchwell Marsh Mussel Survey - February 2013.

- Area: 3.1 hectares
- Coverage: 43%
- Mean Density: 0.82 kg/0.1m^2
- Total Stock: 110 tonnes
- Stock ≥ 45mm: 1 tonne

At the time of the previous survey in October 2012, mussel was found to occur in seven discreet patches covering an area of 3.5 hectares. When the Authority revisited the bed in February 2013, there had been some changes around the edges of the patches that resulted in the mussels occupying six discreet patches and covering 3.1 hectares. Figure 2.5.2 shows the extent of the mussel beds in February 2013 compared to October 2012. Figure 2.5.3 shows the mussels attached to the raised bed of peat.

Figure 2.5.2 Titchwell Marsh mussel bed in February 2013 (Red hatched) compared to October 2012 (black outline)

Within the bed, samples were collected from every fourth hit, producing 26 samples from 252 "hit/miss" determinations. Taken as a whole, the bed was found to have an average coverage of 43% and a mean density of 0.82 kg/0.1m^2. Both of these figures are lower than those recorded the previous October, when the coverage was 53% and the mean density was 1.03kg/0.1m^2. From these figures the total biomass of mussels on the bed was calculated to be 110 tonnes, of which just 1 tonne had attained the Minimum Landing Size (MLS) of 50mm. This meant the biomass of mussels on the bed had declined by 84 tonnes during the winter. While some of this reduction may be attributed to the actual loss of mussels from the bed during winter, some of the reduction will be due to the declining meat yields that mussels undergo in winter when food shortages cause them to metabolise their carbohydrate, protein and lipid reserves. Figure 2.5.4 shows the size frequency of the mussels at Titchwell in October 2012 and February 2013. These size frequencies are very similar, indicating there had been little growth over winter.

Figure 2.5.3 – Photograph of the Titchwell mussel bed in February 2013, showing mussels attached to raised bed of peat.

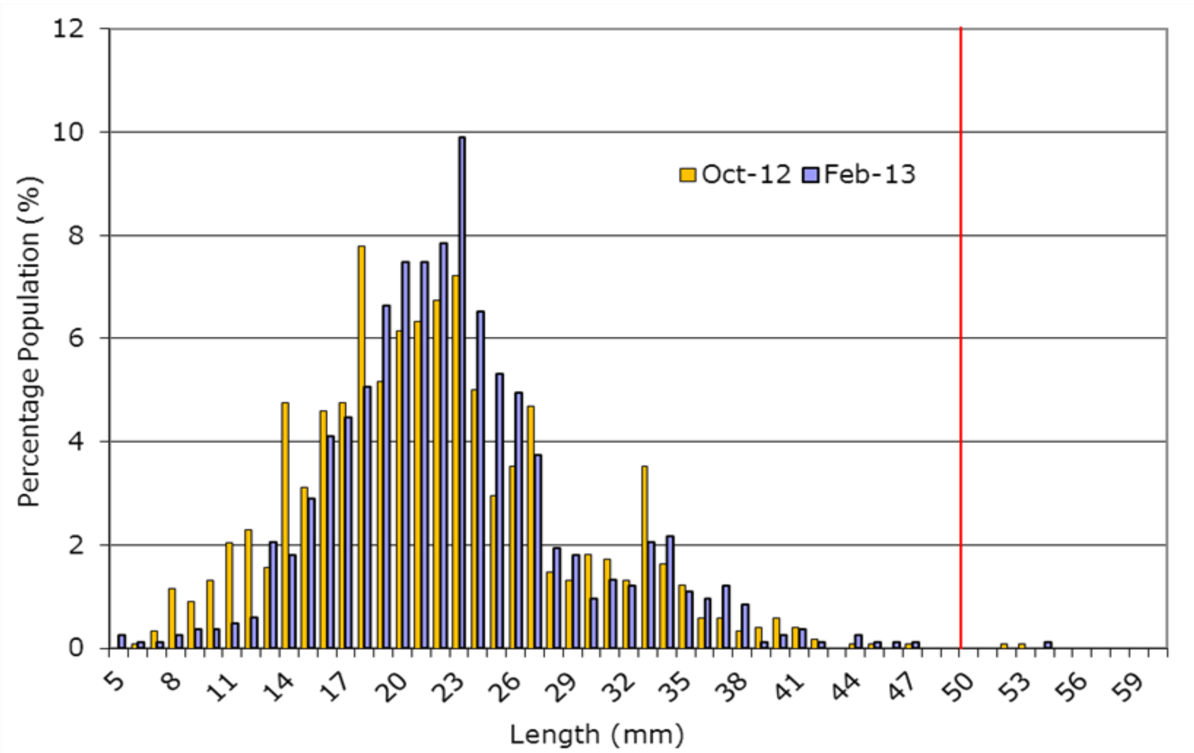


Figure 2.5.4 - Population size frequency of mussels found at Titchwell in October 2012 and February 2013.

2.5.3.2 Titchwell Marsh Mussel Survey – August 2013

- Area: 2.1 hectares
- Coverage: 54%
- Mean Density: 1.10 kg/0.1m^2
- Total Stock: 129 tonnes
- Stock ≥ 45mm: 0 tonnes

The bed was visited again in September 2013, during which samples were collected from every fifth hit, producing 28 samples from 281 "hit/miss" determinations. This survey found that some of the mussels that had been present when surveyed in February had gone. This had resulted in the area of the bed declining from 3.1 hectares to 2.1 hectares (see figure 2.5.5). During the same period there had been a fresh settlement on the bed. This can be seen in figure 2.5.6, which shows the size frequencies of the populations in February and August.

Figure 2.5.5 Titchwell Marsh mussel bed in August 2013 (Red hatched) compared to February 2013 (black outline)

Within the bed, the recruitment of new seed had helped the coverage of mussels to increase from 43% in February to 54%, and the mean density to increase from 0.82 kg/0.1m^2 to 1.10 kg/0.1m^2. This recruitment compensated for the losses that had occurred, the total mussel biomass increasing from 110 tonnes to 129 tonnes. None of these stocks were found to have attained the Minimum Landing Size of 50mm.

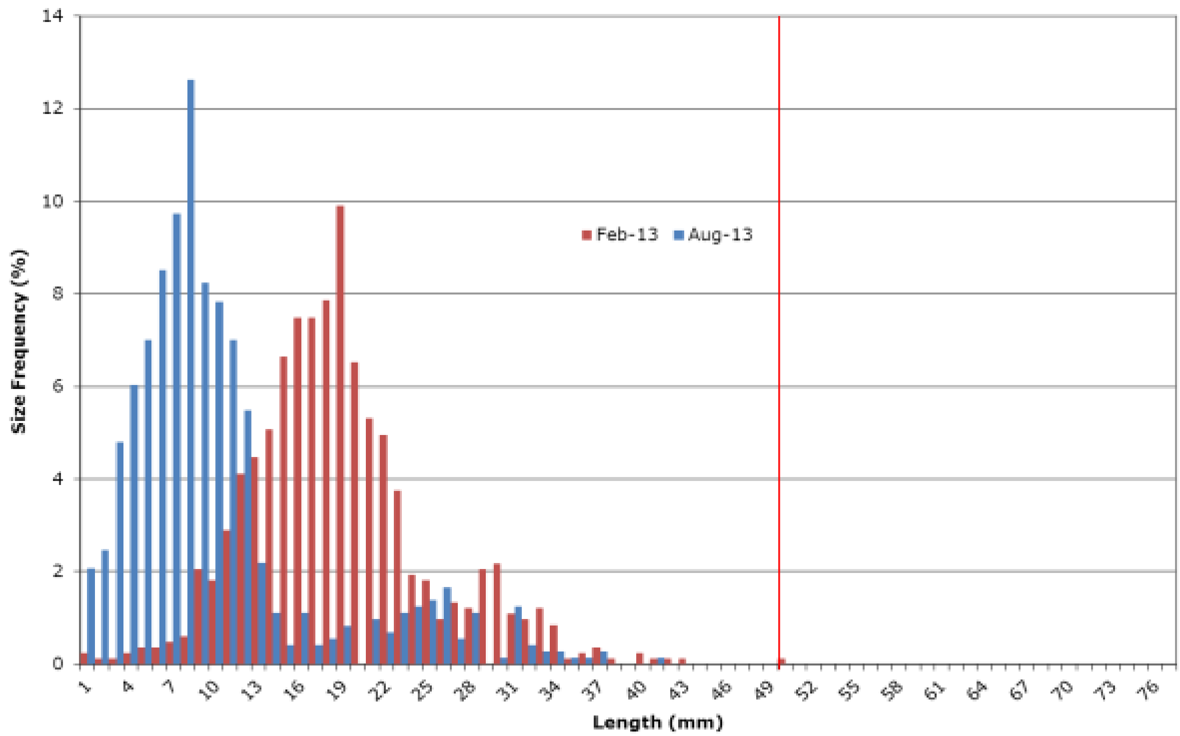


Figure 2.5.6 – Comparison between the population size frequencies of mussels found at Titchwell in February 2013 and August 2013.

2.5.4 Discussion

An outcropping of exposed Neolithic peat on the lower shoreline of Titchwell Marsh provides a suitable habitat for the settlement of mussel seed. Anecdotal evidence from fishermen suggests that this bed is ephemeral in nature, regularly attracting good settlements of seed that are subsequently washed away. Figure 2.5.7 shows the biomass of mussels estimated to be present on this bed during the eight surveys the Authority has conducted there since September 2009. While demonstrating mussels can survive over winter on this bed, it does show clear reductions between the stocks surveyed during the September 2009, September 2010 and October 2010 surveys and the stocks present during their following spring surveys. From this chart it can be seen that the greatest loss occurred following a period when the mussels were at their highest biomass, when they declined from 420 tonnes to just 10 tonnes. The site is particularly exposed, and while the peat provides a firm substrate for mussels to attach to, the accretion of soft, unstable 'mussel mud' beneath the mussels renders the bed vulnerable to wave and storm action. Accretion is greatest when the stocks are high, and during the summer months when the mussels are most active, so it is of no surprise that the greatest losses have occurred when the stocks have been at their peak.

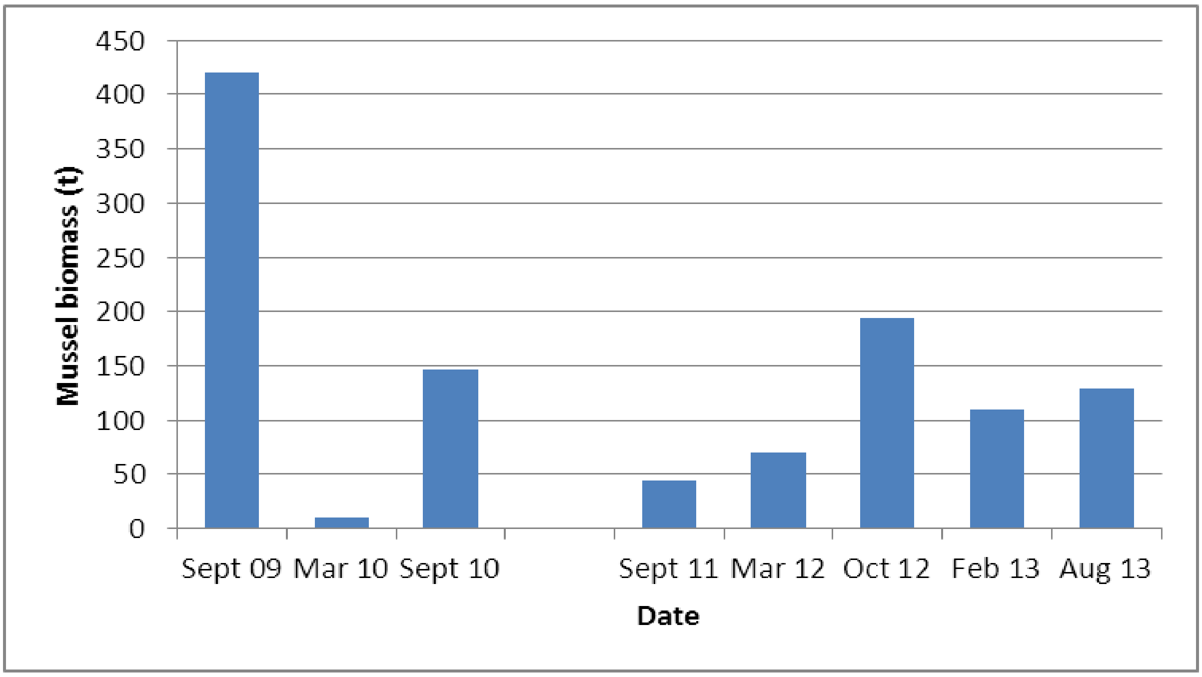


Figure 2.5.7 – Chart showing the total mussel biomass estimated to be present on the Titchwell mussel bed between September 2009 and August 2013

Data from the previous surveys indicate few mussels from this bed attain the Minimum Landing Size of 50mm. This is likely due to the ephemeral nature of the bed causing the majority of the population to be washed away before they reach this size. From a fisheries perspective, this makes the Titchwell bed more valuable to the fishing industry as a seed resource than a source of marketable mussels. Although it is usually the Authority's policy to open ephemeral beds to exploitation once they have been identified, the location of the Titchwell bed is sensitive. The bed is situated within a RSPB maintained nature reserve, so there are concerns regarding the disturbance and competition that a commercial fishery could cause to the birds. Further, fishing activities could also cause irreversible damage to the relatively soft and fragile exposed Neolithic peat that the mussels are attached to. Unless the peat is protected by a layer of pseudo-faeces beneath the mussels, even a hand worked fishery could cause irreparable damage to this feature. Timing a fishery to coincide with when such a protective layer is present, but before the mussels are washed away, is difficult, however, and would require more frequent monitoring than is currently conducted. This would be best achieved by conducting targeted surveys following alerts from fishermen that the beds are in a condition suitable to be fished.

3.0 WASH COCKLE STOCKS

3.1 Introduction

The intertidal cockle stocks in the Wash provide an important resource for the local fishing industry, particularly to the ports of Boston and King's Lynn. Since 2000 cockle landings into these two ports have been worth an average first-sale value of over £1 million, peaking at £2.7 million in 2006. Traditionally this was an artisanal hand-worked fishery but modernization of the fleet and expansion of the markets into Europe have greatly changed the fishery over the past forty years. Innovations during that time have included techniques to improve the efficiency of hand-working, such as "blowing out" (whereby an anchored vessel is manoeuvred in concentric circles during the ebbing tide in order to wash cockles out of the ground into easy to harvest piles) and "prop washing" (a similar practice, but in which the vessel is not anchored). Technological changes include the evolution of larger, more efficient vessels into the fleet and the introduction of hydraulic suction dredges in 1986. The greater efficiency that these methods and technologies have brought, however, has on occasions been detrimental to the stocks. When management measures have not been sufficient to control their immediate impacts, over-fishing has occurred, resulting in declining stocks and "boom and bust" fisheries.

In 1993 the Fishery Order 1992 was introduced to strengthen the management of the shellfisheries in the Wash, but cockle stocks remained low through most of the 1990s. In 1998 an annual Total Allowable Catch (TAC) quota for the cockle fishery was introduced to limit exploitation to sustainable levels. This, together with the subsequent evolution of other management measures, has helped to stabilise the fishery and facilitate a stock recovery through the 2000s. This period has also seen a growing environmental awareness introduced into the management of the fisheries, whereby the fisheries are not just limited to ensure their sustainability, but to protect designated environmental features. This has resulted in the need to submit detailed Habitat Regulations Assessments to Natural England before fisheries can be consented. To facilitate this process, a suite of Management Policies were developed in 2007 to help manage the fisheries in a way that would not have a detrimental impact on the site's Conservation Objective targets. Irrespective of the management measures used, there is little that can be done to control natural events. In 2007 the Wash cockle stocks reached their second highest recorded level, appearing to validate the management measures had brought about the recovery of the fishery. Since 2008, however, the stocks have suffered unusually high mortality rates, undoing much of the progress that the management measures had helped to achieve and making it difficult to identify patches of adult cockles dense enough to fish. Such challenges place even more onus on having accurate survey information so that flexible contingency measures can be used to exploit the stocks without hazarding their sustainability.

This report provides details of the 2013 spring cockle surveys. In the past similar surveys have also been conducted in autumn, but due to unprecedented amounts of other work this year, it was not possible to conduct the autumn programme. Although there is no Minimum Landing Size (MLS) applied to cockles in the Wash, the results presented in this report divide the stocks into two size groups (cockles that are 14mm width and over and those that are under 14mm width). These groups are sometimes referred to in the report and management measures as "adult" and "juvenile" stocks, but these definitions are not strictly accurate, cockle size being influenced by a number of factors in addition to age. These size categories do, nevertheless, play an important role in the management of the fisheries, as to protect juvenile stocks, no cockles under 14mm width, irrespective of age, currently contribute towards the annual TAC.

There are several processes that must be followed in order to open a cockle fishery. These include conducting a thorough stock assessment, analysis of the data, consultation with the industry and Authority members, and the submission of a Habitat Regulations Assessment to Natural England. Providing sufficient time to conduct these tasks ready for a June opening of the fishery necessitates commencing the surveys in March. Once the waters begin warming up in spring, however, the cockles can grow quickly. This creates a disparity between the cockle biomass estimated to be present at the time of the surveys and that which is present during the fishery. Following requests from the industry, the Authority conducted a study in 2013 to assess whether it would be possible to measure the changes that occurred to the cockle stocks during this period. Because mortality will also influence the stock biomass, this aspect also needed to be studied in addition to growth. The details of this study are presented in section 3.6

3.2 Method

The intertidal cockle surveys are preferably conducted during spring tide periods (>6.5m). These allow best access to the beds either using a boat at high water or when walking the beds at low water. During neap tides some of the higher sites are inaccessible to the research boat at high water, while the lower sites may not drain adequately at low water to be accessible on foot. Timing of the high water periods during neap tides is also problematic, in that the night time high water period is usually between midnight and 03:00hrs, usually resulting in the loss of one of the two high water sampling periods.

Samples are collected at regular intervals on a predetermined conventional grid, from which the same sample stations are replicated each year. The majority of the stations on this grid are 370m x 340m apart, with a slightly higher resolution grid of 280m x 340m being used on the Herring Hill, Holbeach, Mare Tail and Gat sands.

Samples are collected either at high water using a $0.1m^2$ Day grab deployed from the research vessel, *Three Counties,* or a $0.1m^2$ quadrat during low water foot surveys. Once collected, the samples are washed over a 3mm mesh washing table (or using a 0.5mm sieve in the case of foot surveys), allowing any cockles present in the sample to be separated from the surrounding sediment. During the washing process the following data are recorded on the survey summary sheet (see figure 3.1):

Station – Record the station number of the sample

Sed – Record the sediment number using the following criteria:
1 – Sand (clean sand)

2 – Silty Sand (mainly sand, but contains some finer material)

3 – Sandy Silt (mainly fine silt but contains some coarser sand grains)

4 – Silt (Fine silty mud, generally fairly sloppy to walk on)

5 – Clay with a thin top veneer of Sand (The clay sediments are more compact and solid than silt).

6 – Clay with a thin top veneer of Silt (The clay sediments are more compact and solid than silt).

7 – Clay (The clay sediments are more compact and solid than silt).

Cockle – Record the approximate number of cockles present in each sample

A1, A2 and A3 – These columns are used to record the number of *Arenicola* casts found in each of three quadrats taken at each station during foot surveys. As casts are disturbed in a Day grab sample and cannot be identified, these three columns are not filled in during Day grab surveys.

Lan – During foot surveys record how many of the three quadrats contain *Lanice* tubes. As only one Day grab sample is taken at each station the presence or absence of *Lanice* tubes is recorded as Y/N.

Mac – Record the number of *Macoma* present in the sample.

SAND							
DATE							
STATION	SED	COCKLE	A1	A2	A3	LAN	MAC
1							
2							
3							
4							
5							
6							
7							
etc							

Figure 3.1 Example of the survey summary sheets used to record additional environmental data collected during cockle surveys

Once cleaned any cockles present in the sample are retained in labelled bags for later analysis (one bag/station). Samples are stored in a cool place out of the sun.

At low water the retained samples are individually measured to the nearest millimetre by length and width. These cockles are separated into three groups:

1. Those of width equal or greater than 16mm
2. Those of width 14 to 15mm

3. Those smaller than 14mm width.

The cockles within each group are then further separated into age classes using their annual growth rings to age them (taking care to identify whether outer ring is the current or previous year's growth). The number of cockles in each age-size group is recorded and the total weight of cockles in each group measured to the nearest 0.01g. Due to the sensitivity of the scales used (200g/0.01g), the weighing of these samples can only take place ashore or once the vessel is aground.

The data acquired from these surveys are transferred to a MapInfo GIS database from which charts of the beds showing cockle densities can be interpolated. The minimum density used to determine the extent of the coverage on the bed is 10 cockles/m^2. The biomass of cockles on the bed is calculated by multiplying the mean weight of the samples to attain a weight per hectare, and applying this figure to the area of coverage. The biomass of fishable stock is determined by using the mean weight of those individuals having reached a width of 14mm or greater.

The additional environmental data collected during the surveys is transferred to a MapInfo GIS database. This data is used to create models showing the distribution of *Lanice conchilega* and *Macoma balthica* using Vertical mapper software with a Nearest Neighbour interpolation methodology. The results of the environmental data are reported in Section 9 of this report.

3.3 Results

The surveys were conducted between March 25th and May 9th, this timing being consistent with the majority of Eastern-IFCA's and ESFJC's previous spring cockle surveys. Some industry members expressed a concern that due to the prolonged winter temperatures, the surveys should have been delayed in order to allow a longer period of growth. As recent years have shown the cockles are vulnerable to high "atypical" mortality rates during warm periods, officers considered the risk associated with delaying the surveys outweighed any benefits. During the course of the surveys, 1,296 stations from a total of 21 sands were sampled. Of these 920 were collected over high water periods using a Day grab and the remaining 376 were collected at low water using a quadrat. Figure 3.2 shows the survey stations that were sampled during the 2013 surveys

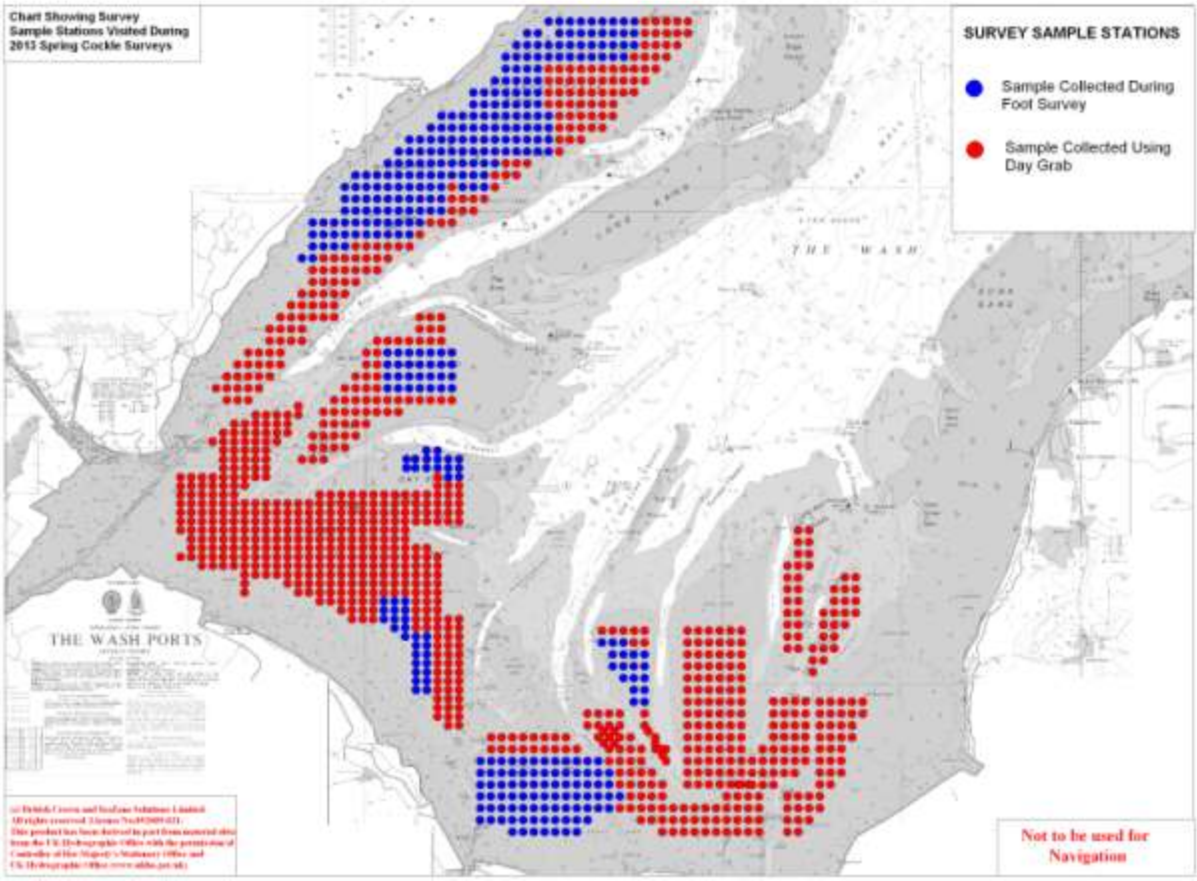


Figure 3.1 Chart showing the positions of the sample stations surveyed during the 2013 spring cockle surveys. Stations in red were sampled at high water using a Day grab. Stations in blue were sampled at low water with a quadrat.

Following analysis of the survey data, the cockle stocks were estimated to be:

Total Adult Stock (≥14mm width)	11,159 tonnes
Total Juvenile Stock (<14mm width)	9,773 tonnes
Total Stock (all sizes)	20,932 tonnes

Although there had been a successful fishery and additional "atypical" mortality losses since the spring survey in 2012, the total cockle biomass was found to have only slightly declined from the 21,108 tonnes recorded the previous year. This can be attributed to the growth of cockles from the strong 2010 year-class cohort compensating for the losses resulting from the fishery and natural mortality. Because a greater proportion of these had attained a size of 14mm width than the previous year, the biomass of "adult" cockles had increased from 7,107 tonnes (34% of the total stock) in 2012 to 11,159 tonnes (53% of the total stock). Figures 3.3 and 3.4 show the distribution of the adult (≥14mm width) and juvenile cockles (<14mm width).

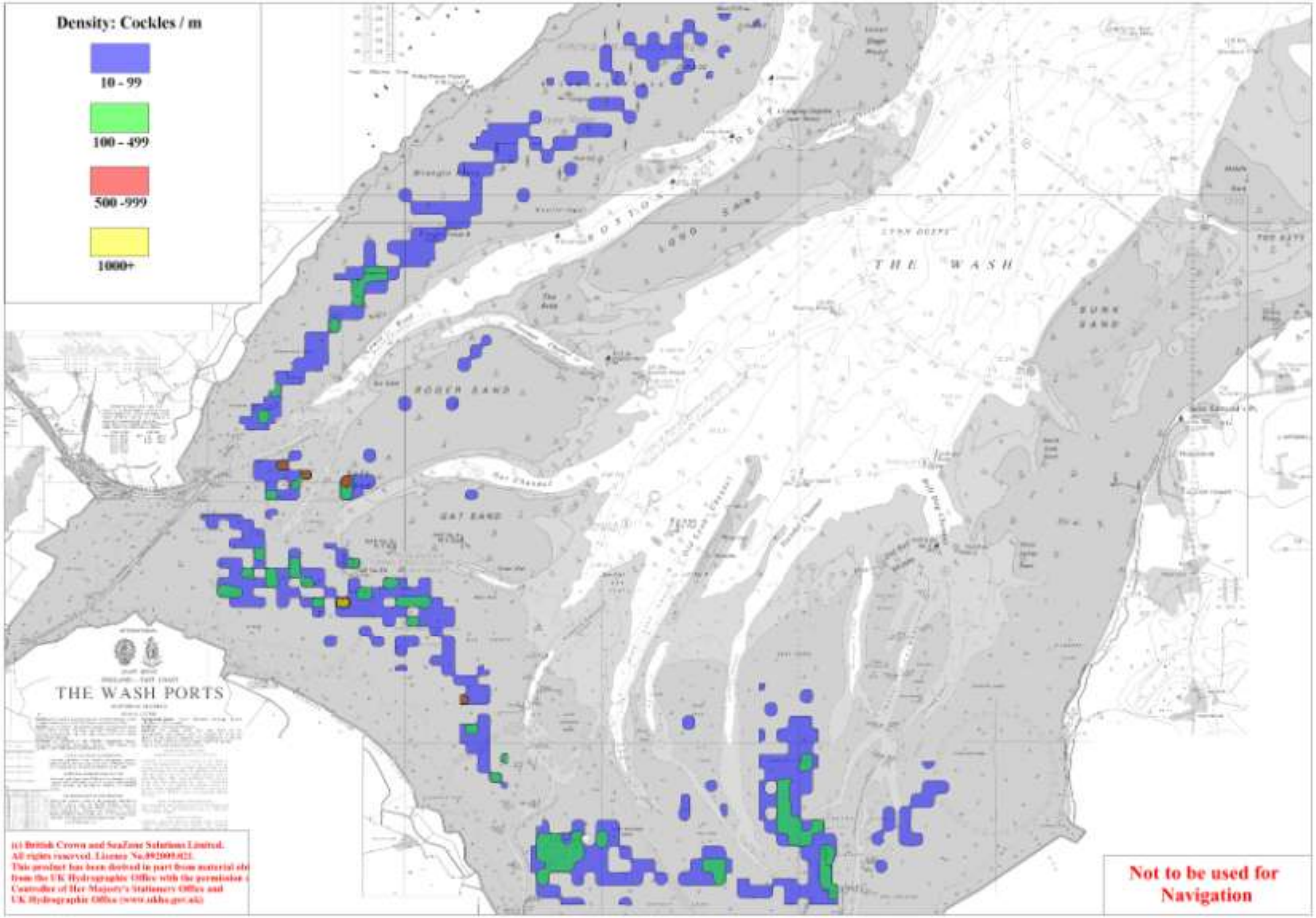


Figure 3.3 Chart showing the distribution of cockles ≥14mm on the Wash intertidal beds when surveyed during the spring 2013 surveys.

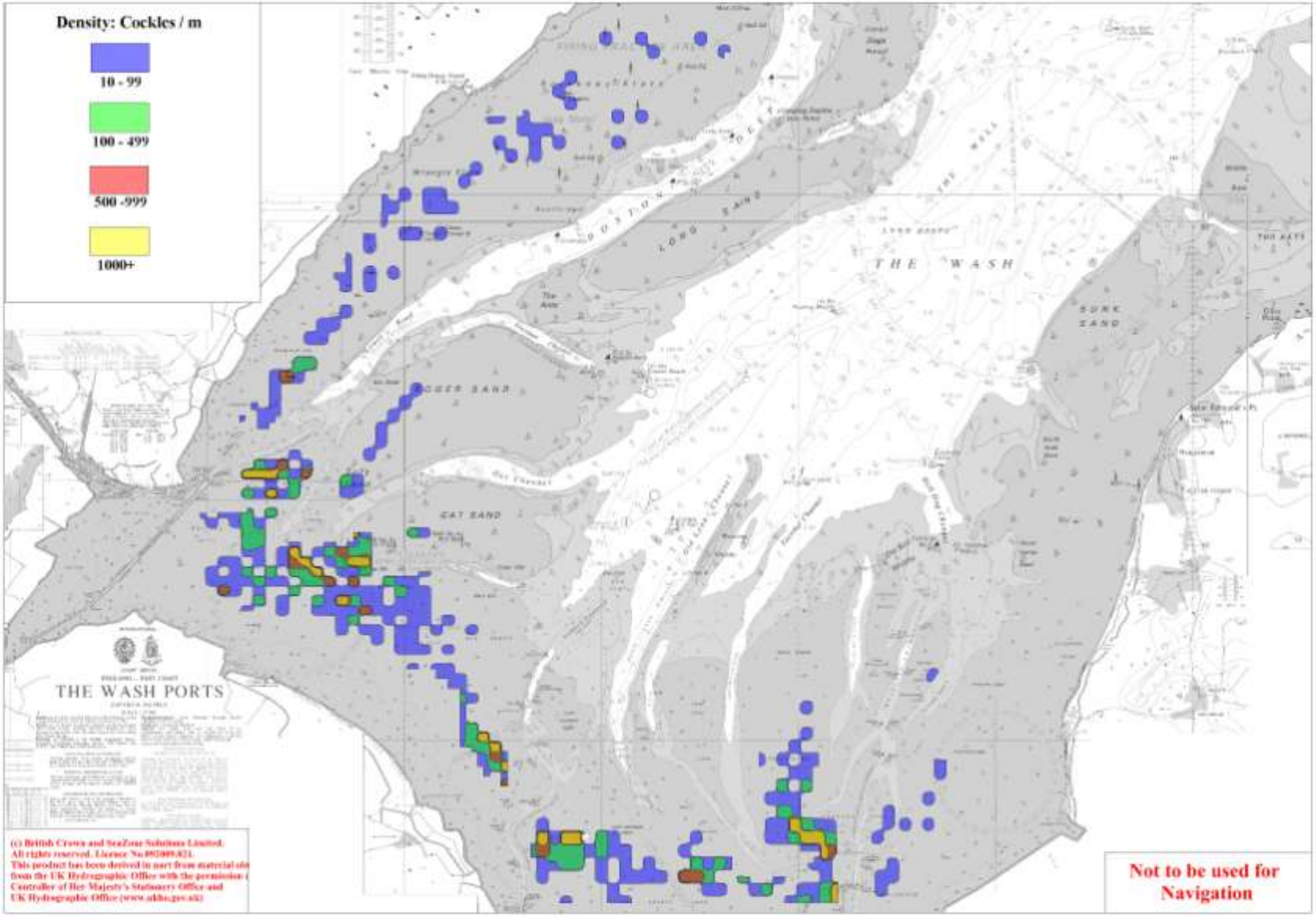


Figure 3.4 Chart showing the distribution of cockles <14mm on the Wash intertidal beds when surveyed during the spring 2013 surveys.

3.3.1 Boston Main

Figures 3.5 and 3.6 show the distribution of "adult" and "juvenile" cockle stocks on Boston Main at the time of the 2013 spring surveys. Boston Main is the collective term for the three survey areas of Butterwick, Wrangle and Friskney. These each include a traditionally surveyed area that were part of the survey programme prior to 2004, and extended areas that were added after that date. The traditional areas cover ground that mostly have elevations below 3.5m (chart datum), while the extended areas cover the higher ground between these regions and the edges of the green marsh.

Historically, these beds have provided the local fishermen with some of the best cockle fishing grounds in the Wash but in recent years high mortalities have occurred. Between 2008 and 2010 these losses caused the stocks to decline from 14,979 tonnes in 2007 to 1,083 tonnes in 2010. Another decline occurred in 2012 after a good spatfall in 2010 had facilitated a recovery. Having identified trends from the previous mortality event, this one had been anticipated, allowing contingency management measures to be developed. These enabled extra quota to be taken from the Wrangle sand once mortality rates reached trigger levels (Jessop, Akesson & Smith, 2012). Even though the industry focused a high proportion of the fishery on Wrangle during the summer, and contingency measures were successfully introduced once the TAC had been exhausted, losses from "atypical" mortality were still high. The combined impact of the fishery and the mortalities caused the stocks on Boston Main to decline from 6,877 tonnes in 2012 to 2,508 tonnes in 2013. Apart from occasional pockets of slower growing cockles, the stocks on these beds are now only present in low densities.

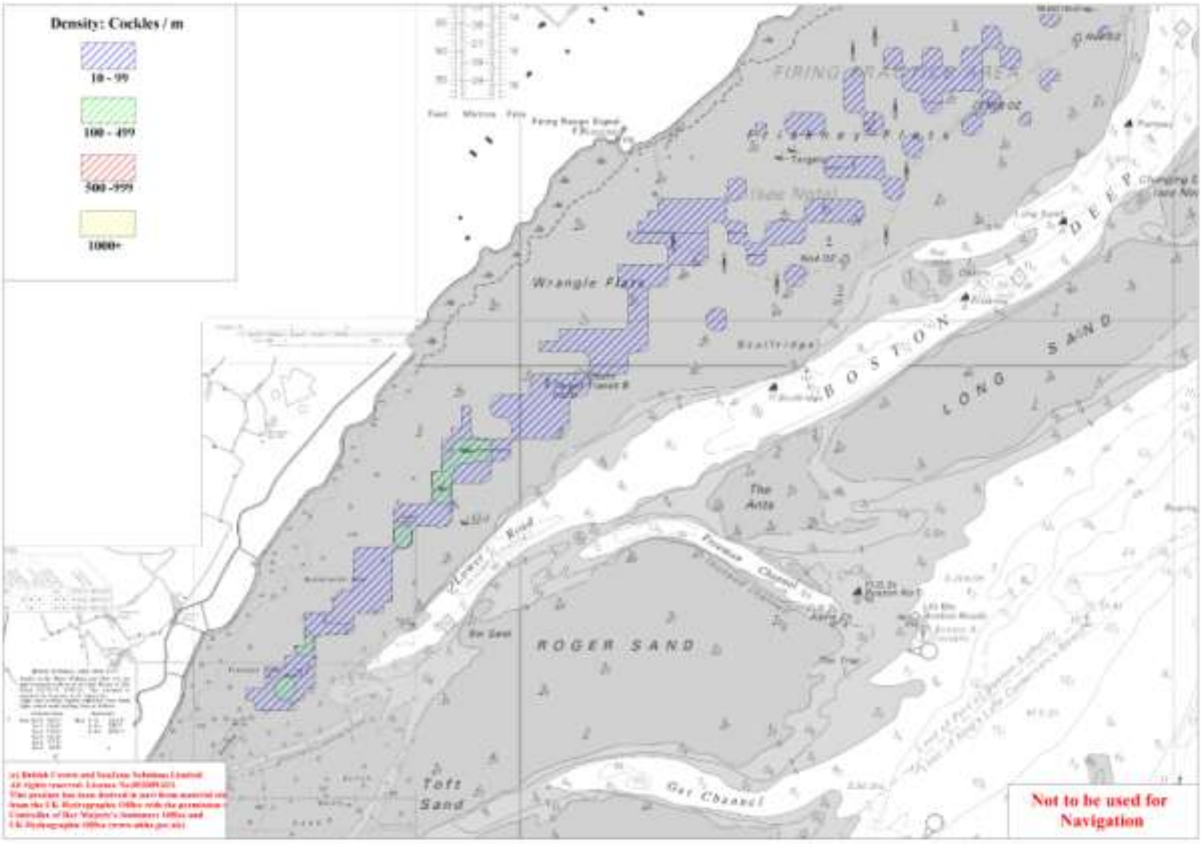


Figure 3.5 Chart showing the distribution of cockles ≥14mm width on Boston Main when surveyed during the spring 2013 surveys.

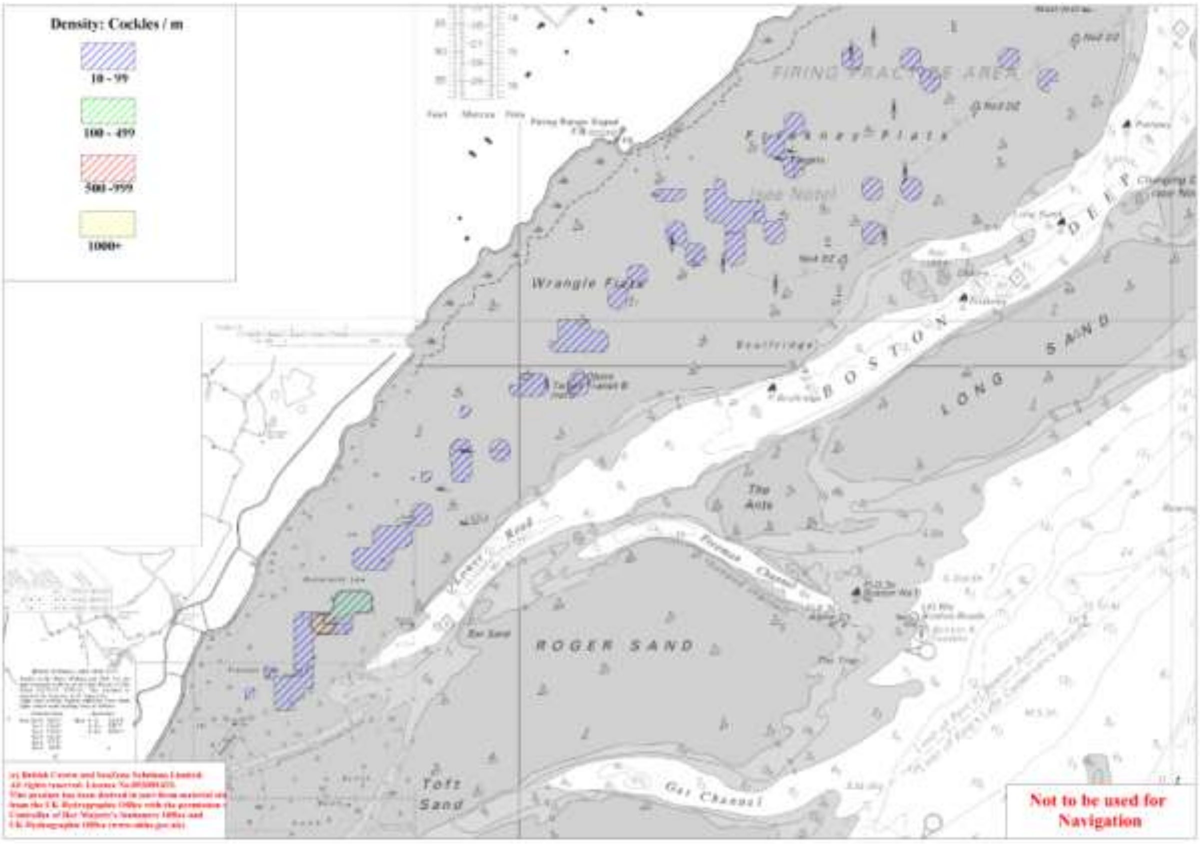


Figure 3.6 Chart showing the distribution of cockles <14mm width on Boston Main when surveyed during the spring 2013 surveys.

3.3.1.1 Butterwick

Butterwick, Standard sites

Adult

- Area: 212 hectares
- Mean Density: 52.94 cockles/m^2
- Mean Biomass: 2.62 tonnes/hectare
- Stock ≥ 14mm: 555 tonnes

Juvenile

- Area: 123 hectares
- Mean Density: 115.46 cockles/m^2
- Mean Biomass: 1.18 tonnes/hectare
- Stock <14mm: 145 tonnes

Surveys were conducted at the regular stations on Butterwick on April 28th and 29th. During this period 38 stations were sampled over the high water periods using a Day grab.
The bed was found to support a mixed population of 2010, 2011 and 2012 year-class cockles, but there was no evidence of the 2009 cohort that had been present the previous year. Those had presumably died during the previous summer's mortality event. While the majority of the cockles from the 2010 cohort had attained a size of 14mm width, those from the two younger cohorts had not. Figure 3.7 shows the cockle population size and age structure at Butterwick at the time of the 2013 survey.

17 of the sample stations, covering an area of 212 hectares were found to support cockles ≥14mm width. This was an improvement on the previous year when only 12 stations covering an area of 110 hectares had supported cockles of this size. Although the area supporting these "adult" cockles had increased, mortalities had reduced their numbers from the previous year. Their mean density had declined from 106.67 cockles/m^2 (range 10 – 750/m^2) to 52.94 cockles/m^2 (range 10 – 170/m^2), and their mean biomass from 4.26 tonnes/hectare to 2.62 tonnes/hectare. From these figures the biomass of cockles ≥14mm width within this area was calculated to be 555 tonnes compared to 470 tonnes the previous year.

Cockles <14mm width were found to be present at 11 stations covering an area of 123 hectares. This is a decline from the 17 stations covering 159 hectares recorded in 2012. Within this area their density had declined from 561.8 cockles/m^2 (range 10 – 2,580/m^2) to 115.46 cockles/m^2 (range 10 – 3,330/m^2), and their mean biomass from 5.96 tonnes/hectare to 1.18 tonnes/hectare. This represented a decline of juvenile cockles in this area from 951 tonnes to 145 tonnes.

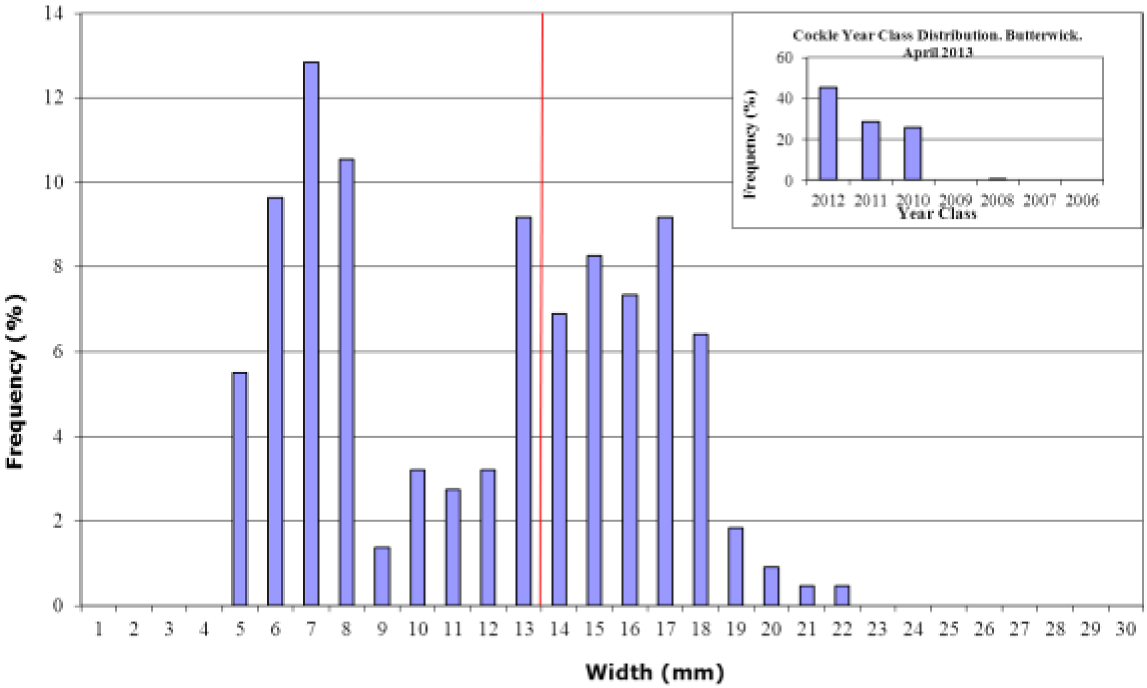


Figure 3.7 Cockle size and age frequencies on Butterwick at the time of the 2013 spring surveys

Butterwick, Extended sites

Adult

- Area: 104 hectares
- Mean Density: 57.27 cockles/m^2
- Mean Biomass: 2.36 tonnes/hectare
- Stock ≥ 14mm: 246 tonnes

Juvenile

- Area: 88 hectares
- Mean Density: 170.91 cockles/m^2
- Mean Biomass: 2.15 tonnes/hectare
- Stock <14mm: 188 tonnes

A survey was conducted within the extended zone of Butterwick on April 28th, during which 20 stations were sampled using a Day grab at high water.

Although the number of stations supporting cockles ≥14mm width within this area had increased from 7 in 2012 to 11, their distribution meant their area of coverage had declined from 148 hectares to 104 hectares. Within this area their mean density was found to have increased from 20.00 cockles/m^2 (range 10 – 30/m^2) to 57.27 cockles/m^2 (range 10 – 290/m^2) and their mean biomass from 0.99 tonnes/hectare to 2.36 tonnes/hectare. From these figures it was calculated that the biomass of cockles ≥14mm width within the extended zone had increased from 146 tonnes to 246 tonnes.

The extent of smaller cockles within this area was found to have declined from 14 stations covering 247 hectares to 11 stations covering 88 hectares. Within this area the mean density had declined from 516.4 cockles/m^2 (range 10 – 2,140/m^2) in 2012 to 170.91 cockles/m^2 (range 10 – 740/m^2), and the mean biomass from 4.33 tonnes/hectare to 2.15 tonnes/hectare. From these figures the biomass of cockles <14mm width within this zone was calculated to have declined from 1,070 tonnes to 188 tonnes.

The total biomass of cockles in Butterwick was calculated to be 700 tonnes compared to 2,637 tonnes the previous year.

3.3.1.2 Wrangle Sand

Wrangle, Standard sites

Adult

- Area: 379 hectares
- Mean Density: 25.15 cockles/m^2
- Mean Biomass: 1.87 tonnes/hectare
- Stock ≥ 14mm: 709 tonnes

Juvenile

- Area: 137 hectares
- Mean Density: 20.00 cockles/m^2
- Mean Biomass: 0.32 tonnes/hectare
- Stock <14mm: 43 tonnes

The cockle surveys were conducted on Wrangle on March 27th & 28th and April 27th & 28th. During these periods 95 stations were sampled, 32 using a Day grab at high water and 63 using a quadrat at low water.

The combination of "atypical" mortalities and fishery pressure had caused significant declines on this bed since the previous year. These impacts had primarily affected the 2010 year-class cohort, reducing this cohort's dominance in 2012 to a more even distribution in 2013. Those cockles that had survived the fishery and mortalities had grown well, with all but the 2012 year-class cohort reaching 14mm width. Figure 3.8 shows the cockle population size and age structure on this bed at the time of the 2013 survey.

33 stations covering and area of 379 hectares were found to support cockles ≥14mm width. This is a reduction from the 48 stations covering 520 hectares recorded the previous year. Within this area the mean density of these cockles had declined from 73.75 cockles/m^2 (range 10 – 790/m^2) to 25.15 cockles/m^2 (range 10 – 130/m^2) and the mean biomass from 3.53 tonnes/hectare to 1.87 tonnes/hectare. From these figures the

biomass of cockles ≥14mm width in Wrangle was calculated to be 709 tonnes compared to 1,833 tonnes in 2012.

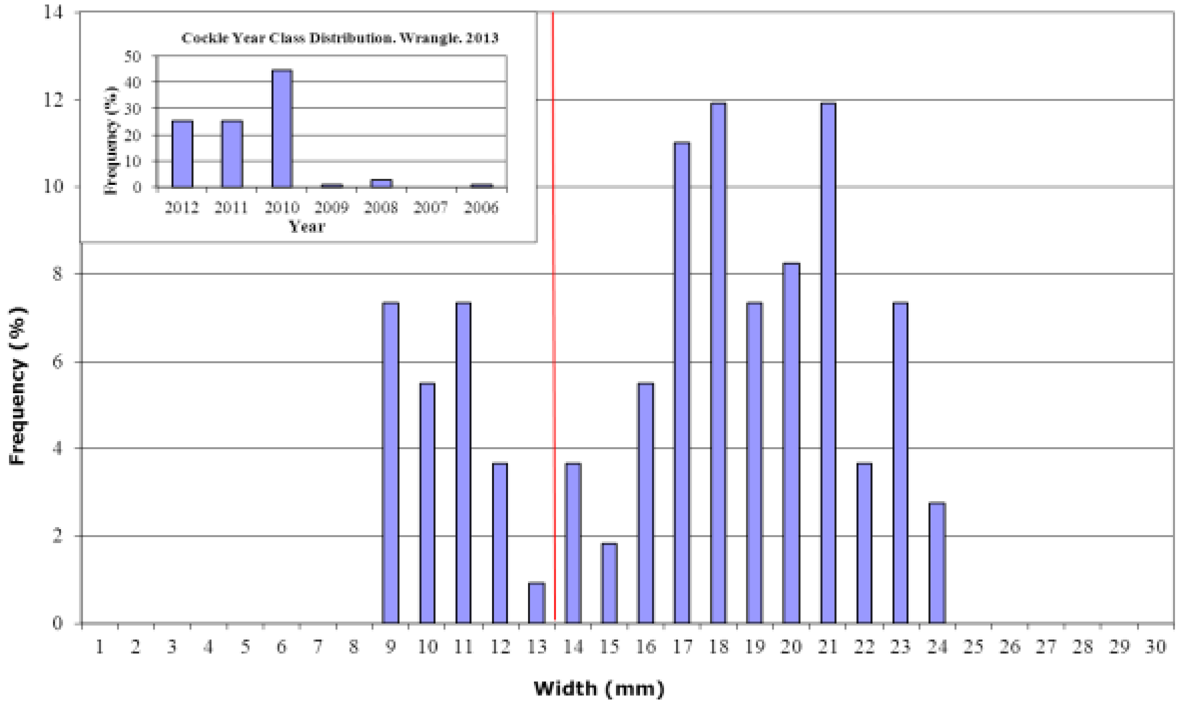


Figure 3.8 Cockle size and age frequencies on Wrangle at the time of the 2013 spring surveys

The above figures only partially reflect the losses encountered on Wrangle during 2012. At the time of the spring surveys in 2012, many of the 2010 year-class cockles were still below 14mm width. As such, their contribution towards the 2012 stocks is not included in those figures. To gain a full picture of their loss, the stocks of cockles <14mm width must also be looked at. The coverage of these smaller cockles was found to have declined from 36 stations covering an area of 388 hectares to 14 stations covering an area of 137 hectares. In addition to the reduction in area, their mean density had declined from 185.0 cockles/m^2 (range 10 – 3,860/m^2) to 20.0 cockles/m^2 (range 10 – 50/m^2) and their mean biomass from 3.71 tonnes/hectare to 0.32 tonnes/hectare. These figures show the stocks of cockles <14mm width in this area had declined from 1,438 tonnes to 43 tonnes.

Wrangle, Extended sites

Adult	Juvenile
• Area: 64 hectares	• Area: 105 hectares
• Mean Density: 10.00 cockles/m^2	• Mean Density: 12.22 cockles/m^2
• Mean Biomass: 0.54 tonnes/hectare	• Mean Biomass: 0.20 tonnes/hectare
• Stock ≥ 14mm: 35 tonnes	• Stock <14mm: 21 tonnes

The extended zone on Wrangle, which covers the band between the main survey area and the edge of the green marsh, was surveyed on March 27th. During this survey 27 stations were sampled, all using a quadrat during the low water period.

Although this area had been too high to attract much fishing effort during 2012, natural losses had still occurred. The area supporting cockles ≥14mm width was found to have declined slightly from 3 stations covering 74 hectares to 3 stations covering 64 hectares. Within this area the mean density of these larger cockles had declined from 23.33 cockles/m^2 (range 10 – 50/m^2) to 10.00 cockles/m^2 (range 10 – 10/m^2) and the mean biomass from 0.73 tonnes/hectare to 0.54 tonnes/hectare. From these figures the biomass of cockles ≥14mm width in this area was calculated to have declined from 54 tonnes to 35 tonnes.

Cockles <14mm width were found at 9 stations covering an area of 105 hectares. This is a slight increase to the 6 stations covering 100 hectares recorded the previous year. Within this area the mean density had declined from 21.67 cockles/m^2 (range 10 - 50/m^2) to 12.22 cockles/m^2 (range 10 - 30/m^2) and the mean biomass from 0.34 tonnes/hectare to 0.20 tonnes/hectare. These figures indicate the stocks have declined from 34 tonnes to 21 tonnes.

Overall, the total cockle stocks on Wrangle were found to be 808 tonnes compared to 3,359 tonnes in 2012.

3.3.1.3 Friskney

Friskney, Standard sites

Adult

- Area: 166 hectares
- Mean Density: 13.53 cockles/m^2
- Mean Biomass: 1.26 tonnes/hectare
- Stock ≥ 14mm: 209 tonnes

Juvenile

- Area: 70 hectares
- Mean Density: 10.00 cockles/m^2
- Mean Biomass: 0.19 tonnes/hectare
- Stock <14mm: 13 tonnes

A foot survey was conducted I this area on March 28th, followed by grab surveys on May 7th & 8th. During these surveys 80 stations were sampled, 30 with a quadrat at low water and 50 with a Day grab. There had only been low densities of cockles present on this bed when surveyed in 2012. The 2013 survey found these had declined further. The cockles that were found were predominantly from the 2010, 2011 and 2012 year-class cohorts. Apart from those from the 2012 cohort, these cockles had all attained a size of 14mm width. Figure 3.9 shows the size and age distribution of these cockles.

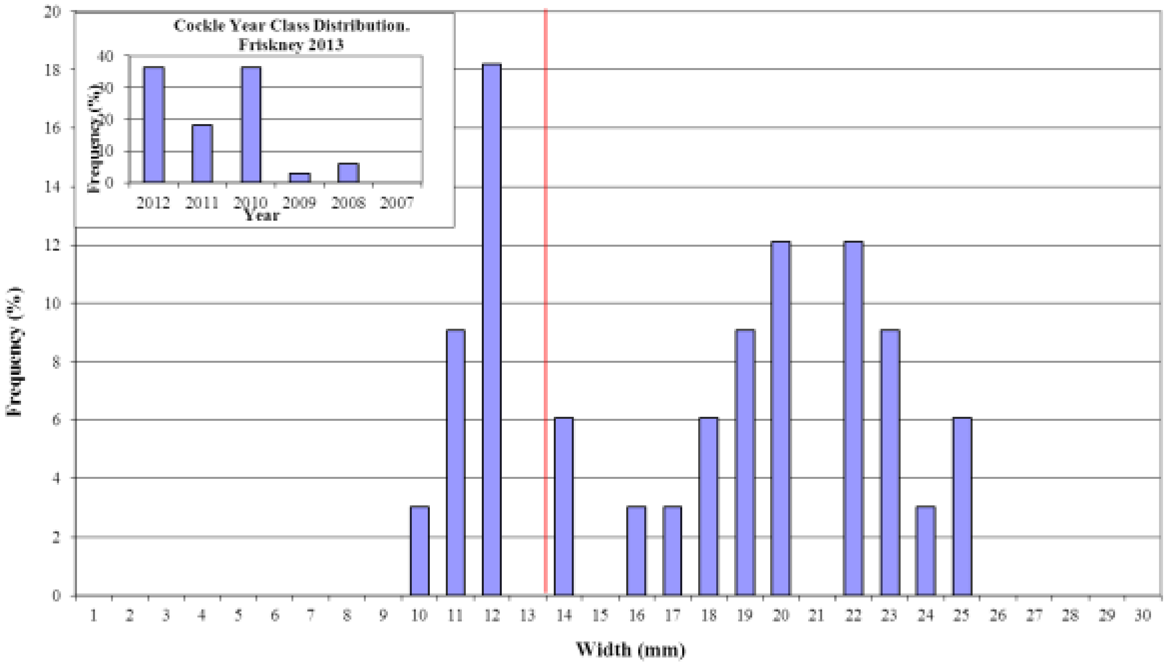


Figure 3.9 Cockle size and age frequencies on Friskney at the time of the 2013 spring surveys

17 stations covering an area of 166 hectares were found to support cockles ≥14mm width. This compares with the 28 stations covering 301 hectares that were recorded in 2012. Within this area the mean density of ≥14mm cockles was found to have declined

from 21.79 cockles/m^2 (range 10 - 70/m^2) to 13.53 cockles/m^2 (range 10 - 20/m^2) and their mean biomass from 1.53 tonnes/hectare to 1.26 tonnes/hectare. Their biomass was calculated to be 209 tonnes compared to 460 tonnes the previous year.

8 stations covering an area of 70 hectares were found to support cockles <14mm width. This compared with 25 stations covering 225 hectares in 2012. Within this area their mean density was found to have declined from 22.80 cockles/m^2 (range 10 - 80/m^2) to 10.00 cockles/m^2 (range 10 - 10/m^2) and their mean biomass from 0.64 tonnes/hectare to 0.19 tonnes/hectare. From these figures it was calculated that the biomass of these smaller cockles had declined from 91 tonnes to 13 tonnes.

Friskney, Extended sites

Adult

- Area: 298 hectares
- Mean Density: 13.08 cockles/m^2
- Mean Biomass: 1.05 tonnes/hectare
- Stock ≥ 14mm: 313 tonnes

Juvenile

- Area: 149 hectares
- Mean Density: 12.31 cockles/m^2
- Mean Biomass: 0.21 tonnes/hectare
- Stock <14mm: 31 tonnes

The extended sites of Friskney cover the band of high ground between the standard zone and the green marsh and also extend north eastwards as far as the Swatchway. As was the case with the standard zone, only low densities of cockles were found here.

The area of the bed supporting cockles ≥14mm width was found to have increased slightly from 19 stations covering 279 hectares in 2012 to 26 stations covering 298 hectares. Within this area the mean density of these cockles was found to have declined from 17.37 cockles/m^2 (range 10 - 40/m^2) to 13.08 cockles/m^2 (range 10 - 30/m^2), but their greater size meant the mean biomass had increased slightly from 0.99 tonnes/hectare to 1.05 tonnes/hectare. From these figures the biomass of cockles ≥14mm width in this area was calculated to be 313 tonnes, an improvement on the 277 tonnes recorded the previous year.

13 stations covering an area of 149 hectares were found to support cockles <14mm width, a reduction from the 14 stations covering 230 hectares recorded in 2012. Within this area their mean density and biomass were found to have also declined slightly from 14.29 cockles/m^2 (range 10 - 40/m^2) to 12.31 cockles/m^2 (range 10 - 30/m^2) and 0.23 tonnes/hectare to 0.21 tonnes/hectare. From these figures the biomass of these small cockles was calculated to be 31 tonnes compared to 53 tonnes the previous year.

Overall, Friskney was found to support a total biomass of 566 tonnes of cockles compared to 881 tonnes the previous year.

3.3.2 Herring Hill

Adult

- Area: 249 hectares
- Mean Density: 62.07 cockles/m^2
- Mean Biomass: 2.44 tonnes/hectare
- Stock ≥ 14mm: 607 tonnes

Juvenile

- Area: 270 hectares
- Mean Density: 101.29 cockles/m^2
- Mean Biomass: 1.89 tonnes/hectare
- Stock <14mm: 510 tonnes

The Herring Hill survey was conducted on April 26th and 27th, during which 67 stations were sampled at high water using a Day grab. Figures 3.10 and 3.11 show the distribution of adult and juvenile cockles found at the time of this survey, while figure 3.12 shows the population size frequency.

Figure 3.10 Chart showing the distribution of cockles ≥14mm width on Herring Hill when surveyed during the 2013 spring surveys.

Figure 3.11 Chart showing the distribution of cockles <14mm width on Herring Hill when surveyed during the 2013 spring surveys.

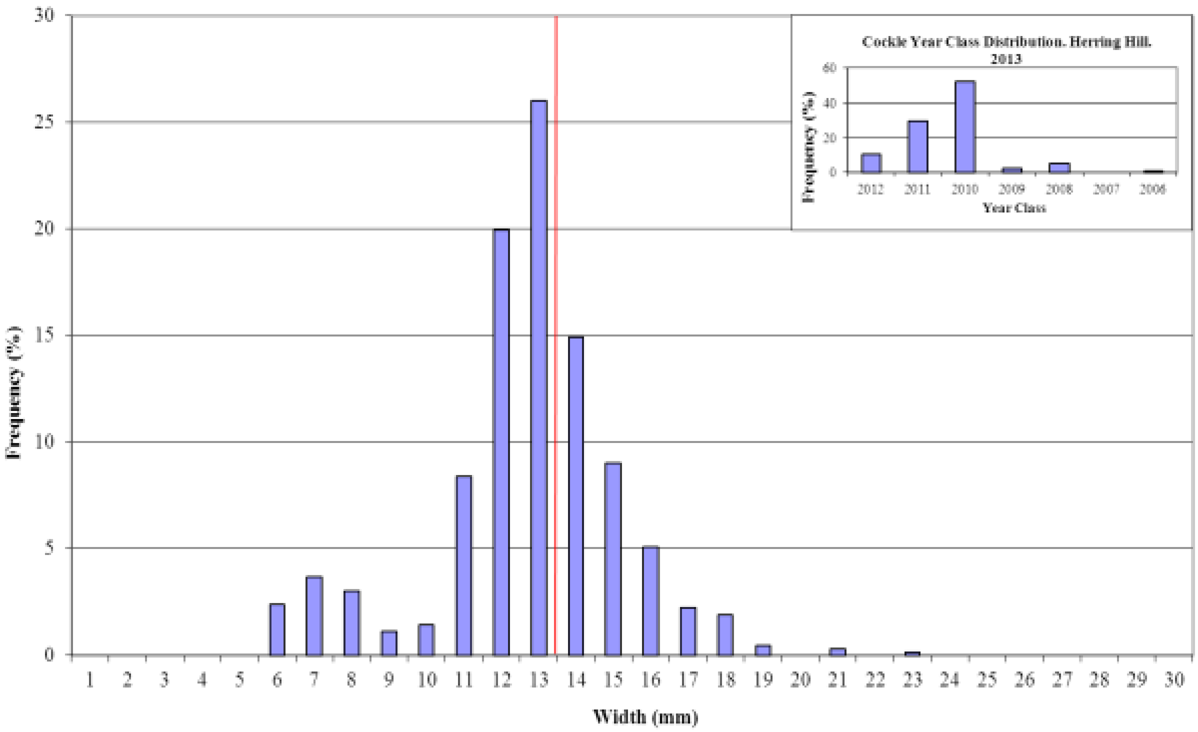


Figure 3.12 Cockle size and age frequencies on Herring Hill at the time of the 2013 spring surveys

Although this bed generally supports high densities of cockles, their growth rates are usually slow due to the high elevation of the sand. As a consequence, cockles on this bed tend to take over four years to attain a size of 14mm width. In 2012 few of the stocks on this bed had reached this size, but an additional year's growth allowed this population to increase by 2013. This enabled the coverage of cockles ≥14mm width to increase from 24 stations covering 189 hectares to 29 stations covering 249 hectares. Within this area the mean density of these cockles was found to have increased from 19.58 cockles/m^2 (range 10 – 70/m^2) to 62.07 cockles/m^2 (range 10 – 370/m^2) and the mean biomass from 0.82 tonnes/hectare to 2.44 tonnes/hectare. These changes meant the biomass of cockles 4mm width at Herring Hill had increased from 154 tonnes in 2012 to 607 tonnes.

Because some of the smaller cockles present in 2012 had attained 14mm width and recruited into the "adult" population, the numbers of cockles <14mm width had declined from the previous year. Their extent was found to have decreased from 36 stations covering 333 hectares to 31 stations covering 270 hectares. Within this area their mean density had declined from 275.6 cockles/m^2 (range 10 – 4,210/m^2) to 101.29 cockles/m^2 (range 10 – 690/m^2). The greater size of these individuals, however, meant the mean biomass had increased from 1.75 tonnes/hectare to 1.89 tonnes/hectare. From these figures the biomass of <14mm width cockles on this bed was calculated to be 510 tonnes compared to 584 tonnes the previous year.

The total cockle biomass on Herring Hill was calculated to be 1,117 tonnes compared to 738 tonnes in 2012.

3.3.3 Black Buoy Sand

Adult

- Area: 129 hectares
- Mean Density: 107.78 cockles/m^2
- Mean Biomass: 4.16 tonnes/hectare
- Stock ≥ 14mm: 536 tonnes

Juvenile

- Area: 169 hectares
- Mean Density: 593.60 cockles/m^2
- Mean Biomass: 11.07 tonnes/hectare
- Stock <14mm: 1,868 tonnes

Prior to 2009 the southern parts of Black Buoy Sand had been surveyed as part of the Herring Hill survey, while the northern parts of this bed had remained outside of the spring survey area. Following the discovery of a dense bed of cockles on the northern part of Black Buoy Sand in 2008, in an area known locally as the Dills Sand, additional sites were added to the survey programme to cover the whole of the Black Buoy Sand.

A survey was conducted on this bed on April 27th & 28th, during which 36 stations were sampled over high water using a Day grab. There had been a good settlement of spat on this sand in 2011 and these individuals were found to still be present in high densities at the time of the 2013 survey. Figures 3.13 and 3.14 show the distribution of adult and juvenile cockles found at the time of this survey. When surveyed in 2012, most of these individuals had been in the 5-8mm size range, but good growth had enabled some of them to attain 14mm by the time of the 2013 survey. Figure 3.15 shows the population's size and age frequency in 2013.

Because some of the 2011 year-class individuals had reached 14mm width since the 2012 survey, the extent of these larger cockles had increased from 7 survey stations covering 59 hectares to 18 stations covering 129 hectares. Within this area their mean density had increased from 14.29 cockles/m^2 (range 10 – 30/m^2) to 107.78 cockles/m^2 (range 10 – 560/m^2) and their mean biomass from 0.93 tonnes/hectare to 4.16 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on this sand was calculated to have increased from 55 tonnes to 536 tonnes.

Figure 3.13 Chart showing the distribution of cockles ≥14mm width on Black Buoy Sand when surveyed during the 2013 spring surveys.

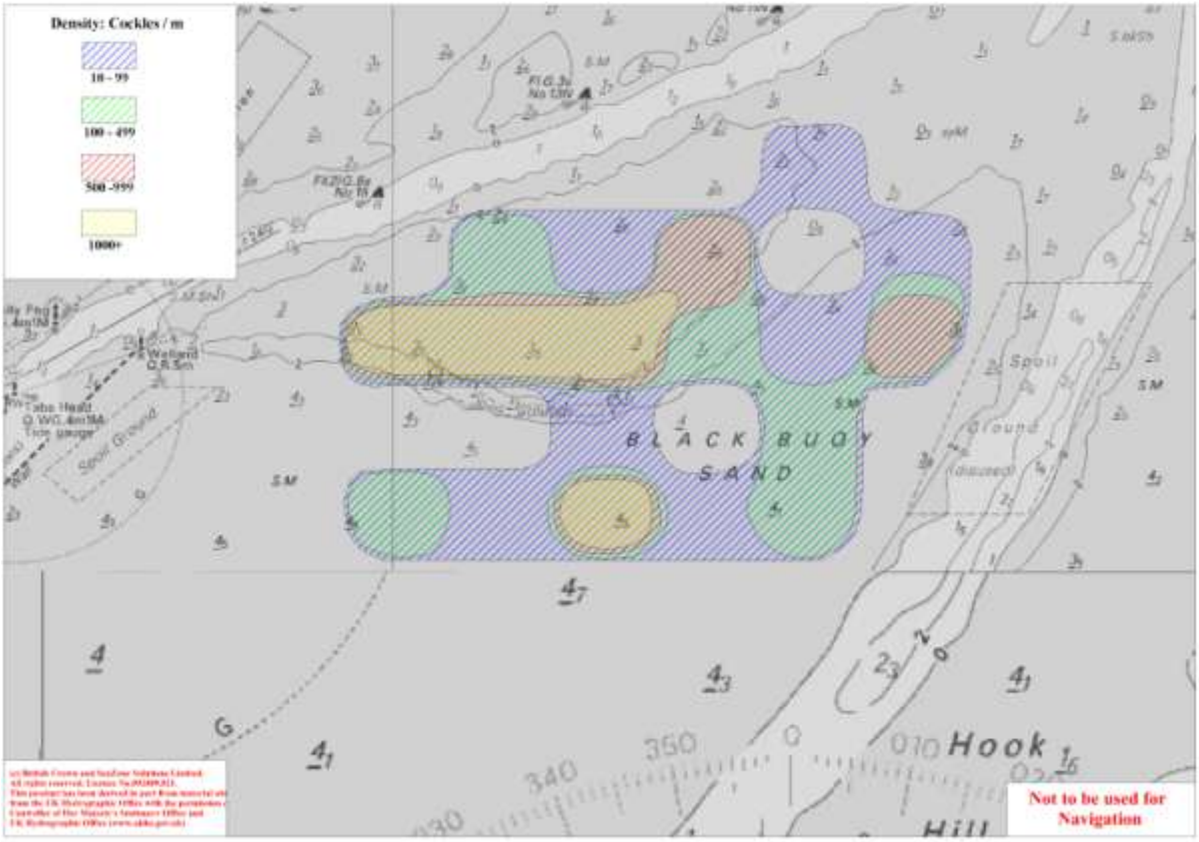


Figure 3.14 Chart showing the distribution of cockles <14mm width on Black Buoy Sand when surveyed during the 2013 spring surveys.

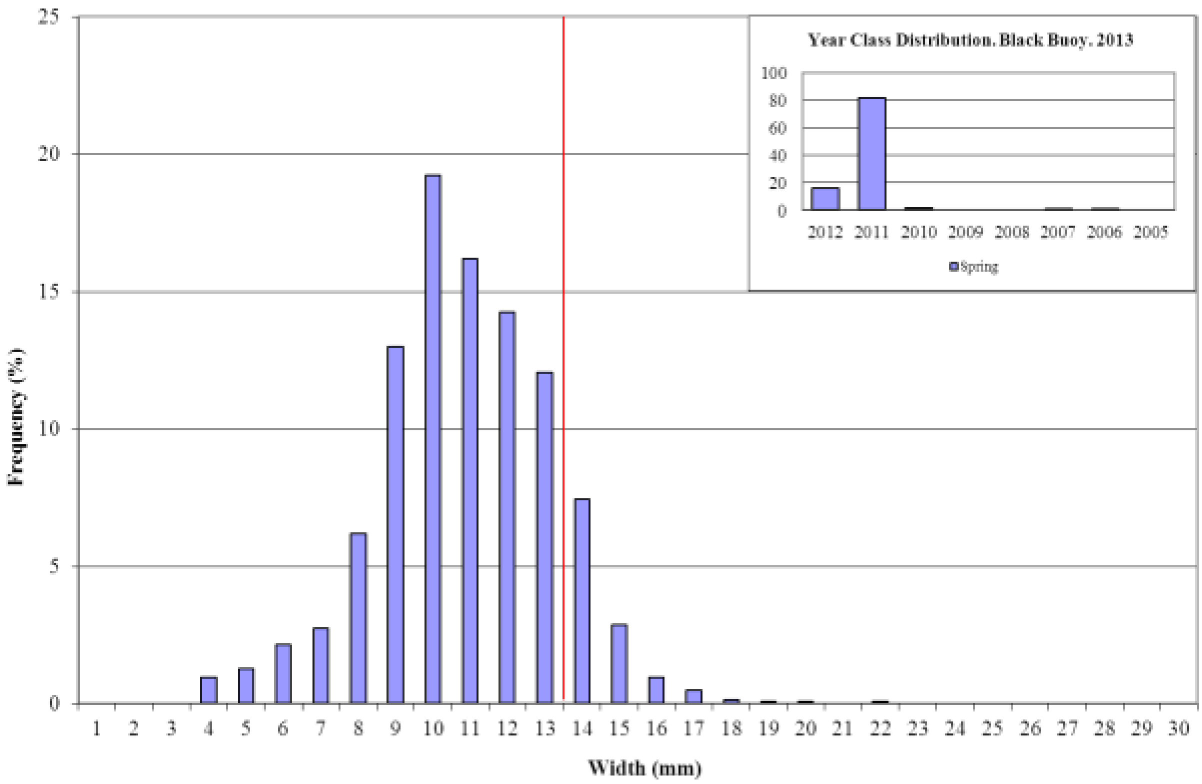


Figure 3.15 Cockle size and age frequencies on Black Buoy Sand at the time of the 2013 spring surveys

22 stations covering 169 hectares were found to support cockles <14mm width. This was an increase on the previous year when 16 stations covering 148 hectares had supported cockles of this size. There had been a light settlement during 2012 that had contributed towards this group, but most of this increase was believed to be due to the high densities of cockles spreading out. Within this area the mean density of these cockles was found to have declined from 1,255 cockles/m^2 (range 10 – 6,730/m^2) to 593.60 cockles/m^2 (range 10 – 4,630/m^2) but due to their greater size, their mean biomass had increased from 3.57 tonnes/hectare to 11.07 tonnes/hectare. These changes meant the biomass of small cockles on this bed had increased from 528 tonnes in 2012 to 1,868 tonnes.

The total biomass of cockles on this bed had increased from 583 tonnes in 2012 to 2,404 tonnes.

3.3.4 Mare Tail

Adult

- Area: 203 hectares
- Mean Density: 115.00 cockles/m^2
- Mean Biomass: 4.65 tonnes/hectare
- Stock ≥ 14mm: 946 tonnes

Juvenile

- Area: 368 hectares
- Mean Density: 678.68 cockles/m^2
- Mean Biomass: 2.80 tonnes/hectare
- Stock <14mm: 1,030 tonnes

Mare Tail was surveyed on April 25th, during which 66 stations were sampled using a Day grab over the high water period.

In 2012 the stocks on this bed had been dominated by individuals from the 2010 year-class cohort. At that time they had mostly been within a 8-12mm size range, but following a year's growth, many of this group had attained 14mm width by the time of the 2013 survey. The 2013 survey also found that there had been a good settlement on this bed during the preceding summer, this new cohort numerically dominating the stocks. Figures 3.16 and 3.17 show the distribution of adult and juvenile cockles found at the time of this survey, while figure 3.18 shows the population size and age frequencies.

Although there had been recruitment into the ≥14mm cockle population between surveys the extent of this group had decreased from 24 stations covering 242 hectares in 2012 to 22 stations covering 203 hectares. Within this area, however, the mean density was found to have increased from 36.25 cockles/m^2 (range 10 – 170/m^2) to

115.00 cockles/m^2 (range 10 – 420/m^2) and the mean biomass from 1.88 tonnes/hectare to 4.65 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on this bed was calculated to have increased from 465 tonnes to 946 tonnes.

38 stations covering an area of 368 hectares were found to support cockles <14mm width. Although this is comparable in size with the 360 hectares recorded in 2012, the distribution was slightly different. The mean density of these smaller cockles was found to have increased from 468.57 cockles/m^2 (range 10 – 2,600/m^2) to 678.68 cockles/m^2 (range 10 – 5,250/m^2), mainly due the successful recruitment of the 2012 year-class cohort. Because these individuals were only small compared to those 2010 year-class cockles that had recruited into the "adult" population, however, the mean biomass in this area had dropped from 6.03 tonnes/hectare to 2.80 tonnes/hectare. This meant the biomass of small cockles on this bed had declined from 2,172 tonnes to 1,030 tonnes.

The total cockle stock on Mare Tail was calculated to be 1,976 compared to 2,628 tonnes the previous year.

Figure 3.16 Chart showing the distribution of cockles ≥14mm width on Mare Tail when surveyed during the 2013 spring surveys.

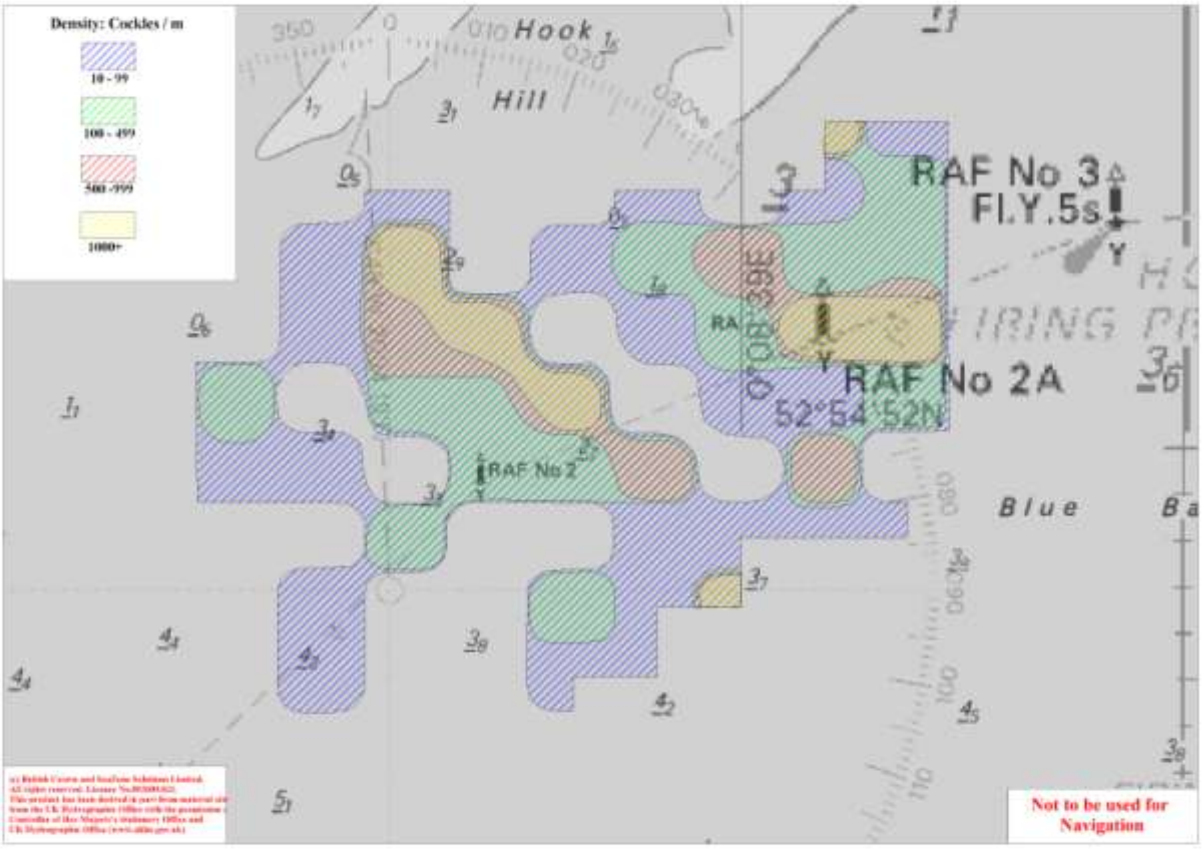


Figure 3.17 Chart showing the distribution of cockles <14mm width on Mare Tail when surveyed during the 2013 spring surveys.

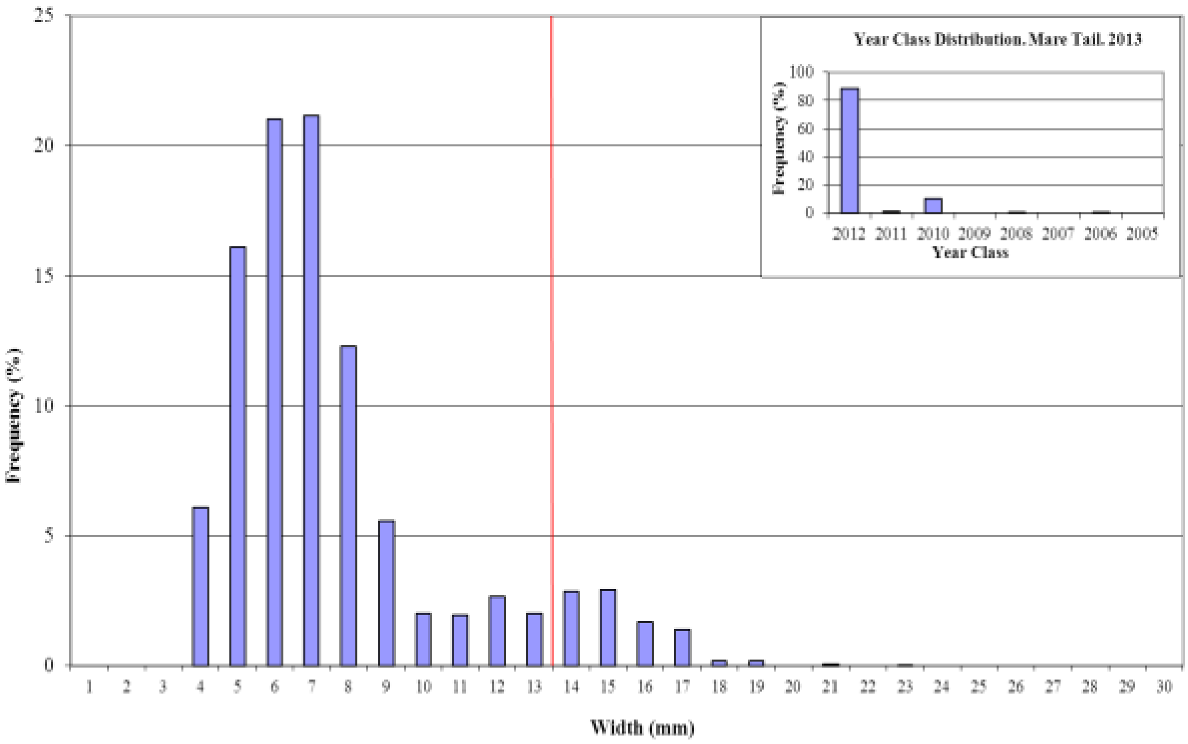


Figure 3.18 Cockle size and age frequencies on Mare Tail at the time of the 2013 spring surveys

3.3.5 Holbeach Range

Adult

- Area: 598 hectares
- Mean Density: 79.71 cockles/m^2
- Mean Biomass: 2.33 tonnes/hectare
- Stock ≥ 14mm: 1,395 tonnes

Juvenile

- Area: 618 hectares
- Mean Density: 181.14 cockles/m^2
- Mean Biomass: 2.86 tonnes/hectare
- Stock <14mm: 1,766 tonnes

The surveys at Holbeach Range were conducted on April 13th, 14th, 15 & 25th. During this period 163 stations were sampled over high water periods using a Day grab, while a further 26 stations close to the bombing targets were sampled on foot at low water.

When surveyed in 2012 the stocks on this bed had been dominated by the 2011 year-class cohort, most of which had been in the 3-6mm size range. A more even distribution between the 2010, 2011 and 2012 cohorts was found when surveyed in 2013, with a predominant size range between 10-16mm. Figures 3.19 and 3.20 show the distribution of adult and juvenile cockles found at the time of this survey, while figure 3.21 shows the population size frequency.

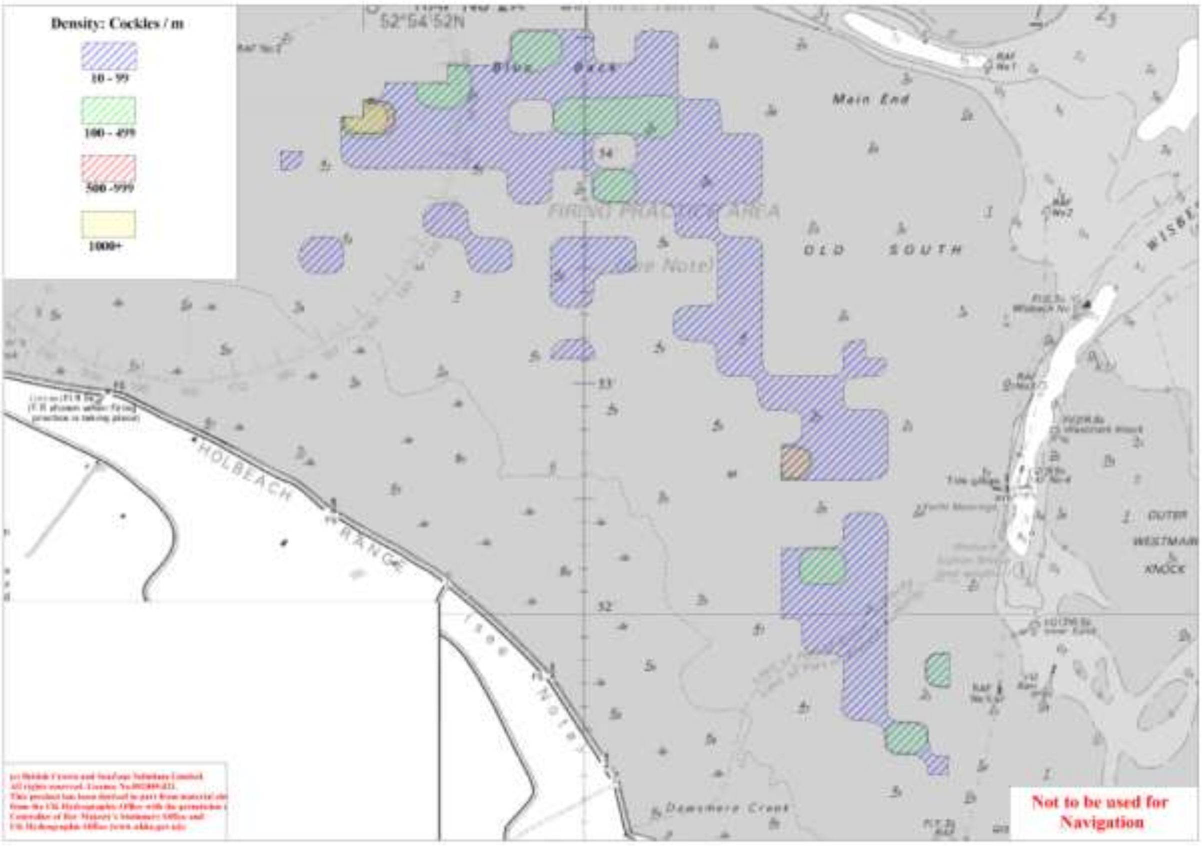


Figure 3.19 Chart showing the distribution of cockles ≥14mm width on Holbeach when surveyed during the 2013 spring surveys.

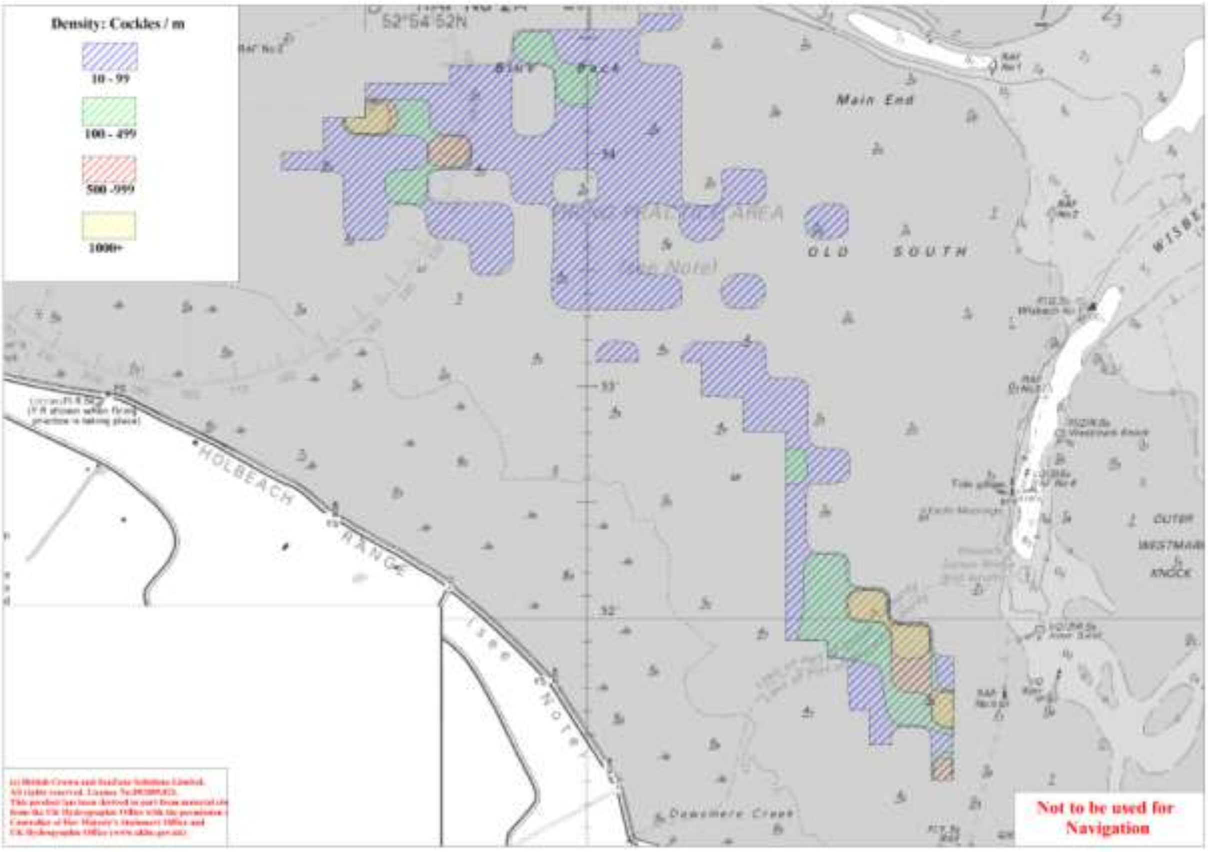


Figure 3.20 Chart showing the distribution of cockles <14mm width on Holbeach when surveyed during the 2013 spring surveys.

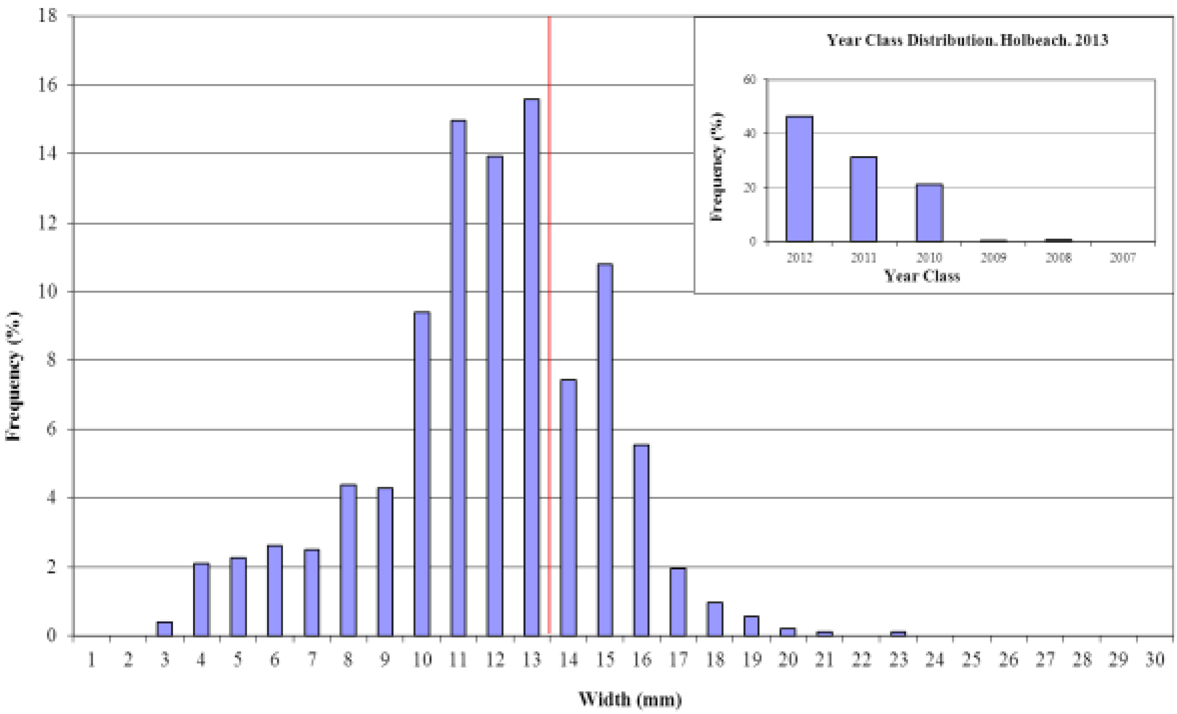


Figure 3.21 Cockle size and age frequencies on Holbeach at the time of the 2013 spring surveys

There had been good recruitment of "juvenile" cockles into the "adult" population between the surveys. This enabled the extent of the stock of cockle ≥14mm width to increase from 44 stations covering 404 hectares to 68 stations covering 598 hectares. Within this area their mean density had increased from 19.55 cockles/m^2 (range 10 – 200/m^2) to 79.71 cockles/m^2 (range 10 – 1,710/m^2) and their mean biomass from 0.94 tonnes/hectare to 2.33 tonnes/hectare. This enabled the biomass of cockles ≥14mm width on this sand to increase from 378 tonnes to 1,395 tonnes

Cockles <14mm width were found to be present at 79 stations covering 618 hectares. While this was an increase to the 74 stations supporting cockles of this size the previous year, their distribution meant the area of coverage had declined from 664 hectares to 618 hectares. Within this area the mean density was found to have declined from 1,057 cockles/m^2 (range 10 – 16,370/m^2) to 181.14 cockles/m^2 (range 10 – 3,400/m^2). Although some of this reduction can be attributed to some cockles attaining 14mm width between surveys and recruiting into the adult population, most will be due to high mortality among year-0 cockles. This is supported by the figures for the mean biomass of these cockles declining by a lesser amount, from 2.93 tonnes/hectare to 2.86 tonnes/hectare. From these figures the biomass of cockles <14mm width on this bed was calculated to be 1,766 tonnes compared to 1,943 tonnes in 2012.

Combined, the total cockle biomass in Holbeach was calculated to be 3,161 tonnes compared to 2,321 tonnes the previous year.

3.3.6 Roger/Toft

Adult

- Area: 122 hectares
- Mean Density: 94.55 cockles/m^2
- Mean Biomass: 4.40 tonnes/hectare
- Stock ≥ 14mm: 538 tonnes

Juvenile

- Area: 118 hectares
- Mean Density: 26.00 cockles/m^2
- Mean Biomass: 0.56 tonnes/hectare
- Stock <14mm: 66 tonnes

This sand was surveyed on April 11th, during which 61 stations were sampled over high water using a Day grab and a further 28 stations at low water using a quadrat. The extent of the survey had been extended further north than previous surveys in order to incorporate a small patch of cockles that had been identified following the surveys in 2012. Apart from a small patch of high density cockles on the northern part of the Roger sand, this bed had only supported a sparse coverage of cockles at the time of the 2012 survey, augmented in places by small patches of year-0 juveniles. The survival and growth of these 2011 year-class cockles enabled the stocks on this bed to improve by the time of the 2013 survey. Figures 3.22 and 3.23 show the distribution of adult and juvenile cockles found at the time of this survey, while figure 3.24 shows the population size frequency.

Cockles ≥14mm width were found to be present at 11 stations covering an area of 122 hectares. Because the survey area had been increased from the previous year, this figure could not be compared directly with the 5 stations covering 57 hectares recorded in 2012. A survey conducted in September 2012, however, had found this additional area had only contained 5.5 hectares of cockles, indicating most of the increase was not just due to the inclusion of the new area. The mean density of cockles ≥14mm width was found to be 94.55 cockles/m^2 (range 10 – 740/m^2). This compared with 14.00 cockles/m^2 (range 10 – 30/m^2) recorded in 2012 for the main survey area, and 1,012.9 cockles/m^2 (range 120 – 2,580/m^2) recorded in the extended area. Although it appeared that the inclusion of the small dense patch situated in the extended area in 2012 could be heavily influencing the 2013 figures, this area was fished and suffered high "atypical" mortality rates during 2012. The 2013 survey revealed the mean density of cockles ≥14mm width within this extended area had declined to 15.00 cockles/m^2 (range 10 – 20/m^2). In 2013 the mean biomass over the whole site was found to be 4.40 tonnes/hectare, compared to 1.47 tonnes/hectare in 2012. The biomass of cockles ≥14mm was calculated to be 538 tonnes, of which 41 tonnes were situated in the extended area. This shows that while there has been a good increase within the main survey area from 88 tonnes in 2012, within the extended area the stocks had declined from 317 tonnes.

Cockles <14mm width were found at 10 stations covering an area of 118 hectares. These were a mixture of juvenile cockles that had settled in 2012 and a small proportion of 2011 year-class cockles that had not attained 14mm width. These figures compared with 3 stations covering 36 hectares were found to support cockles of this size in 2012. Although high densities of spat had been found in the extended area in September 2012, no juveniles were found in this area during the 2013 survey. Over the whole site, the mean density of small cockles was found to be 26.00 cockles/m^2 (range 10 – 40/m^2), a slight improvement on the 20.00 cockles/m^2 (range 10 – 40/m^2) recorded in 2012. During the same period, the mean biomass of these cockles had increased by a greater extent than the mean density, more than doubling from 0.25 tonnes/hectare to 0.56 tonnes/hectare. From these figures the biomass of cockles <14mm width on this sand was calculated to be 66 tonnes, an improvement on the 9 tonnes recorded the previous year.

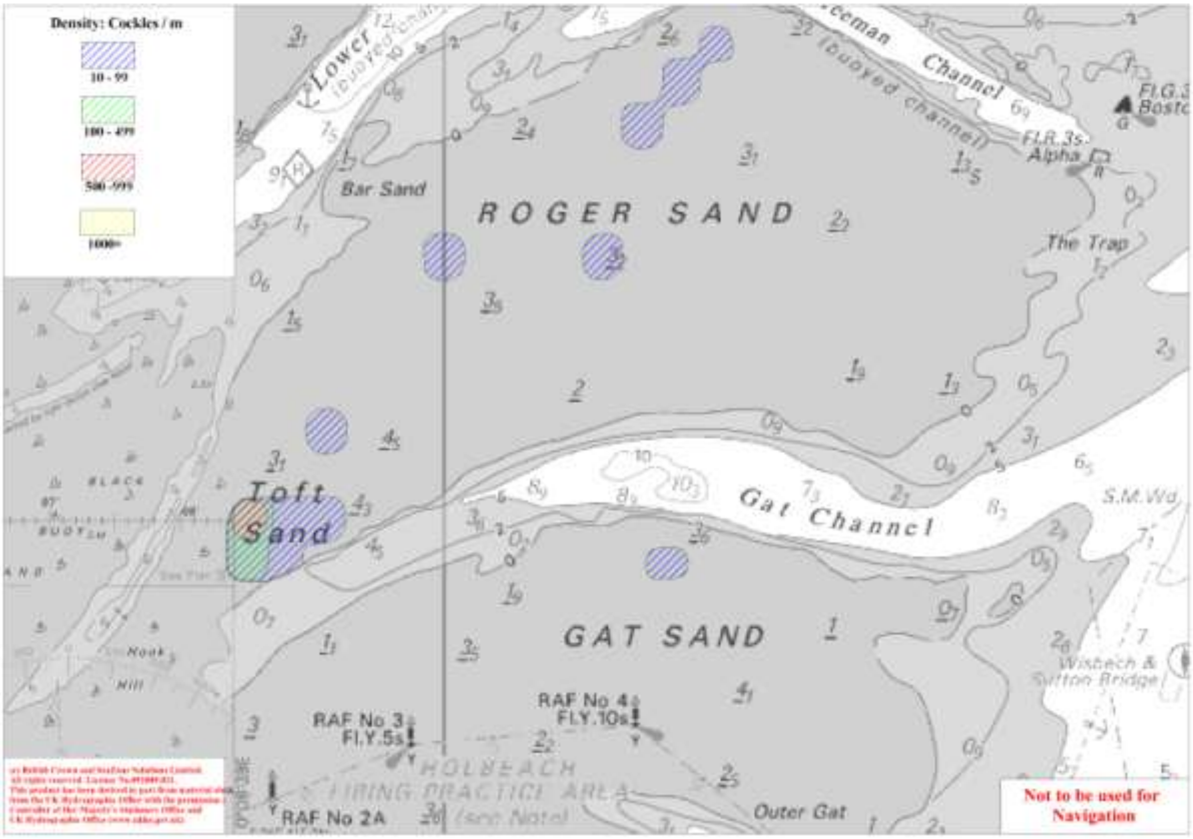


Figure 3.22 Chart showing the distribution of cockles ≥14mm width on the Roger/Toft and Gat beds when surveyed during the 2013 spring surveys.

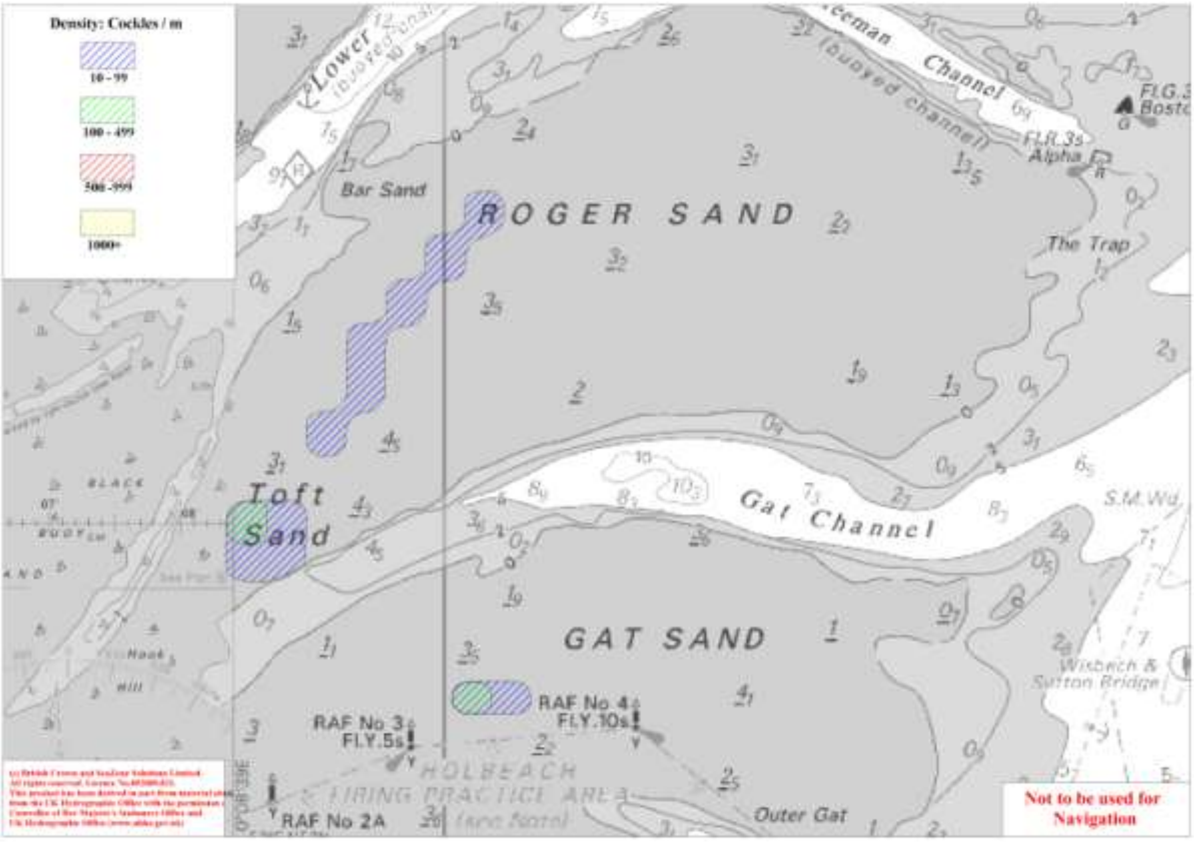


Figure 3.23 Chart showing the distribution of cockle <14mm width on the Roger/Toft and Gat beds when surveyed during the 2013 spring surveys.

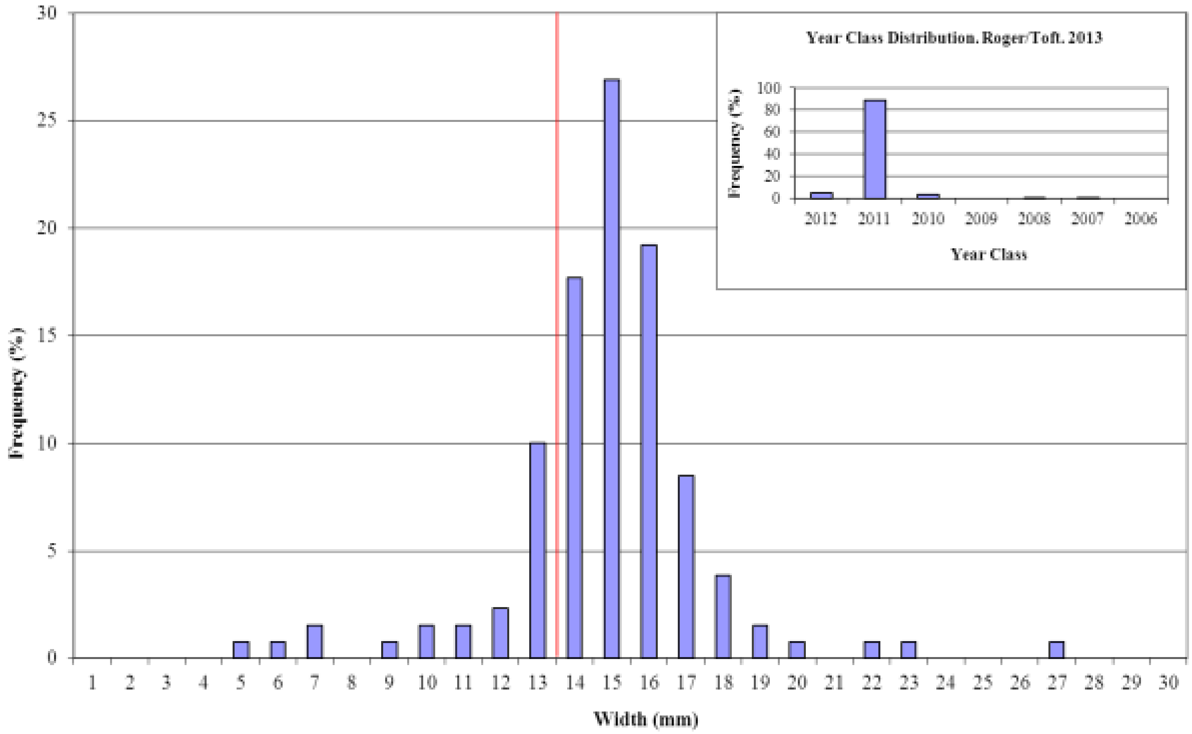


Figure 3.24 Cockle size and age frequencies on Roger/Toft at the time of 2013 spring surveys

3.3.7 Gat Sand

Adult

- Area: 8 hectares
- Mean Density: 10.00 cockles/m^2
- Mean Biomass: 1.59 tonnes/hectare
- Stock ≥ 14mm: 13 tonnes

Juvenile

- Area: 17 hectares
- Mean Density: 240.0 cockles/m^2
- Mean Biomass: 1.60 tonnes/hectare
- Stock <14mm: 28 tonnes

The Gat sand was surveyed on April 12th, during which 49 stations were sampled over high water using a Day grab and further 28 with a quadrat at low water.

When this bed had been surveyed in 2012 only four cockles had been found. The 2013 survey found there had been a localised settlement on this bed between the two surveys. The distribution of the cockles found on this bed can be seen in figures 3.22 and 3.23, while the size frequency of the population is displayed in figure 3.25.

Only a single cockle was found on this bed that had attained a size of 14mm width. Scaled up, this represented a coverage of 8 hectares and total biomass of 13 tonnes.

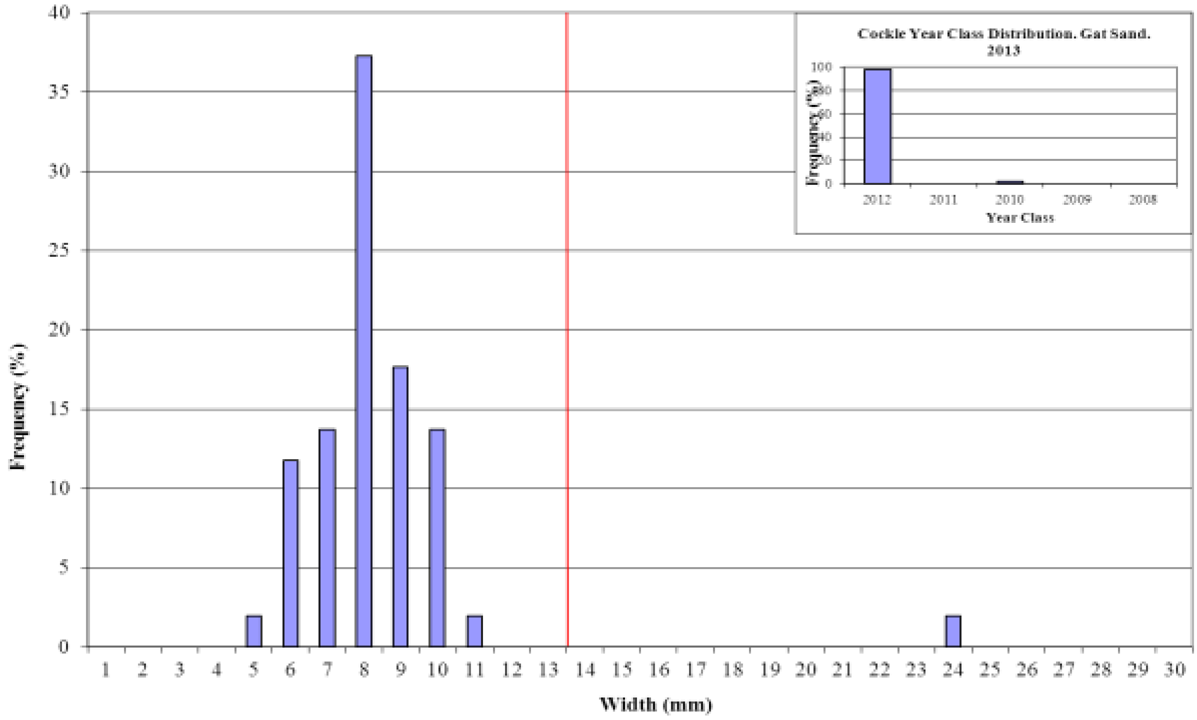


Figure 3.25 Cockle size and age frequencies on the Gat Sand at the time of 2013 spring surveys

Cockles <14mm width were found in two samples covering an area of 17 hectares. These had a mean density of 240.00 cockles/m^2 (range 10 – 470/m^2) and mean biomass of 1.60 tonnes/hectare. From these figures the biomass of cockles <14mm width on this bed was calculated to be 28 tonnes.

3.3.8 Long Sand

The Long Sand supported a successful fishery in the late 1970s, but has since attracted very little settlement. As a consequence, the bed has only been surveyed sporadically when time has been available. A survey was conducted in April 2012, in which no cockles were found. The bed was not surveyed during the 2013 survey programme.

3.3.9 Inner Westmark Knock

Adult

- Area: 259 hectares
- Mean Density: 125.45 cockles/m^2
- Mean Biomass: 5.08 tonnes/hectare
- Stock ≥ 14mm: 1,315 tonnes

Juvenile

- Area: 192 hectares
- Mean Density: 411.25 cockles/m^2
- Mean Biomass: 4.87 tonnes/hectare
- Stock <14mm: 937 tonnes

A foot survey was conducted on Inner Westmark Knock on March 25th, during which 32 stations were sampled with a quadrat. A further 8 stations were sampled on April 10th, using a Day grab at high water.

The survey conducted on this bed in 2012 had found the stocks were dominated by 2010 year-class cockles that were mostly within a size range of 9-13mm width, although a small proportion had attained 14mm. The 2013 survey found that this cohort had declined and the bed now supported a more even distribution of 2010, 2011 and 2012 year-class cockles. By the time of this survey, the majority of the 2010 cohort had attained 14mm width. Figure 3.26 shows the population size frequency of these cockles at the time of the survey, while figures 3.27 and 3.28 show the distribution of adult and juvenile stocks over both this and the Breast sand.

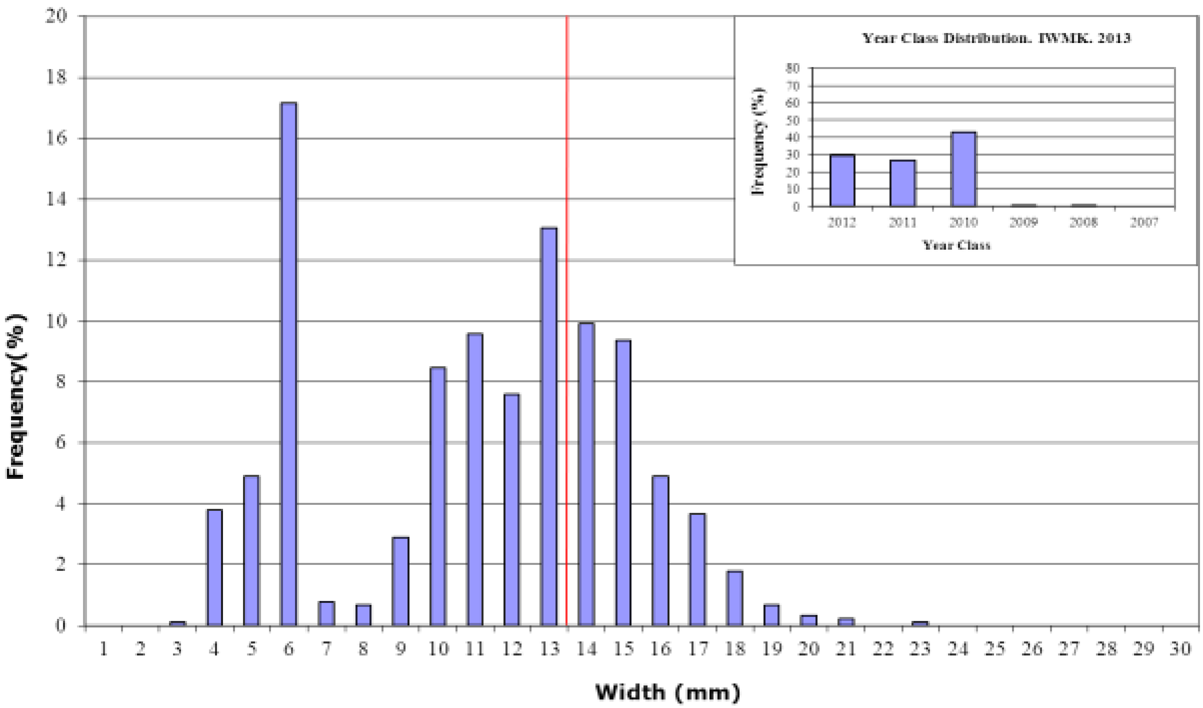


Figure 3.26 Cockle size and age frequencies on Inner Westmark Knock at the time of 2013 spring surveys

Because most of the remaining 2010 year-class cockles had grown to 14mm width between surveys, the population of cockles ≥14mm width had increased since 2012. Their area of coverage had increased from 13 stations covering 186 hectares to 22 stations covering an area of 259 hectares. Within this area their mean density was found to have increased from 63.84 cockles/m^2 (range 10 – 330/m^2) to 125.45 cockles/m^2 (range 10 – 320/m^2) and their mean biomass from 2.45 tonnes/hectare to 5.08 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on this sand was calculated to be 1,315 tonnes compared to 455 tonnes in 2012.

Although there had been a settlement during 2012, these were not as numerous as the 2010 cockles that had either died or recruited into the adult population. As a consequence, the population of cockles <14mm width had declined since the previous survey. The coverage was found to have declined from 19 stations covering 260 hectares to 16 stations covering 192 hectares. Within this area the mean density had declined from 657.9 cockles/m^2 (range 10 – 2,580/m^2) to 411.25 cockles/m^2 (range 10 – 1,500/m^2) and the mean biomass from 9.28 tonnes/hectare to 4.87 tonnes/hectare. From these figures the biomass of cockles <14mm width on this sand was calculated to be 937 tonnes compared to 2,412 tonnes in 2012.

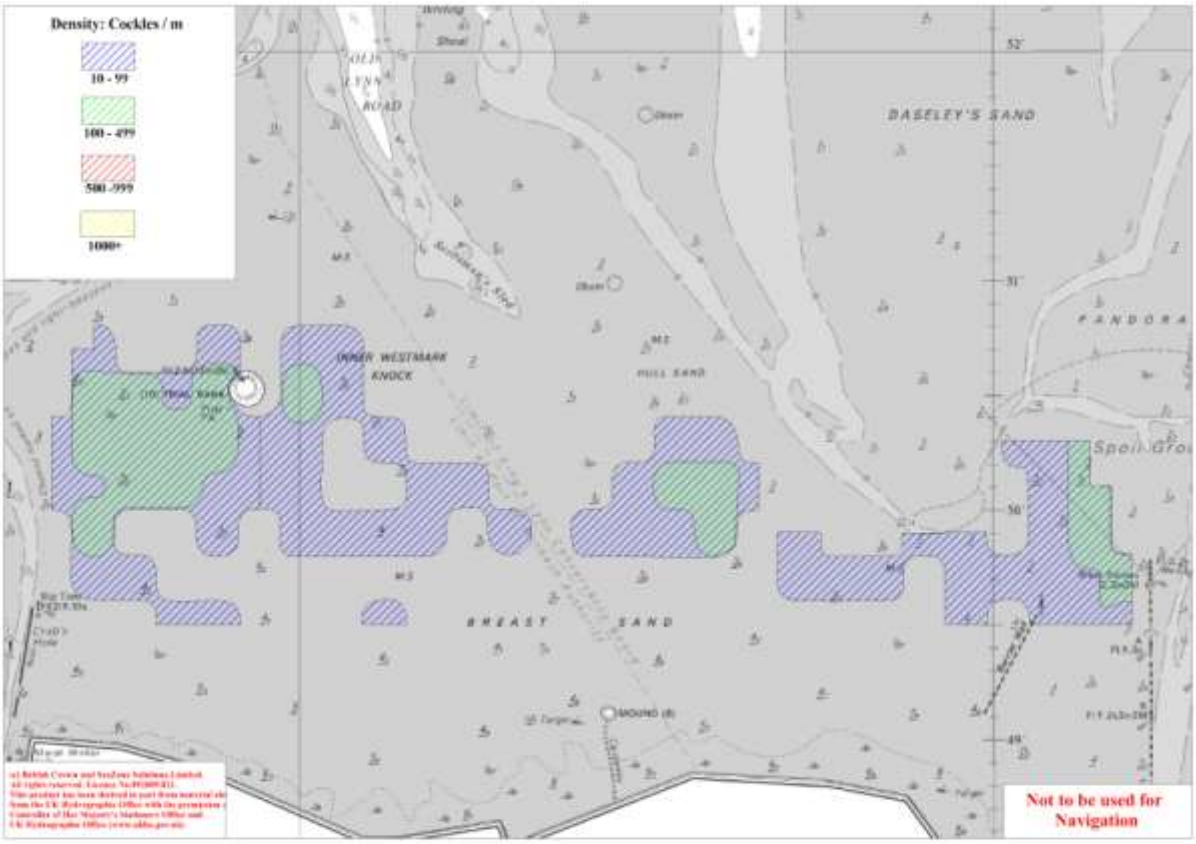


Figure 3.27 Chart showing the distribution of cockles ≥14mm width on the Inner Westmark Knock and Breast beds when surveyed during the 2013 spring surveys.

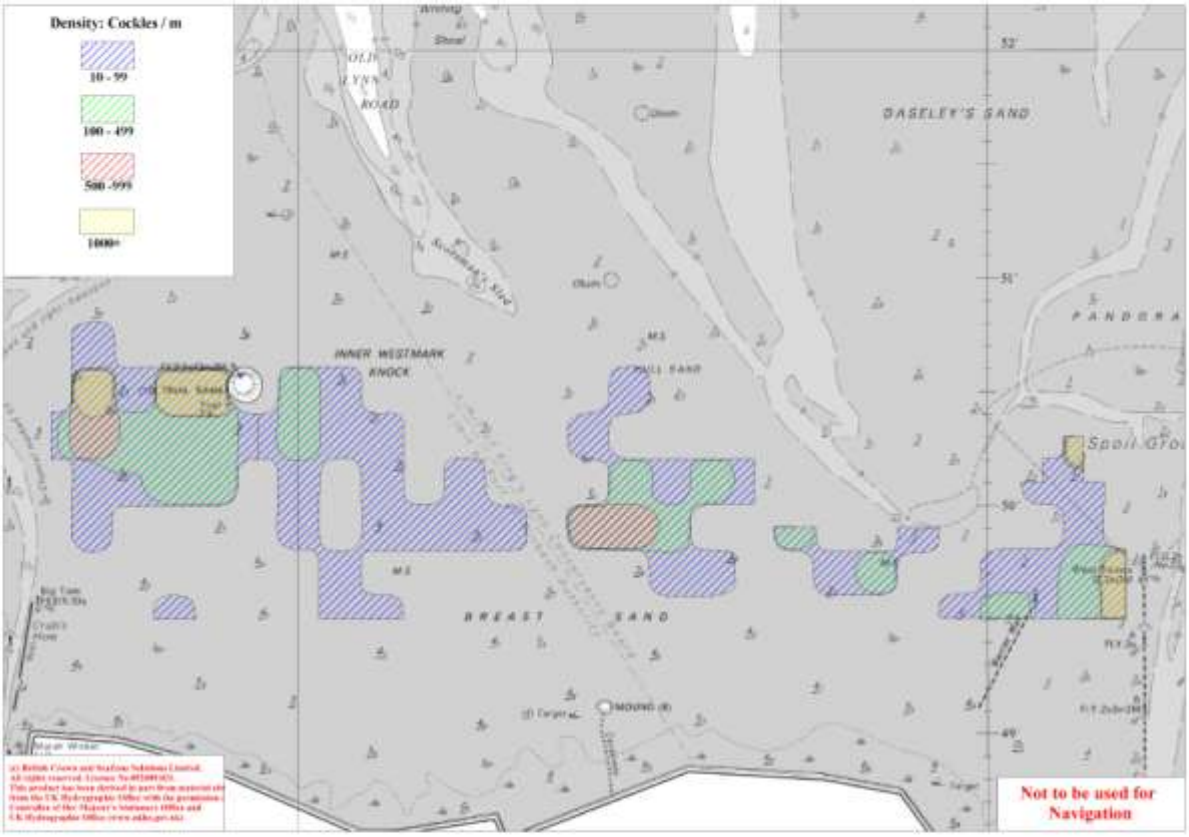


Figure 3.28 Chart showing the distribution of cockles <14mm width on the Inner Westmark Knock and Breast beds when surveyed during the 2013 spring surveys.

The total biomass of cockle on this bed was calculated to have declined from 2,867 tonnes in 2012 to 2,252 tonnes, mainly due to the decline of the 2010 year-class population.

3.3.10 Breast Sand

Adult

- Area: 498 hectares
- Mean Density: 54.80 cockles/m^2
- Mean Biomass: 4.11 tonnes/hectare
- Stock ≥ 14mm: 2,045 tonnes

Juvenile

- Area: 473 hectares
- Mean Density: 140.44 cockles/m^2
- Mean Biomass: 3.02 tonnes/hectare
- Stock <14mm: 1,428 tonnes

Surveys were conducted on the breast sand on April 2nd, 10th, 13th and 14th. During this period 66 stations were sampled over high water periods using a day grab, while a further 51 stations were sampled on foot at low water using a quadrat.

When surveyed in 2012 this bed had supported a large population of 2011 year-class cockles that had been of a 4-9mm size range, and less numerous populations of 2010 and 2008 cockles. The 2013 survey found that the most numerous group were still from the 2011 cohort, but their numbers had declined from the previous year. The distribution of the cockles on this bed can be seen in figures 3.27 and 3.28, while figure 3.29 shows the population size frequency.

49 stations were found to support cockles ≥14mm width. Although this was the same as in 2012, changes to the distribution of the stations meant their coverage had declined from 580 hectares to 498 hectares. Although the mean density of this population had declined from 61.63 cockles/m^2 (range 10 – 940/m^2) to 54.80 cockles/m^2 (range 10 – 410/m^2), their larger size meant the mean biomass had increased from 2.60 tonnes/hectare to 4.11 tonnes/hectare. These changes meant the biomass of cockles ≥14mm width on this bed had increased from 1,508 tonnes to 2,045 tonnes.

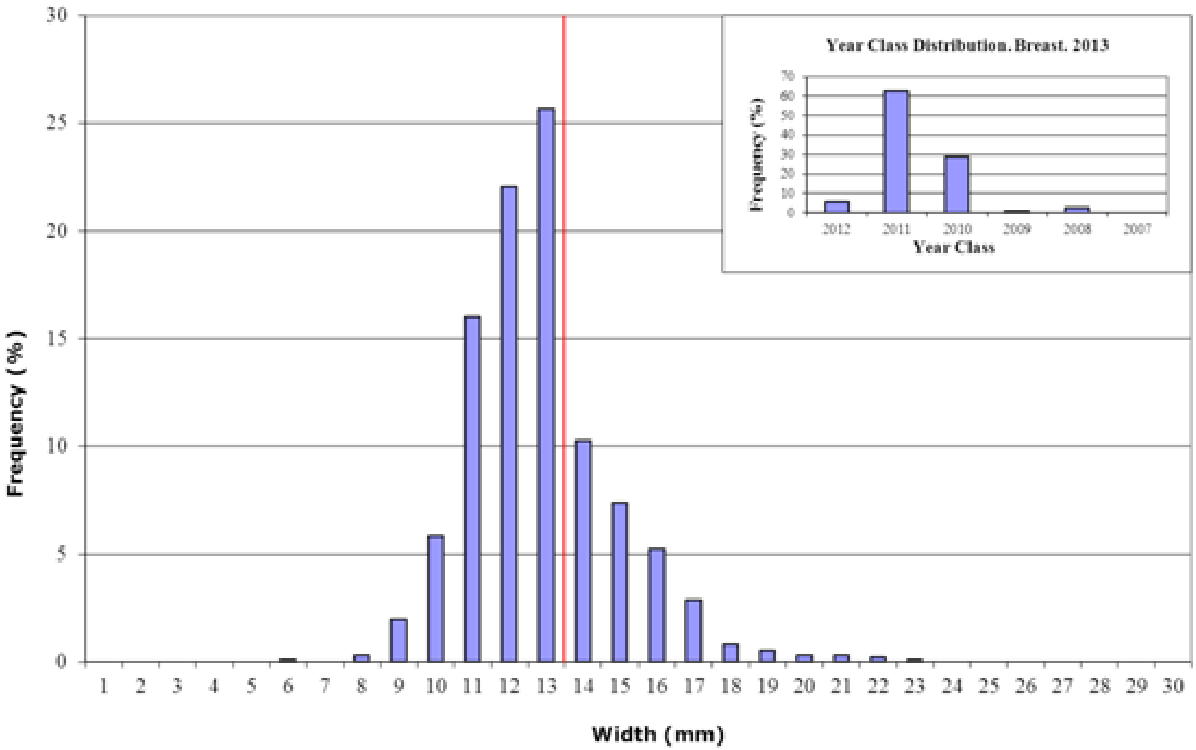


Figure 3.29 Cockle size and age frequencies on the Breast sand at the time of 2013 spring surveys

The population of cockles <14mm width was found to have declined from the previous year. This resulted in the coverage of these smaller cockles declining from 60 stations covering 712 hectares in 2012 to 45 stations covering an area of 473 hectares. Within this area the mean density had declined from 350.50 cockles/m^2 (range 10 – 3,210/m^2)

to 140.44 cockles/m^2 (range 10 – 1,360/m^2), but due to their greater size the mean biomass had increased from 2.49 tonnes/hectare to 2.49 tonnes/hectare. From these figures the biomass of cockles <14mm width on this bed was calculated to be 1,428 tonnes compared to 1,769 tonnes in 2012.

The total cockle biomass on this bed was found to have increased from 3,277 tonnes to 3,473 tonnes.

3.3.11 Whiting Shoal/Hull Sand

Adult

- Area: 20 hectares
- Mean Density: 40.00 cockles/m^2
- Mean Biomass: 5.51 tonnes/hectare
- Stock ≥ 14mm: 111 tonnes

Juvenile

- Area: 0 hectares
- Mean Density: 0 cockles/m^2
- Mean Biomass: 0 tonnes/hectare
- Stock <14mm: 0 tonnes

The Whiting Shoal/Hull sand was surveyed on April 14th, during which 20 stations were surveyed over high water using a Day grab. This bed had benefitted from a good settlement in 2008, but had not attracted any subsequent recruitment. Although these cockles appeared to have only suffered light "atypical" mortalities, they had supported several fisheries. As a consequence, only a sparse coverage now remains on this bed. Figure 3.30 shows the population size frequency of these cockles at the time of the spring survey, while figure 3.31 shows the distribution of adult cockles found on this and the Thief sand.

2 stations covering an area of 20 hectares were found to support cockles ≥14mm width. This was a reduction from 2012, when 3 stations covering 25 hectares supported these stocks. Within the bed the mean density had declined from 76.67 cockles/m^2 (range 60 – 100/m^2) to 40.00 cockles/m^2 (range 10 – 70/m^2) and the mean biomass from 7.90 tonnes/hectare to 5.51 tonnes/hectare. From these figures the biomass of cockles≥14mm width on this bed was calculated to have declined from 200 tonnes in 2012 to 111 tonnes.

No cockles smaller than 14mm width were found.

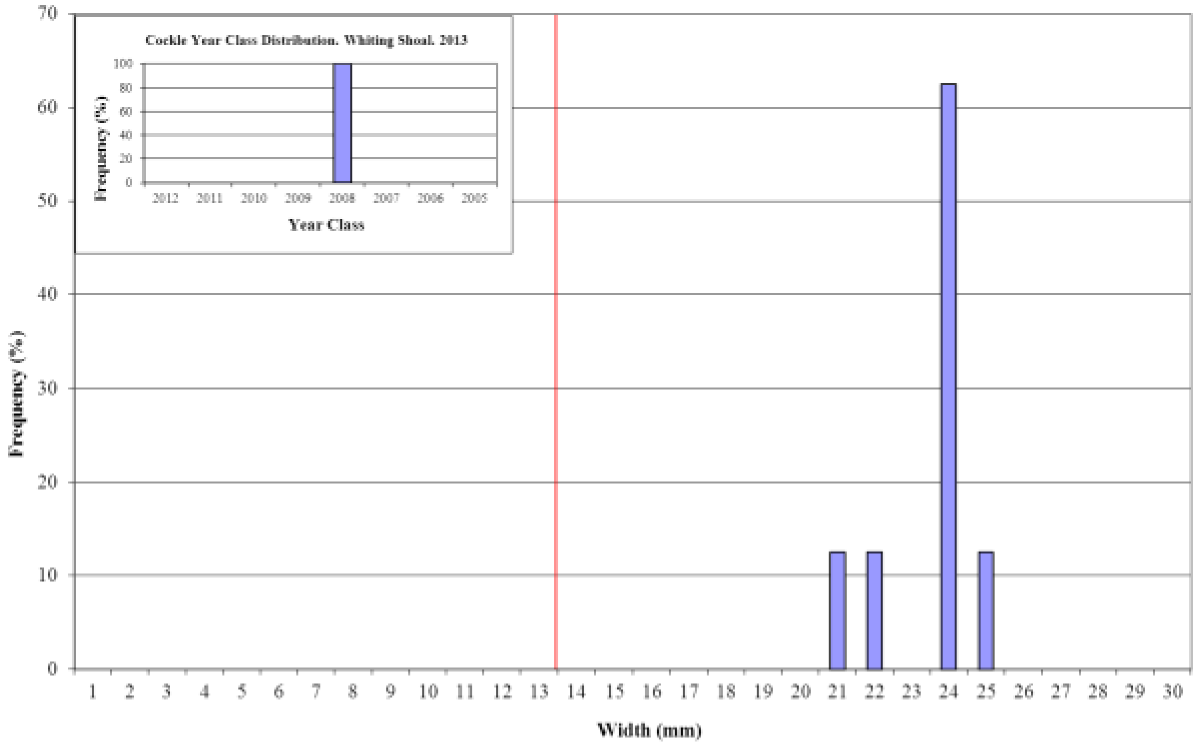


Figure 3.30 Cockle size and age frequencies on Whiting Shoal/Hull Sand at the time of spring 2012 surveys

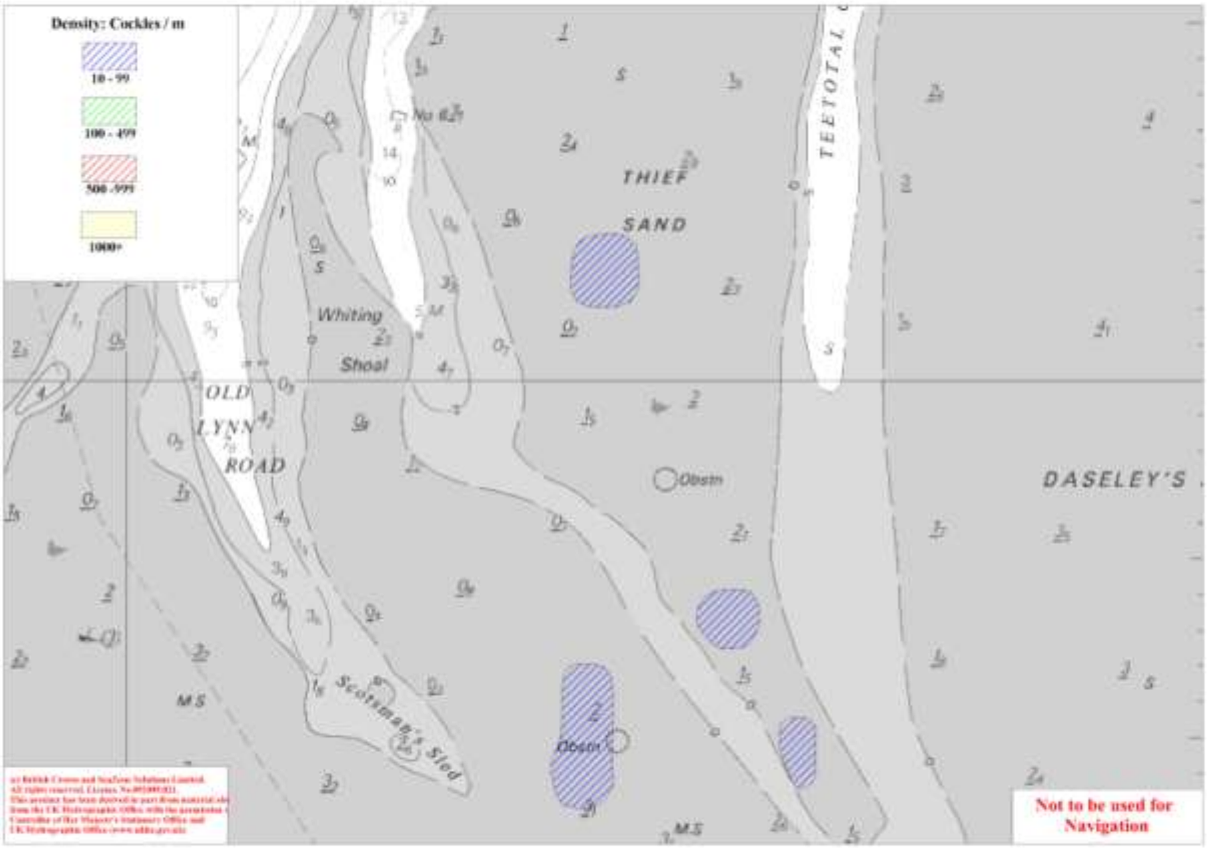


Figure 3.31 Chart showing the distribution of cockles ≥14mm width on the Whiting Shoal and Thief beds when surveyed during the 2013 spring surveys.

3.3.12 Thief Sand

Adult

- Area: 26 hectares
- Mean Density: 17.50 cockles/m^2
- Mean Biomass: 2.06 tonnes/hectare
- Stock ≥ 14mm: 53 tonnes

Juvenile

- Area: 0 hectares
- Mean Density: 0 cockles/m^2
- Mean Biomass: 0 tonnes/hectare
- Stock <14mm: 0 tonnes

The Thief sand was surveyed on April 24th, during which 17 stations were sampled at high water using a Day grab and 18 stations at low water with a quadrat. There had been a dense settlement in 2008 on the southern end of this bed but little subsequent recruitment. Having supported several fisheries, these stocks had become sparse. Figure 3.31 shows the distribution of cockles on this bed, while figure 3.32 shows the population size frequency.

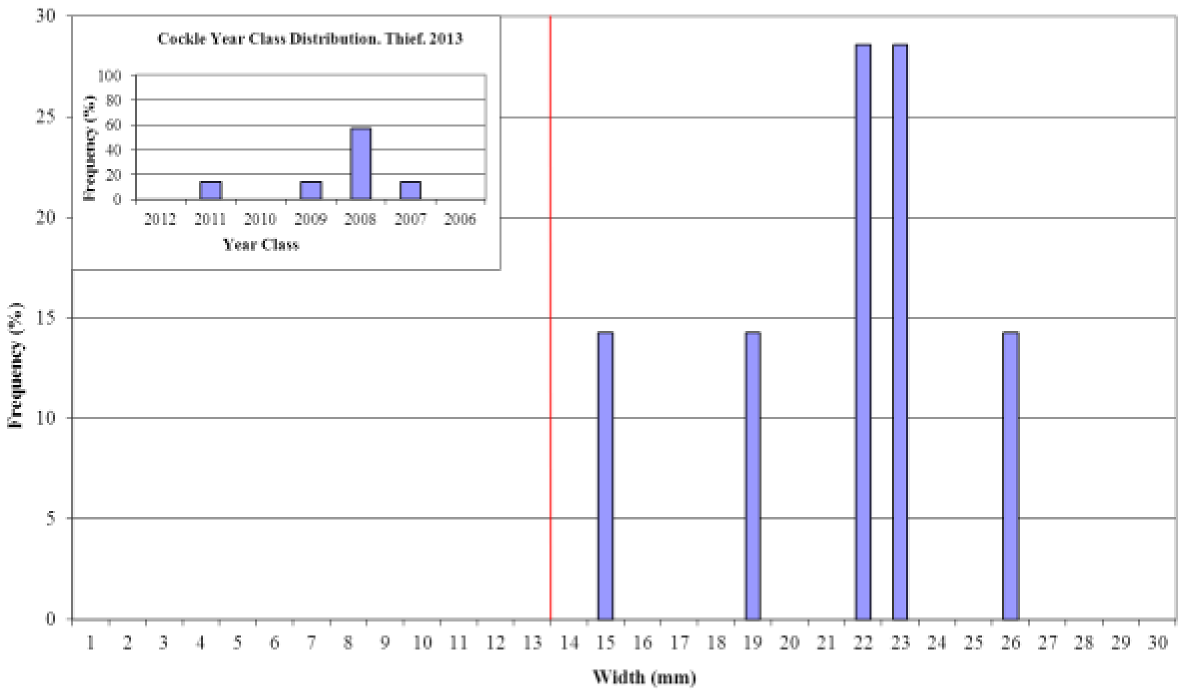


Figure 3.32 Cockle size and age frequencies on Thief Sand at the time of 2013 spring surveys

All of the cockles sampled during the 2013 survey had attained a size of 14mm width. These were found in 4 samples, representing an area of 26 hectares. This was a reduction to the previous year when 50 hectares had supported cockle on this bed. Within this area the mean density was found to be 17.50 cockles/m^2 (range 10 – 30/m^2), a decline from the 40.00 cockles/m^2 (range 10 – 110/m^2) recorded the previous year. The mean biomass was also found to have declined from 3.99 tonnes/hectare to 2.06 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on this bed was calculated to have declined from 147 tonnes in 2012 to 53 tonnes.

3.3.13 Daseley's

Adult

- Area: 487 hectares
- Mean Density: 70.00 cockles/m^2
- Mean Biomass: 2.57 tonnes/hectare
- Stock ≥ 14mm: 1,253 tonnes

Juvenile

- Area: 329 hectares
- Mean Density: 203.60 cockles/m^2
- Mean Biomass: 4.47 tonnes/hectare
- Stock <14mm: 1,468 tonnes

Daseley's sand was surveyed on April 24th, during which 84 stations were surveyed over high water using a Day grab. When surveyed in 2012 this bed had been dominated by a population of 2011 year-class cockles that were mostly in a 5-9mm size range. The 2013 survey found this was still the dominant cohort but their size range had increased to 11-16mm. Figure 3.33 shows the size frequency of these cockles, while figures 3.34 and 3.35 show the distribution of the adult and juvenile stocks over the bed.
Because some of the 2011 year-class cockles had attained 14mm width between surveys, the abundance of cockles ≥14mm width had improved from the previous survey. Their extent had increased from 28 stations covering 334 hectares to 44 stations covering 487 hectares. Within this area their mean density had increased from 18.57 cockles/m^2 (range 10 – 80/m^2) to 70.00 cockles/m^2 (range 10 – 440/m^2) and their mean biomass from 0.96 tonnes/hectare to 2.57 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on Daseley's was calculated to have increased from 320 tonnes to 1,253 tonnes.

The combination of natural mortalities and the recruitment of some of the juvenile population into the adult stock meant there were fewer cockles <14mm width on this sand than the previous year. Their extent had declined from 35 stations covering 440 hectares to 28 stations covering 329 hectares and their mean density from 477.4 cockles/m^2 (range 10 – 4,350/m^2) to 203.6 cockles/m^2 (range 10 – 1,670/m^2). Because the mean size of these cockles was larger than the previous year, however, their mean biomass had increased from 1.52 tonnes/hectare to 4.47 tonnes/hectare. This meant that overall the biomass of cockles <14mm width on this sand had increased from 667 tonnes in 2012 to 1,468 tonnes.

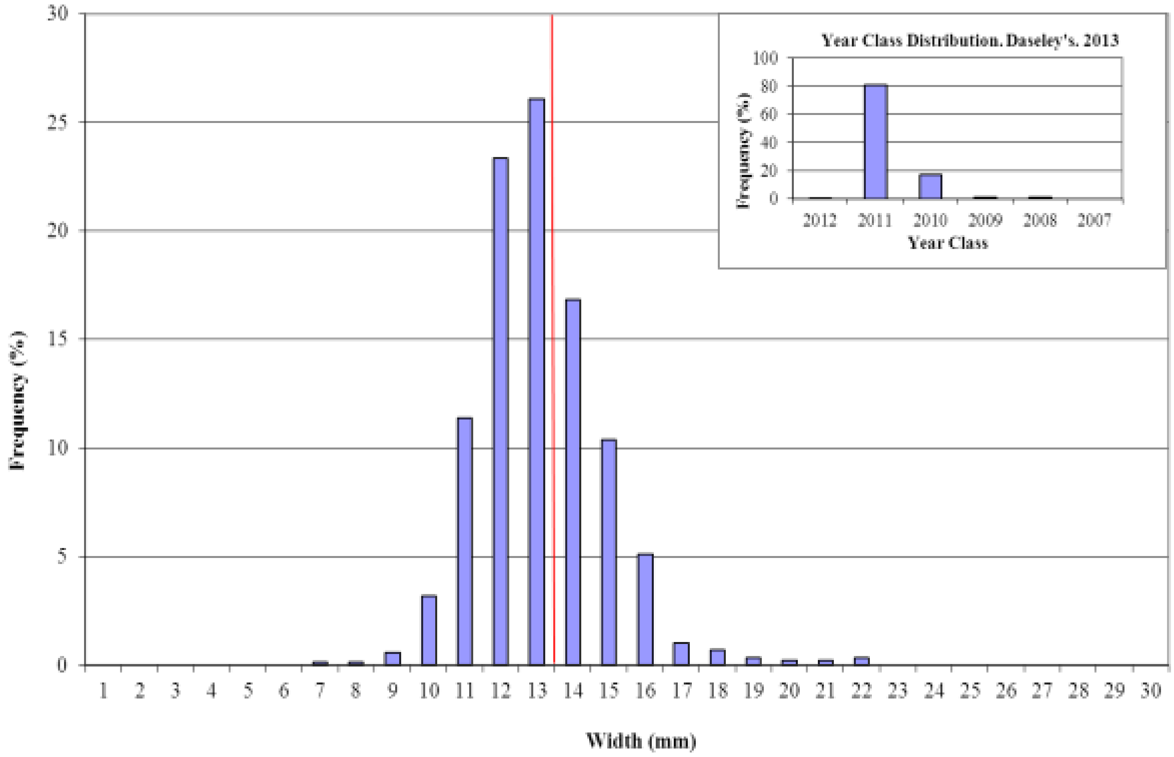


Figure 3.33 Cockle size and age frequencies on Daseley's at the time of 2013 spring surveys

Figure 3.34 Chart showing the distribution of cockles ≥14mm width on the Daseley's, Pandora, Blackguard, Styleman's and Peter Black sands when surveyed during the 2013 spring surveys.

Figure 3.35 Chart showing the distribution of cockles <14mm width on the Daseley's, Pandora, Blackguard, Styleman's and Peter Black sands when surveyed during the 2013 spring surveys.

3.3.14 Styleman's

Adult

- Area: 0 hectares
- Mean Density: 0 cockles/m^2
- Mean Biomass: 0 tonnes/hectare
- Stock ≥ 14mm: 0 tonnes

Juvenile

- Area: 9 hectares
- Mean Density: 10.00 cockles/m^2
- Mean Biomass: 0.02 tonnes/hectare
- Stock <14mm: 0.2 tonnes

Styleman's sand was surveyed on May 8th, during which 23 stations were sampled over the high water period using a Day grab. When surveyed in 2012 this bed was found to support 45 tonnes of Year 1+ cockles and 26 tonnes of 2011 year-class spat. This latter population had been present in densities of 490.0 cockles/m^2 (range 30 –950/m^2) with a mean biomass of 1.18 tonnes/hectare. The 2013 survey found that these had all disappeared and the only cockle found during the survey had been a small 2012 year-class individual.

3.3.17 Blackguard

Adult

- Area: 0 hectares
- Mean Density: 0 cockles/m^2
- Mean Biomass: 0 tonnes/hectare
- Stock ≥ 14mm: 0 tonnes

Juvenile

- Area: 0 hectares
- Mean Density: 0 cockles/m^2
- Mean Biomass: 0 tonnes/hectare
- Stock ≥ 14mm: 0 tonnes

Blackguard sand was surveyed on May 8th, during which 23 stations were sampled over the high water period using a Day grab. Although localised patches of cockles have been found on this sand during some of the past surveys, the 2011, 2012 and 2013 surveys have all failed to find any stocks on this bed.

3.3.18 Pandora

Adult

- Area: 60 hectares
- Mean Density: 66.00 cockles/m^2
- Mean Biomass: 2.64 tonnes/hectare
- Stock ≥ 14mm: 158 tonnes

Juvenile

- Area: 67 hectares
- Mean Density: 120.00 cockles/m^2
- Mean Biomass: 3.15 tonnes/hectare
- Stock <14mm: 212 tonnes

The Pandora sand was surveyed on May 8th, during which 35 stations were sampled over the high water period using a Day grab. When surveyed in 2012 this bed was found to support 16 tonnes of Year 1+ cockles and 195 tonnes of 2011 year-class spat. This spat had an area of 5 stations covering 56 hectares, had a mean density of 880.0 cockles/m^2 (range 10 – 4,190/m^2) and a mean biomass 3.50 tonnes/hectare. The 2013 survey found that although natural mortality had reduced their numbers, the juveniles that had survived had grown well, and some had attained 14mm width. The distribution of these cockles can be seen in figures 3.34 and 3.35, while the size distribution of the population is shown in figure 3.36.

5 stations covering an area of 60 hectares were found to support cockles ≥14mm width. These had a mean density of 66.00 cockles/m^2 (range 10 –270/m^2) and a mean biomass 2.64 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on this bed was calculated to be 158 tonnes.

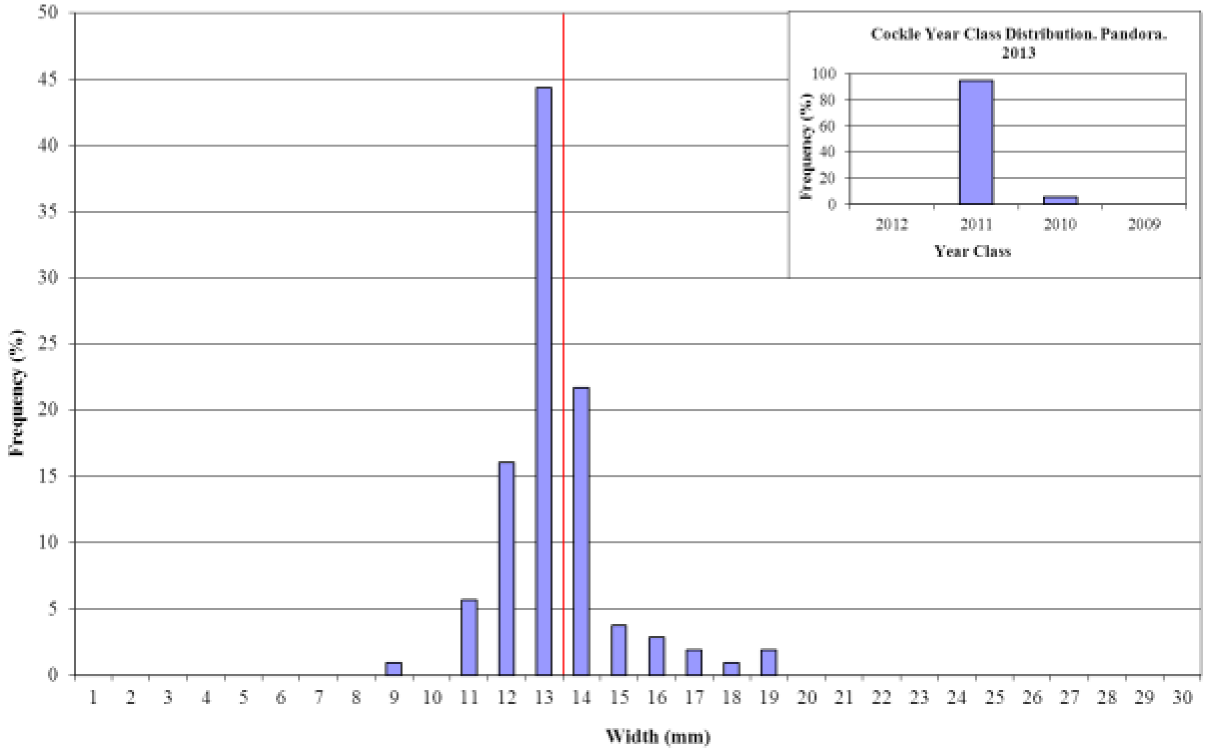


Figure 3.36 Cockle size and age frequencies on Pandora at the time of 2013 spring surveys

6 stations covering an area of 67 hectares were found to support cockles <14mm width. Within this area their mean density was found to be 120.0 cockles/m^2 (range 10 – 520/m^2) and their mean biomass 3.15 tonnes/hectare. From these figures the biomass of cockles <14mm width on this bed was calculated to be 212 tonnes.
The total cockle stock on this bed was calculated to have increased from 211 tonnes in 2012 to 370 tonnes.

3.3.19 Peter Black

Adult	**Juvenile**
• Area: 115 hectares	• Area: 96 hectares
• Mean Density: 21.00 cockles/m^2	• Mean Density: 12.22 cockles/m^2
• Mean Biomass: 1.06 tonnes/hectare	• Mean Biomass: 0.22 tonnes/hectare
• Stock ≥ 14mm: 122 tonnes	• Stock <14mm: 19 tonnes

The Peter Black Sand was surveyed on May 8th and 9th, during which 42 stations were surveyed at high water using a Day grab. In 2012 the stocks on this bed had been dominated with individuals from the 2010 year-class cohort, the majority of which were in an 11-13mm size range. The 2013 survey found these had survived and grown >14mm width. There had also been a settlement during 2012. Figures 3.34 and 3.35 show the distribution of the cockle stocks on this bed, while figure 3.37 shows the population size frequency at the time of the spring survey.

The coverage of Cockles ≥14mm width was found to have increased from 5 stations covering an area of 48 hectares to 10 stations covering an area of 115 hectares. Within this area their mean density was found to have increased from 12.0 cockles/m^2 (range 10 - 20/m^2) to 21.0 cockles/m^2 (range 10 - 50/m^2) and their mean biomass from 0.65 tonnes/hectare to 1.06 tonnes/hectare. From these figures the biomass of cockles ≥14mm width on this bed was calculated to have increased from 31 tonnes to 122 tonnes.

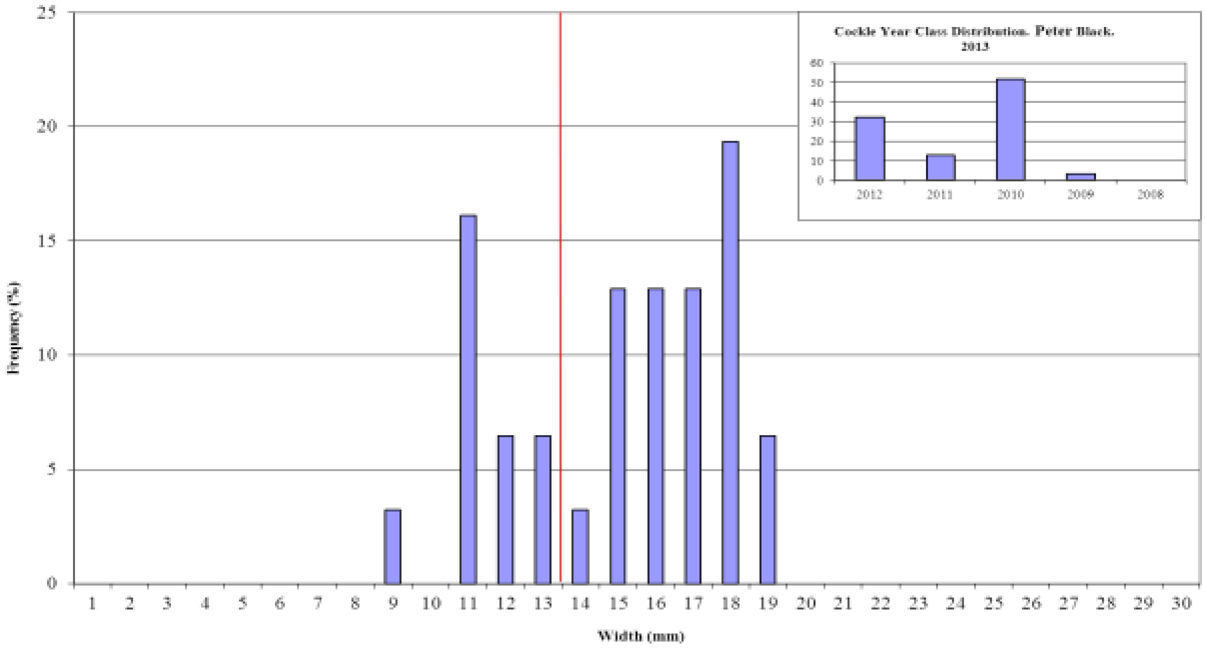


Figure 3.37 Cockle size and age frequencies on Peter Black sand at the time of 2013 spring surveys

The extent of the 2010 year-class cockles was greater than that of the 2012 cohort so the coverage of cockles <14mm width was found to have declined from 14 stations covering 160 hectares to 9 stations covering 96 hectares. Within this area the mean density was found to have declined from 21.43 cockles/m^2 (range 10 – 50/m^2) to 12.22 cockles/m^2 (range 10 – 20/m^2) and the mean biomass from 0.36 tonnes/hectare to 0.20 tonnes/hectare. The biomass of cockles <14mm width was calculated to have declined from 57 tonnes to 19 tonnes.

The total biomass of cockles on this bed was found to have increased from 88 tonnes to 141 tonnes.

Table 3.1 Summary of cockle stocks on the Wash intertidal beds. Spring 2013										
	ADULT				**JUVENILES**					
SAND	**Area (ha)**	**Mean Density (no/m^2)**	**Mean Weight (t/ha)**	**Biomass (t)**	**Area (ha)**	**Mean Density (no/m^2)**	**Mean Weight (t/ha)**	**Biomass (t)**	**Total Biomass (t)**	**%Adult**
Butterwick	212	52.94	2.62	555	123	115.46	1.18	145	700	79
Wrangle	379	25.15	1.87	709	137	20.00	0.32	43	752	94
Friskney	166	13.53	1.26	209	70	10.00	0.19	13	222	94
Butterwick Ext	104	57.27	2.36	246	88	170.91	2.15	188	434	57
Wrangle Ext	64	10.00	0.54	35	105	12.22	0.19	21	56	63
Friskney Ext	298	13.08	1.05	313	149	12.31	0.21	31	344	91
Roger/Toft	122	94.55	4.40	538	118	26.00	0.56	66	604	89
Gat	8	10.00	1.59	13	17	240.00	1.60	28	41	32
Herring Hill	249	62.07	2.44	607	270	101.29	1.89	510	1117	54
Black Buoy	129	107.78	4.16	536	169	593.60	11.07	1868	2404	22
Mare Tail	203	115.00	4.65	946	368	678.68	2.80	1030	1976	48
Holbeach	598	79.71	2.33	1395	618	181.14	2.86	1766	3161	44
IWMK	259	125.50	5.08	1315	192	411.25	4.87	937	2252	58
Breast	498	54.80	4.11	2045	473	140.44	3.02	1428	3473	59
Thief	26	17.50	2.06	53	0	0.00	0.00	0	53	100
Whiting Shoal	20	40.00	5.51	111	0	0.00	0.00	0	111	100
Daseley's	487	70.00	2.57	1253	329	203.60	4.47	1468	2721	46
Styleman's	0	0.00	0.00	0	9	10.00	0.02	0.2	0.2	0
Pandora	60	66.00	2.64	158	67	120.00	3.15	212	370	0
Blackguard	0	0.00	0.00	0	0	0.00	0.00	0	0	0
Peter Black	115	21.00	1.06	122	96	12.22	0.20	19	141	87
Total	**3997**			**11159**	**3398**			**9773.2**	**20932.2**	**53**

3.4 Discussion

Table 3.1 summarises the cockle stocks found on the Wash intertidal beds following the spring surveys. From this table it can be seen that the total cockle biomass was calculated to be 20,932 tonnes, of which 11,159 tonnes had attained a size of 14mm width. Although this was a small decline in total biomass from 21,106 tonnes recorded the previous year, the adult (cockles ≥14mm width) population had increased significantly from 7,107 tonnes. This was mainly due to a high proportion of the dominant 2010 year-class cohort reaching 14mm between surveys. Whereas in 2012 only those on the faster growing beds has managed to reach this size at the time of the spring survey, by 2013 those on all but the slowest growing beds had done so.

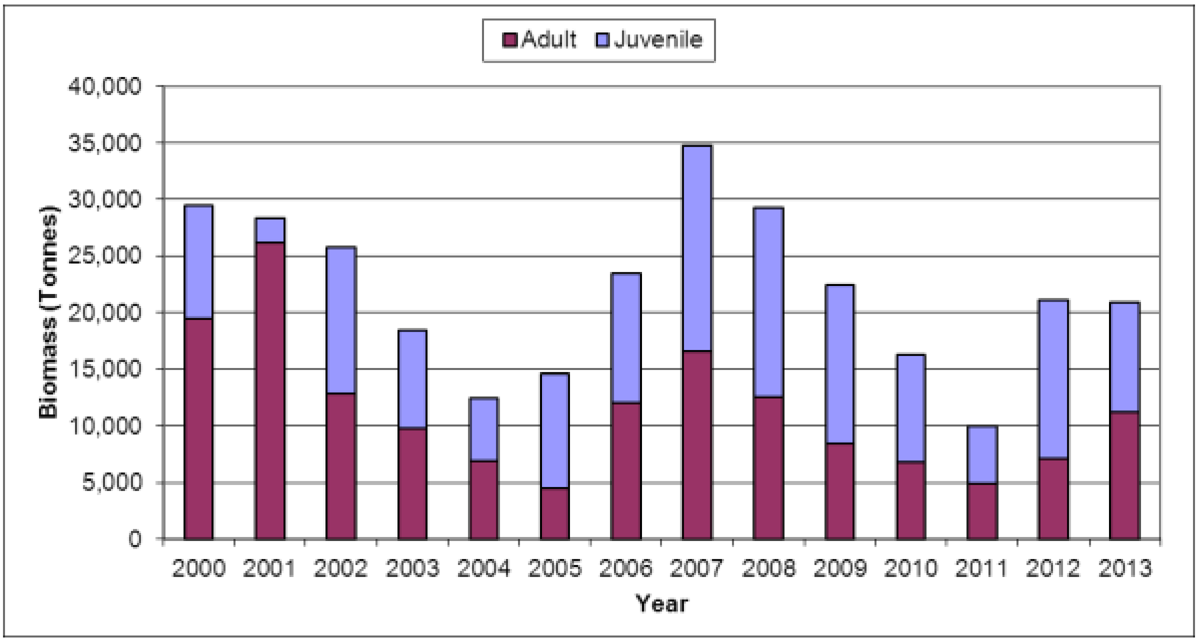


Figure 3.38 Biomass of cockle stocks at the time of the spring surveys between 2000 and 2013

Figure 3.38 shows how the stocks in 2013 compare with the previous thirteen years. From this table it would appear that following a period of decline between 2008 and 2011, the stocks are showing signs of recovery and stability. Such hopes should be viewed cautiously, however. The recent recovery has been facilitated by the recruitment and growth of a strong 2010 year-class cohort which boosted the total cockle biomass in 2012 and the adult biomass in 2013. So far the majority of this cohort have not been affected by the atypical mortalities that caused the decline between 2008 and 2011. It does not mean they are resistant to it, though. Observations suggest mainly larger cockles are affected, and the majority of this cohort are only just beginning to reach that size range. Those on the faster growing beds of Friskney and Wrangle did succumb in high numbers during the summer of 2012 and if similar trends are followed to what have been observed in recent years, mortalities are expected to be high among this cohort during the summer of 2013. Such mortalities would usually be identified during the winter cockle surveys but as time limitations meant these surveys were not conducted this year, their extent will not be known until the 2014 spring surveys. With mortalities among the 2010 year-class cohort anticipated to be high, and fewer juvenile stocks present in the population than in 2012 to replace them, the stocks are expected to decline by 2014.

On the 5th June 2013 the Marine Protected Area Sub-Committee convened to agree management measures for the 2013 cockle fishery. In addition to the opportunity for widespread hand-work fisheries, the survey results had identified the potential for a discrete dredge fishery in Holbeach bombing range. Although this site offered only limited access to the hand-work fishery, however, the majority of the fishermen expressed concern over the proposal for a dredge fishery at this site. It was determined, therefore, that the 2013 fishery should be hand-worked only, with a TAC of 3,720 tonnes. The Sub-Committee were also asked to consider additional management options for two dense patches of 2011 year-class cockles that the surveys had identified on the Dills and Daseley's sands. At the time of the surveys the majority of these cockles had not reached 14mm width but were expected to do so during the course of the fishery. On one hand, with only limited juvenile cockles elsewhere in the population, these two areas were likely to offer significant contributions towards the 2014 fishery. This would usually constitute reason enough to keep these patches closed. Their high densities, however, posed a dilemma, as these cockles were in imminent danger of "ridging out" due to over-crowding. If they were not fished during 2013, large numbers would most likely be lost. The officers proposed keeping a temporary closure on these two areas at the start of the fishery. This would allow these small cockles to grow to commercial size, while at the same time encouraging the fishermen to initially harvest some of the lower density cockles from the 2010 year-class cohort that were most vulnerable to "atypical" mortality losses. This proposal was not received with any enthusiasm from the industry, however, who argued the danger of "ridging out" out-weighed the potential benefits a temporary closure would produce. The fishery was opened, therefore, in all areas barring some small discrete patches that supported dense populations of 2012 year-class juveniles. This fishery was opened on June 20th, with the majority of the fishermen targeting either the Dills or Daseley's from the beginning. This fishery remained open until the TAC was exhausted on September 25th. Following the closure of this fishery an extension was granted between the 8th and 14th October, in order to exploit large numbers of cockles that had begun to "ridge out" on the Breast sand.

3.5 Assessment of the impact of the hand-worked cockle fishery's use of bulk bags to facilitate "prop-washing"

3.5.1 Introduction

Between the 1960s and 1986 hand-worked cockle fishermen in the Wash frequently used a practice known as "blowing-out" to facilitate the harvesting of cockles. "Blowing-out" involved anchoring the vessel to the seabed with a large anchor and then circling the vessel as the tide dropped using a rope approximately 60m in length. As each circle was completed, the rope would be shortened prior to the next circle being conducted, culminating in the vessel conducting a series of concentric circles. As the vessel circled, the backwash from the propeller would wash the top layer of sand from above the cockles and wash any cockles present towards the centre of the circle. This practice would frequently result in deep rings being scoured into the sand, often exposing the anoxic layer, and leaving deep piles of cockles near the centre of the rings. Because these rings frequently took up to a year to disappear and un-harvested cockles were frequently left un-scattered to die, "blowing-out was banned in 1986.

Following the introduction of hydraulic suction dredges for harvesting cockles in 1986, few fishermen hand-worked cockles again in the Wash until 2005. Following 2005, a growing number of fishermen who were disenchanted with the short cockle seasons associated with the dredge fishery, opted for hand-working as their preferred method for harvesting cockles. "Blowing-out" was still banned, so most fishermen began using a method known as "prop-washing" to facilitate cockle harvesting. Using this method the vessel's propeller is still used to wash away the top layer of sand from above the cockles, but because the vessel is not anchored to the seabed, there is insufficient precision to the circling to conduct concentric rings. This prevents all of the cockles from a wide area being washed into deep piles. Also, as the vessel cannot apply as much power as when anchored, the scouring in the sand is not as deep. When conducted responsibly, this does not expose the anoxic layer and facilitates a faster recovery.

In 2006 it was highlighted that some individuals were using empty 1 tonne bulk bags as sea anchors to facilitate "prop-washing. Uncertain what impact this activity could have, but fearing it could lead to greater disturbance of the seabed, the use of bulk bags was prohibited in accordance with Regulation No.1 of the Wash Fishery Order 1992. Fishermen were advised:

"No vessel participating in the hand-worked cockle fishery may employ any equipment that either fixes the vessel to the seabed or slows the vessel's movement while the

vessel's engine is running. This includes anchors, sea anchors, drogues or any other equipment that could be used as an anchor or sea anchor. This includes the use of bulk bags."

Following the ban on the use of bulk bags during "prop-washing", concerns were raised from several fishermen who argued their use of bags was not to allow them to use more power when "prop-washing" but to enable them to turn in a tighter circle. They contested that this was safer when several vessels were working in close proximity and actually created less disturbance on the seabed because their rings were smaller. In July 2013 the Authority conducted an assessment of the impact that the use of bags had on the seabed when used responsibly to facilitate turning during "prop-washing".

3.5.2 Method

Two vessels that regularly participate in the hand-worked cockle fishery were used for the study. Both vessels were asked to conduct "prop-washing" activities on the first day of the study without using a bulk bags. On the second day they were asked to use a bulk bag to facilitate turning while "prop-washing".

The following data was recorded each day for both vessels:

- The length of time that was taken to conduct "prop-washing" activities.
- The engine revs used by the vessels while "prop-washing"
- The depth of water beneath the keel at the start of "prop-washing"
- The depth of water beneath the keel at the finish of "prop-washing"

At low water the physical disturbance to the seabed was measured in terms of the following criteria:

- Radius of the disturbed ring
- Width of the disturbed ring
- Average depth of disturbance within ring

3.5.3 Results

On July 6th 2013, the rings created by the two participating vessels were monitored. Neither vessel had used bulk bags on this occasion. On July 7th, their rings were again assessed, the vessels having used bulk bags to facilitate prop-washing. On both occasions the vessels were working in close proximity to each other on similar sediments. The weather/sea state was calm on both occasions.

Tables 3.5.1 and 3.5.2 show the results from this study.

Table 3.5.1 – The length of time each vessel spent "prop-washing", their engine power used and the water depth beneath their keels at the start and finish of activities.

Vessel	**Time (minutes)**	**Engine revs (RPM)**	**Start depth (cm)**	**End depth (cm)**
Without bags				
Vessel A	20	1400	90	15
Vessel B	24	1400	130	30
With bags				
Vessel A	20	1400	90	20
Vessel B	25	1400	130	30

Table 3.5.2 – Physical dimensions of the rings created during the "prop-washing" activities

Vessel	**Ring radius (m)**	**Ring width (m)**	**Ring depth (cm)**
Without bags			
Vessel A	22.75	3.0	2-3
Vessel B	21	3.5	4-6
With bags			
Vessel A	16.5	2.2	2-4
Vessel B	15.25	2.25	3-5

3.5.4 Discussion

During the study, both vessels took care to replicate their "prop-washing" activities when employing a bulk bag as when not using a bag. Vessel B undertook activities for slightly longer than Vessel A and in slightly deeper water, but these differences were consistent over both days.

In both cases the use of the bags enabled the vessels to manoeuvre in circles that were 27.5% smaller in radius than had been possible without using bags. Additionally, the width of both vessel's rings were found to be smaller when bags had been employed. In terms of the overall area of disturbance, employing bags reduced the area from 400.6m^2 to 212.9m^2 for vessel A and from 423.4m^2 to 199.7m^2 for vessel B. This equated to a 46.9% reduction for vessel A and a 52.8% reduction for vessel B.

In terms of the depth of disturbance within the rings, vessel A’s disturbance increased slightly from between 2-3cm without a bag to 2-4cm with a bag. By contrast, vessel B’s depth of disturbance reduced from 4-6cm without a bag to 3-5cm with a bag. No deep holes were created by either vessel, with or without bags.

Concerned about the possible impacts that the use of bulk bags could have when “prop-washing”, ESFJC prohibited their use in 2006. This study has shown, however, that when used responsibly to facilitate turning, their use reduces the disturbance both in terms of the surface area of disturbance and the volume of sediment disturbed. Using bulk bags during “prop-washing” activities can, therefore, reduce the impact that this activity has on the infauna within the fished area and the quantity of sediment that is suspended.

3.6 Assessing the impact of growth and mortality when determining the annual Total Allowable Catch (TAC) for the Wash cockle fishery

3.6.1 Introduction

Following the decline in the Wash cockle stocks during the 1990s, an annual quota known as the Total Allowable Catch (TAC) was introduced in 1998 as a management measure to ensure the cockle stocks were fished in a sustainable manner. Since its introduction, the baseline TAC allocated to the cockle fishery has always been 33.3% of the biomass of the adult (≥14mm width) cockle stocks. This figure has always been calculated from a baseline survey conducted in spring. Barring surveys conducted in 2009 and 2010, these surveys have always been conducted between the end of March to the end of April. (The 2009 and 2010 surveys were conducted one month later because there was prior agreement with the industry for a later opening date for the fishery.)

In recent years there have been requests from members of the fishing industry for the Authority to take into account cockle growth when determining the annual TAC for the cockle fishery. Their argument for this request is that substantial growth can occur between the time that the spring survey is conducted in April and the commencement of the fishery in June or July, thus depriving them of their full 33.3% allocation. Although autumn surveys have demonstrated that growth can be significant, care should be taken when considering adjusting the TAC to account for growth. Growth is not a recent phenomenon. It has always occurred, but has never been used to adjust the TAC at the start of the fishery. The baseline stock figure obtained from the spring surveys has always been precisely that – a baseline value from which the TAC has been calculated.

Although the Authority has so far never adjusted the TAC at the start of the fishery to account for growth, it does not mean doing so would make the fishery unsustainable. On some occasions the TAC has been increased at the end of the season when significant growth has been demonstrated to have occurred, with no noticeable impact to the sustainability of the fishery. In theory the 33.3% TAC should have facilitated sustainability of the stocks since its introduction. If this level of TAC was too high the fishery would be unsustainable and would have resulted in a long-term depletion of stocks. Figure 3.6.1, which shows the biomass of cockle stocks within the Wash Regulated beds since 2000, does not show a terminal decline of stocks.

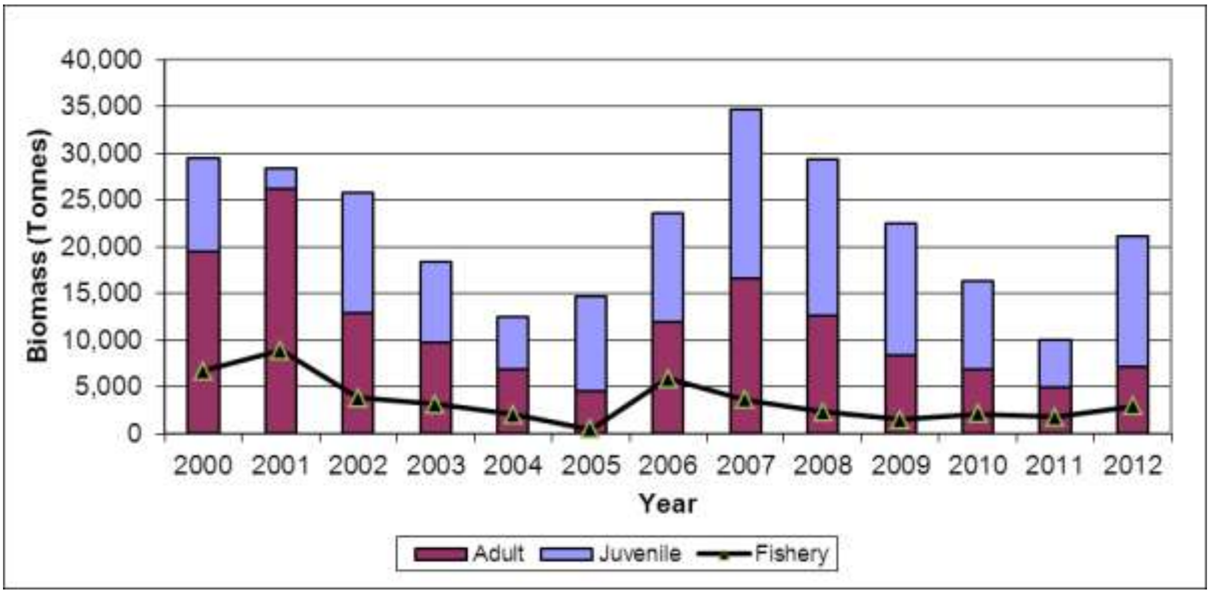


Figure 3.6.1 - Chart showing the biomass of cockle stocks within the Wash Regulated beds between 2000 and 2012 and the quantity of those stocks harvested annually

Instead of showing a terminal decline, the stocks in figure 3.6.1 appear to follow a natural population curve, the shape of which has been greatly influenced by sporadic recruitment of juvenile stocks and periods of high natural mortality. During years of poor recruitment the stocks have tended to decline irrespective of fisheries' influence, while following years of exceptional recruitment they have increased as strong year classes have entered the population and grown. This indicates that the current level of exploitation is not having a large long-term impact on stock levels. Irrespective of this, care should be taken not to disrupt any balance that may have been achieved between the stock levels and the size of the TAC. Just because the current level of exploitation does not appear to have an adverse impact on the population dynamics does not mean a slight increase of effort will not have an adverse impact. Natural balances can be easily over-turned. Any changes to the current management measures should be carefully applied and closely monitored following their adoption.

There are safety nets already in place that could provide scope for the TAC to be safely adjusted for a trial period. Subsequent to the introduction of the TAC in 1998 as a management measure, other management policies have been introduced to protect the cockle stocks. These include Conservation Objective targets limiting the exploitation of the stocks below thresholds required for over-wintering wader populations and the protection of small cockles from the dredge fishery. The TAC has also fallen in recent years in terms of its proportion of the total cockle stock. Although it has remained at 33.3% of the ≥14mm width cockle biomass, one impact of the recent atypical mortality has been to disproportionately reduce the biomass of these larger cockles from an average of 55.7% between 2000 and 2007 to 41.1% between 2008 and 2012.

Due to the high levels of atypical mortality that had occurred in the Wash since 2008, in 2012 the Authority adopted contingency management measures that allowed the TAC to be increased on beds on which cockle mortalities were predicted to be high. This allowed additional cockles to be removed from the Wrangle and Roger sands that would otherwise have died. Limited resources meant the Authority could not conduct projects to monitor both cockle growth and cockle mortality during 2013. At a Planning and Communication Sub-Committee meeting on 11th March 2013, the members chose to proceed with the project to monitor growth rates during the coming year.

<u>Factors for consideration when assessing growth rates</u>

There are several environmental factors that need to be considered when assessing growth rates of cockles. Elevation of the bed, cockle density and local hydrodynamics are all known to affect growth rates. In addition to these spatial effects, growth rates can vary temporarily from year to year due to the population age structure and differences in average water temperatures. Due to these latter variables, the Authority adopted a methodology that assesses actual growth at set periods during the year rather than applying a mean annual growth co-efficient based on annual survey results.

Figures 3.6.2 to 3.6.4 show the relative growth of cockles from the 2004 year-class cohort between 2005 and 2007 (This cohort was chosen for demonstration purposes because there were only low densities of older cockles present at the time of settlement and because of its widespread settlement). These charts show there is considerable spatial variation in growth rates across the Wash. Any methodology adopted to assess growth rates would require sufficient sample stations to provide a representative sub-sample of these variables. Randomised and stratified sampling techniques were both considered for this project. Due to the number of variables that effect growth, however, a stratified sampling regime was considered too complex for this project and a randomised technique was adopted.

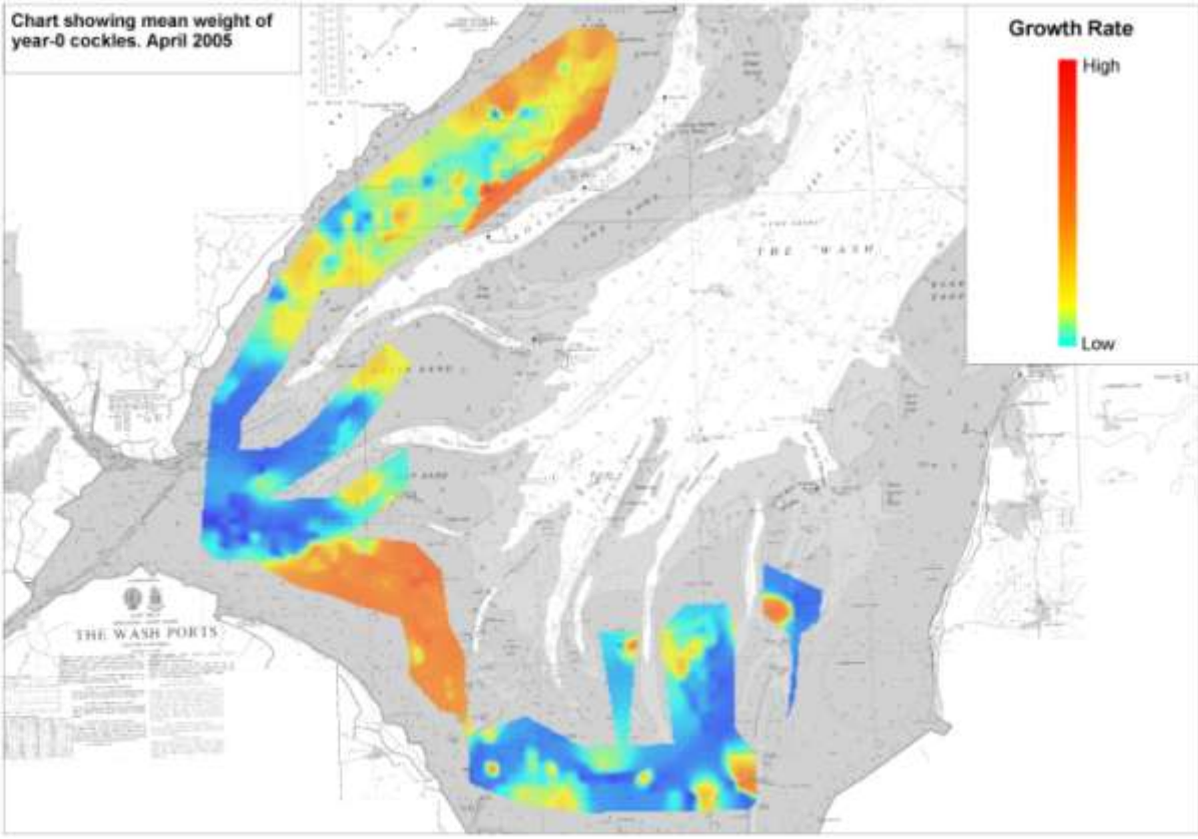


Figure 3.6.2 - Chart showing the variation in mean weight of year-0 cockles. April 2005

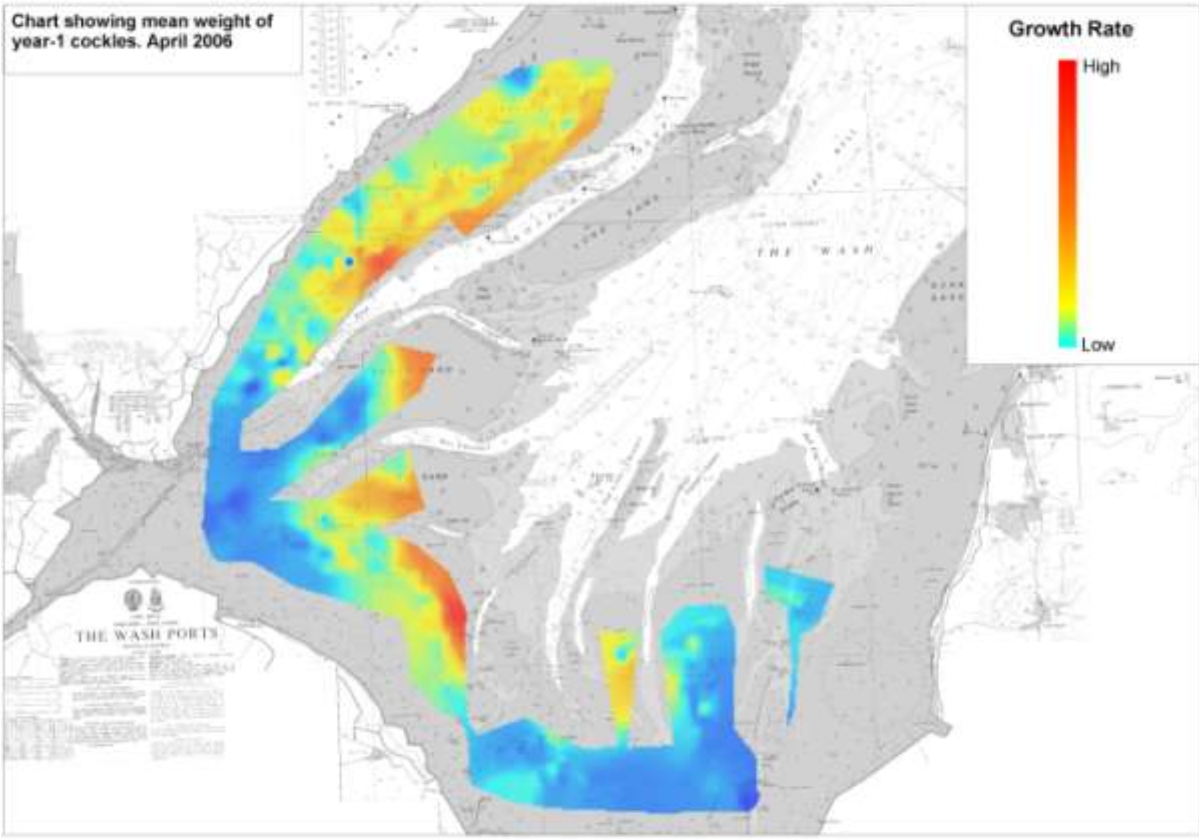


Figure 3.6.3 - Chart showing the mean variation in weight of year-1 cockles. April 2006

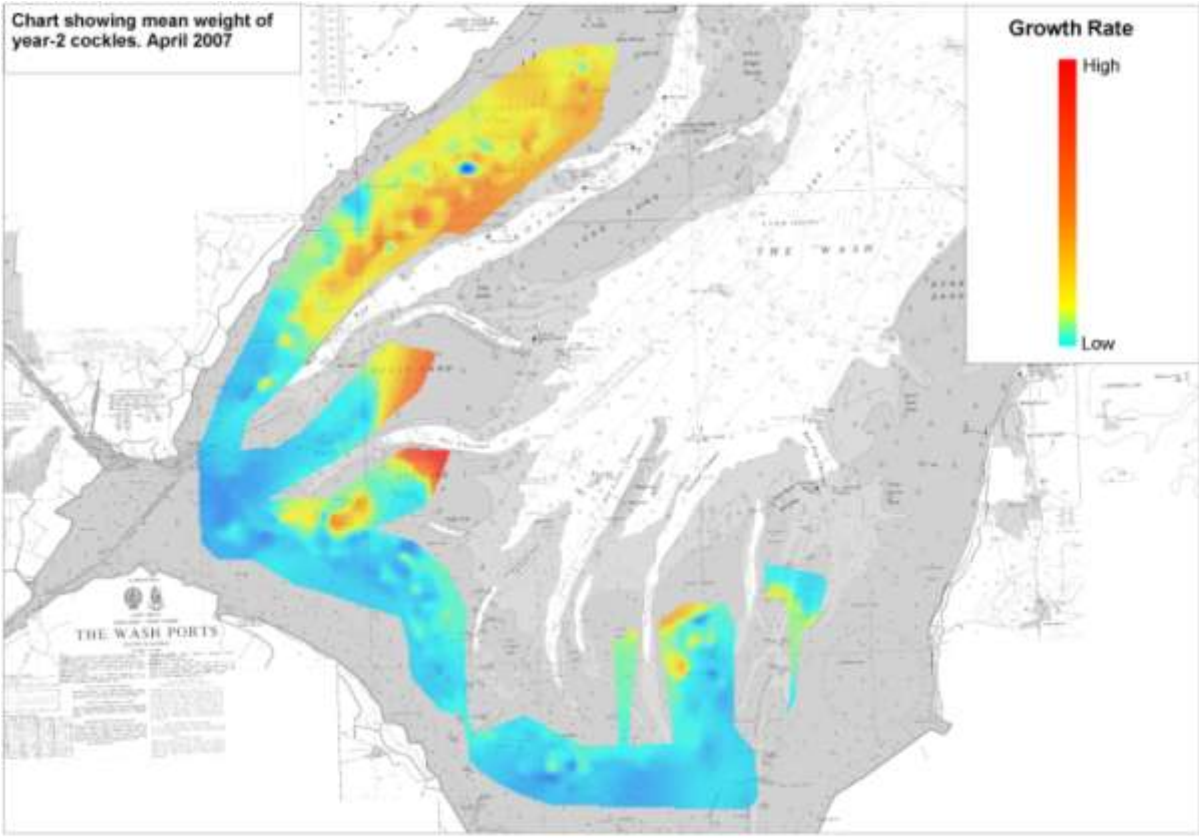


Figure 3.6.4 - Chart showing the variation in mean weight of year-2 cockles. April 2006

3.6.2 Method used for assessing cockle growth and mortality rates

The spring cockle surveys were conducted as normal in order to provide baseline data concerning the state of the cockle stocks. Approximately 10% of the stations sampled during these surveys were randomly selected to be used as representative growth assessment stations. These stations were then re-sampled in June, prior to the cockle fishery opening, to provide an assessment of cockle growth during the interim period.
The intertidal beds were divided into 11 assessment areas (figure 3.6.5). To facilitate the potential application of growth rates to the management of cockle stocks, the borders of these areas roughly matched the boundaries of the beds used during the spring cockle surveys. Table 3.6.1 shows details of these areas including the number of spring survey sample stations contained within each assessment area.

Within each assessment area, sample stations were selected for the growth study. These were chosen randomly from the survey stations used during the spring cockle surveys. Because many of the survey stations rarely support cockles, to maximise the number of valid samples the assessment sites were randomly chosen from the sites that had supported cockles in 2012. The number of stations chosen within each site for growth assessments depended on how many sample stations were present within the site. For sites with less than 100 survey stations, 10 stations were selected for the growth assessment study. For sites containing more than 100 stations, 10% of the stations were selected. In practice it was not possible to collect samples from all of these stations during both study periods. The data from any stations that had not been sampled on both occasions were subsequently removed from analysis.

In addition to assessing cockle growth, it was also hoped to determine the level of background mortality in each area. The numbers of cockles in each sample were to be used to determine mortality rates. In order to compensate for localised variation that could impact on the number of cockles found at each location, two replicates were taken at each site and their data averaged.

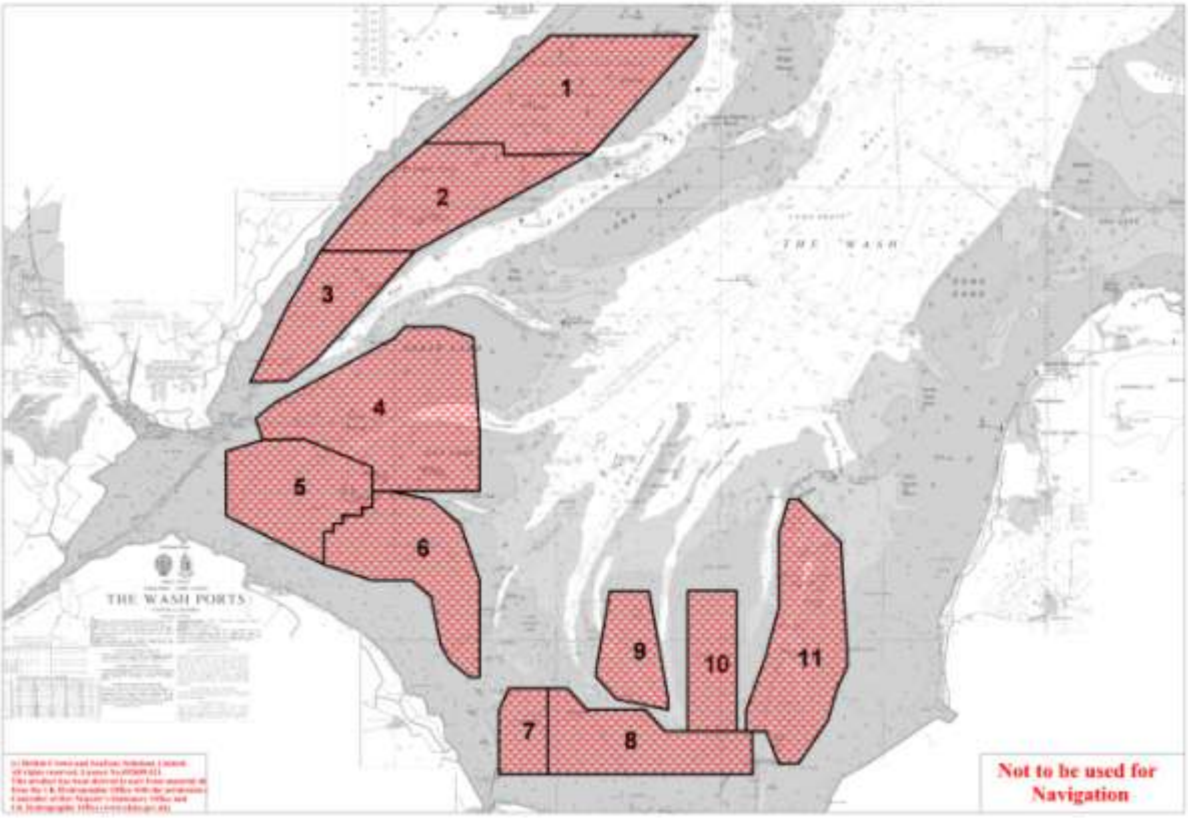


Figure 3.6.5 – Chart showing the 11 areas chosen for assessing cockle growth

Table 1 – The areas used for the Cockle Growth Assessment study and the numbers of spring survey stations and growth assessment stations contained within them

Area	Beds covered	Spring survey stations	Growth assessment sites
1	Friskney Friskney Extension	187	19
2	Wrangle Wrangle Extension	120	12
3	Butterwick Butterwick Extension	81	10
4	Dills Roger/Toft Gat	182	18
5	Mare Tail	61	10
6	Holbeach	152	15
7	Inner Westmark Knock	43	10
8	Breast	130	13
9	Whiting Shoal Thief	56	10
10	Daseley's	84	10
11	Pandora Styleman's Blackguard Peter Black	133	13

Sampling at each station was conducted at high water using a $0.1m^2$ Day grab deployed from the research vessel, *Three Counties*. Once collected, the samples were washed over a 3mm mesh washing table allowing any cockles present in the sample to be separated from the surrounding sediment. These cockles were then retained in labelled bags and stored in a cool place for later analysis (one bag/sample). At low water the age of each cockle was determined from their annual growth rings and their length and width measured to the nearest millimetre. These were then individually weighed to the nearest 0.01g.

The data were entered into Microsoft Excel for analysis and MapInfo 10.5 for display. For each area cockles were grouped into age cohorts of 2012, 2011 and 2010 and older year classes. Analysis was conducted to determine the total numbers and the mean widths and weights of the cockles within each cohort for each area and their 95% confidence limits.

3.6.3 Results

Stations surveyed

Although 140 stations were initially selected to be sampled for this study, practical difficulties in the field meant it was only possible to sample 115 of these stations on both occasions. Figure 3.6.6 shows the locations of the 115 stations that were sampled both at the time of the initial surveys and again in June.

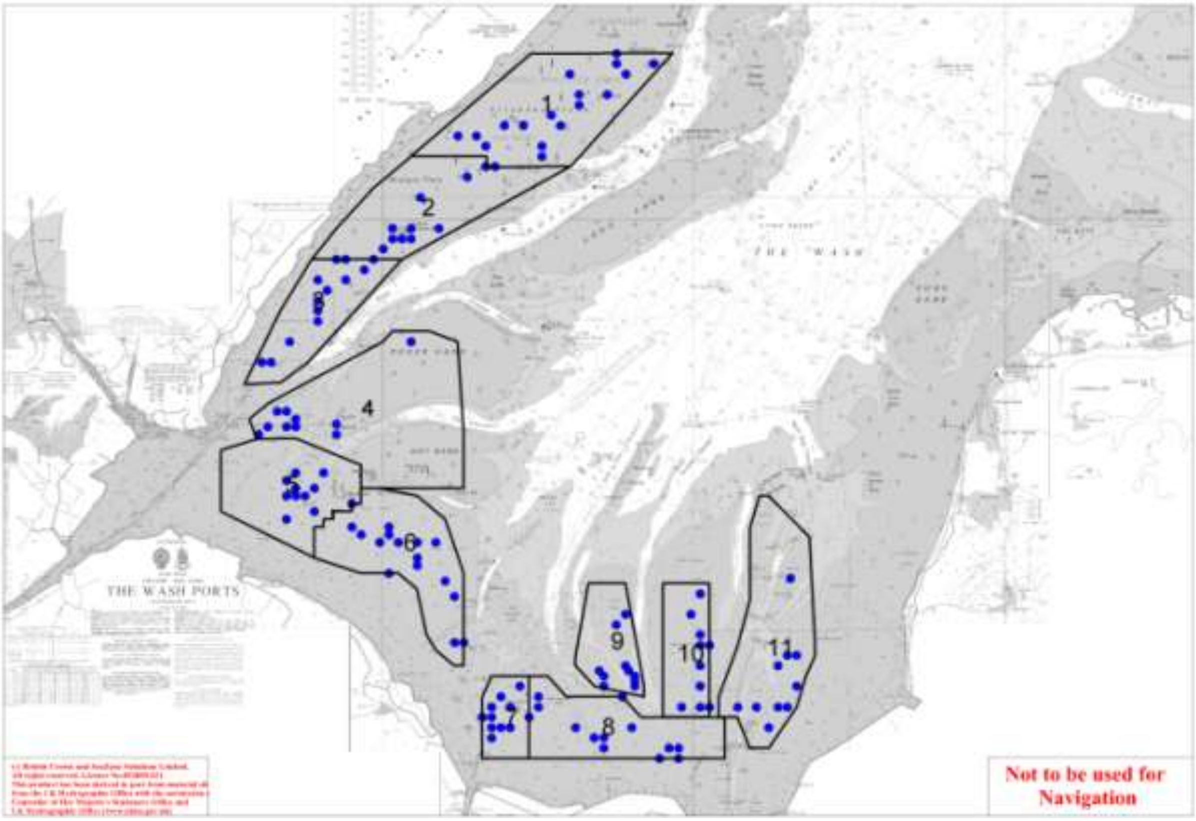


Figure 3.6.6 – Chart showing the positions of the stations sampled during the study

Total cockle numbers

Figure 3.6.7 shows the total number of cockles found in the samples from each area at the time of the spring surveys and when sampled again in June. This chart clearly shows the variability in cockle densities that were present on the different beds of the Wash, with only low densities present on the Friskney, Wrangle, Whiting Shoal, Thief, Pandora, Peter Black and Styleman's sands; moderate densities at Butterwick and high densities present at Black Buoy, Mare Tail, Holbeach, Inner Westmark Knock, Breast and Daseley's.

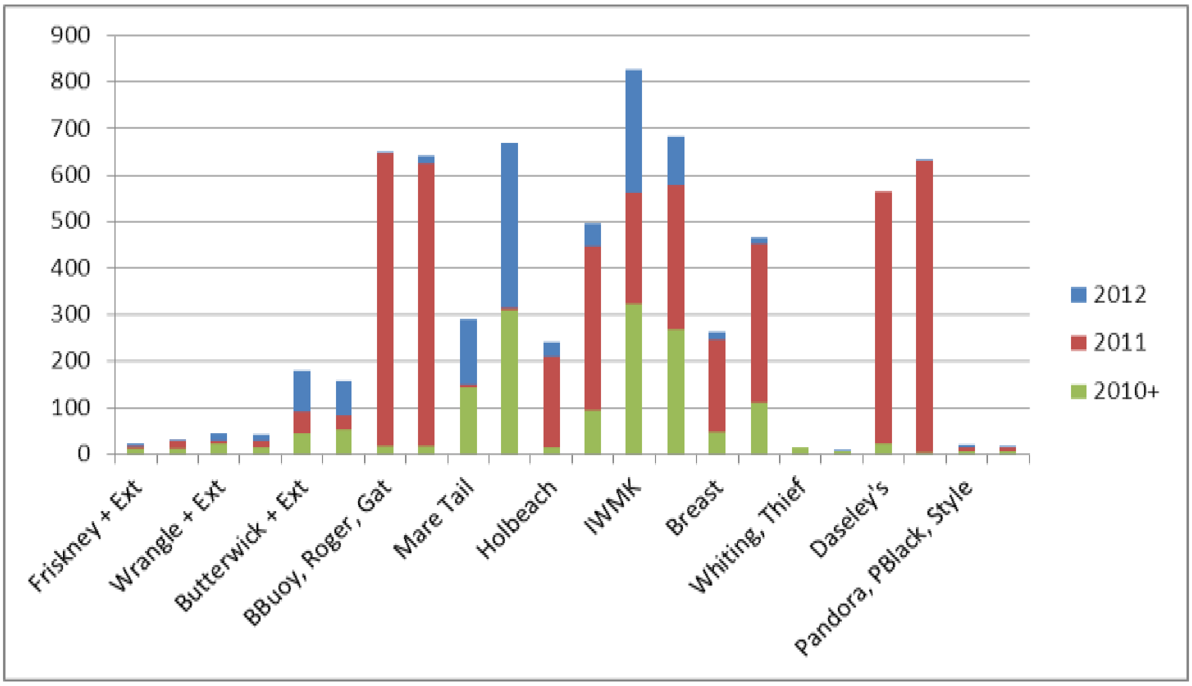
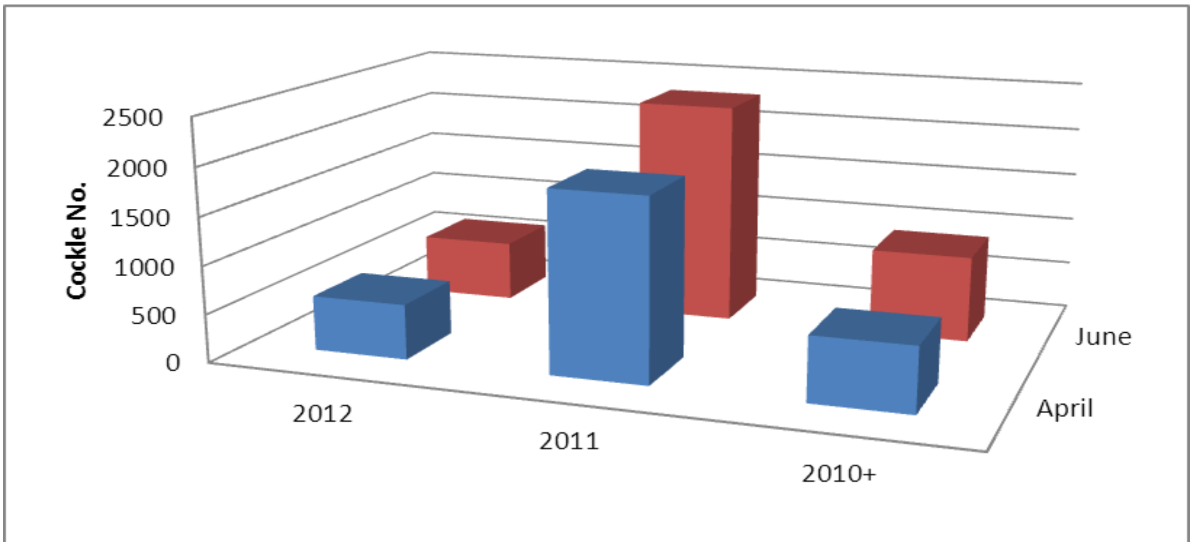


Figure 3.6.7 – Chart showing the numbers of cockles found in the samples from each area at the time of the spring surveys and in June



	2012	2011	2010+
April	573	1880	669
June	631	2317	898

Figure 3.6.8 – Chart showing the total number of cockles from each age cohort collected during the sampling in April and June

Figure 3.6.8 shows the total number of cockles from each year-class collected in the samples during the study. On both sampling occasions the dominant cohort was found to be from the 2011 year-class, which represented 60% of the population. While this cohort dominated the Black Buoy, Holbeach, Inner Westmark Knock, Breast and Daseley's beds, it was only present in low numbers in the other zones.

It was hoped during this study to use the differences in cockle numbers between the two surveys to determine the extent of any mortality that may have occurred between surveys. Although two samples had been taken from each station on both occasions in order to reduce any localised variations in cockle numbers that might be present, these localised variations proved too high for any estimation of mortality to be attempted. Figure 3.6.8 shows that rather than observing a deficit in cockle numbers between the two sampling occasions, the overall number of cockles collected in June was 23% higher than collected during the initial surveys. Although these increases were statistically significant individually at some of the zones (Mare Tail, Holbeach and the Breast sands), analysis using paired t-tests of all of the samples collected found that overall the difference was not significant at a $p<0.05$ level of confidence. In order to assess mortality using this method, more replicates would be required at each station to reduce the impact of local variations in density.

Impact of growth

Zone 1 – Friskney

Figure 3.6.9 shows the cockles in Zone 1 increased in width slightly between the initial survey in April and the subsequent survey in June. This is more apparent in figure 3.6.10, which shows the mean widths of the cockles in each of the three age cohorts from this population. Similarly, figure 3.6.11 shows the increase in mean weight of these cockles between the two sampling periods. Although both of these latter two figures show increases in mean width and weight, the low numbers of cockles in the samples from this zone mean the 95% confidence intervals are poor.

Taking the whole population of the cockles sampled from Zone 1 into account, their mean weight was found to have increased from 7.23g in April to 9.48g in June, an increase of 31%. Excluding any impact that mortality may have had, if this figure was applied to the 566 tonnes of cockles estimated to be present in Zone 1 in April, their biomass would have increased to 742 tonnes. Also, as many of the 2012 cockles that had been <14mm width in April had attained a size of ≥14mm width in June, the proportion biomass of cockles that had attained 14mm width had increased from 92.2% to 99.2%.

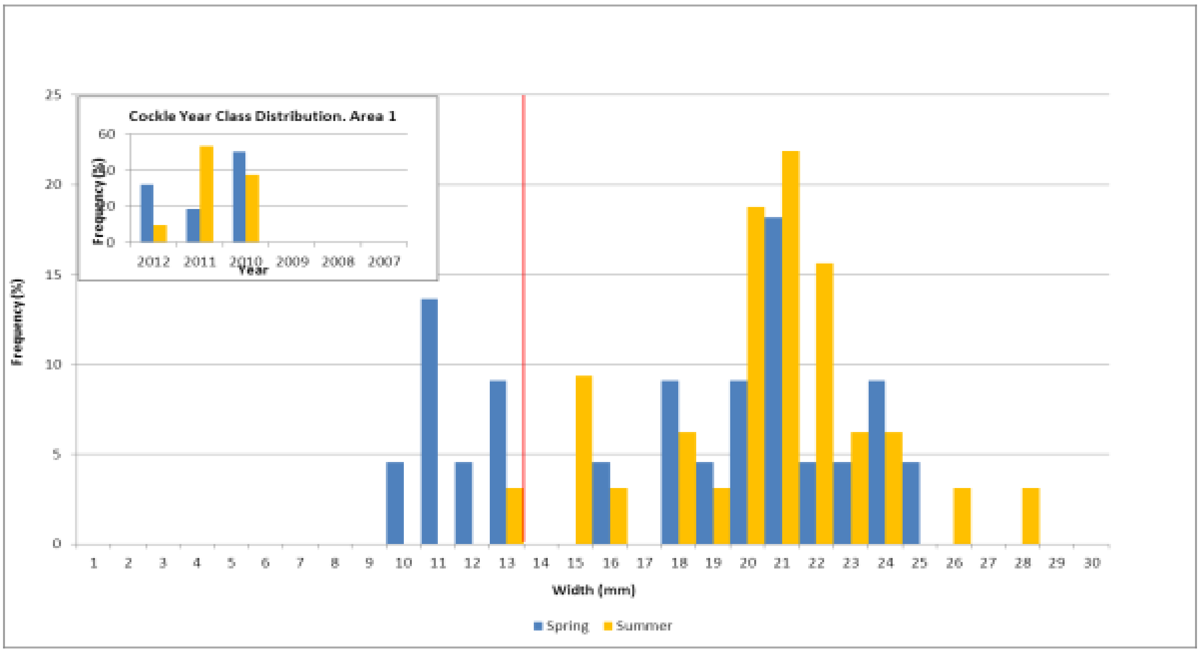


Figure 3.6.9 – Chart showing the cockle size frequency at Zone 1 in April and June

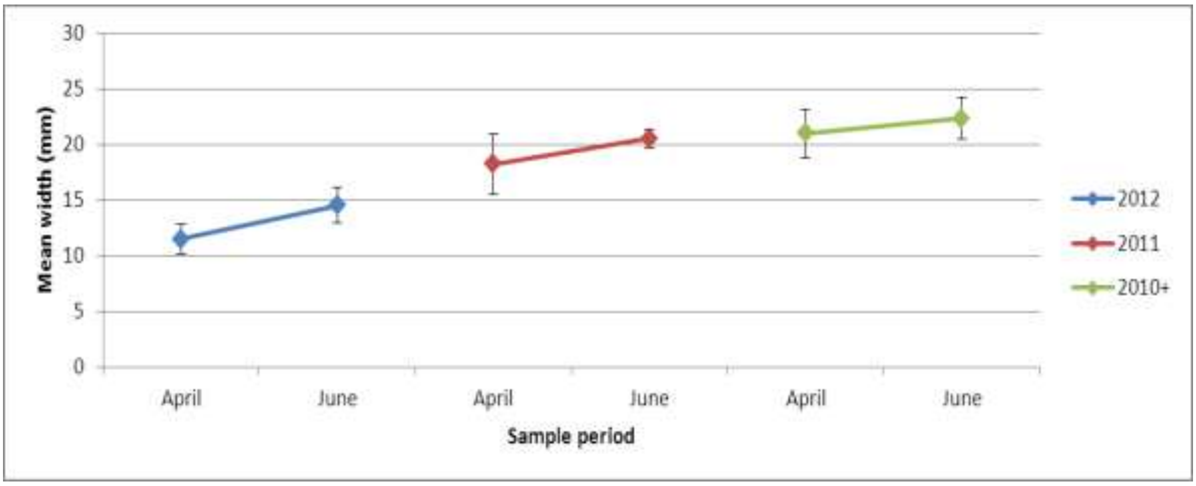


Figure 3.6.10 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 1 in April and June

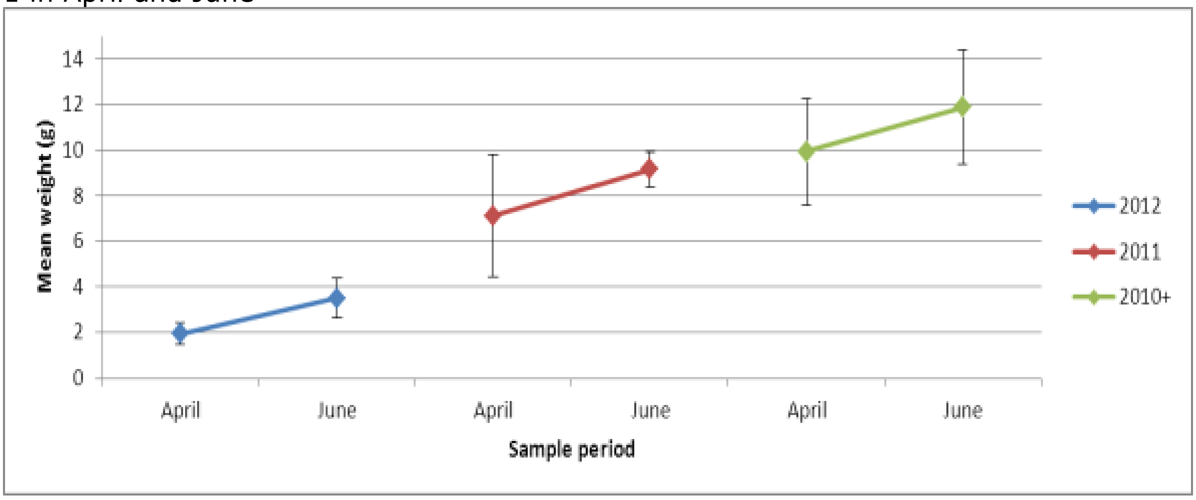


Figure 3.6.11 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 1 in April and June

Zone 2 - Wrangle

Figure 3.6.12 shows there was a similar growth among the cockles sampled in Zone 2 to that seen in Zone 1. Again this growth was most noticeable among the smaller cockles. Figures 3.6.13 and 3.6.14 show the differences in mean width and weight of the three age cohorts between the two sample periods. Increases can be seen in both the mean width and mean weight of all three age cohorts, but the 95% confidence limits for the mean weights of the 2011 and older cohorts are poor.

Overall, the mean weight of the cockles sampled from Zone 2 was found to have increased from 6.03g to 7.12g, an increase of 18%. If this figure is applied to the 808 tonnes of cockles estimated to have been present in this zone in April, the biomass would have increased to 955 tonnes (assuming zero mortality). Although some of the <14mm cockles had achieved 14mm between sampling periods, this number was less than seen in Zone 1. The proportion biomass of ≥14mm cockles had, therefore, increased to a lesser extent from 92.1% to 93.7%.

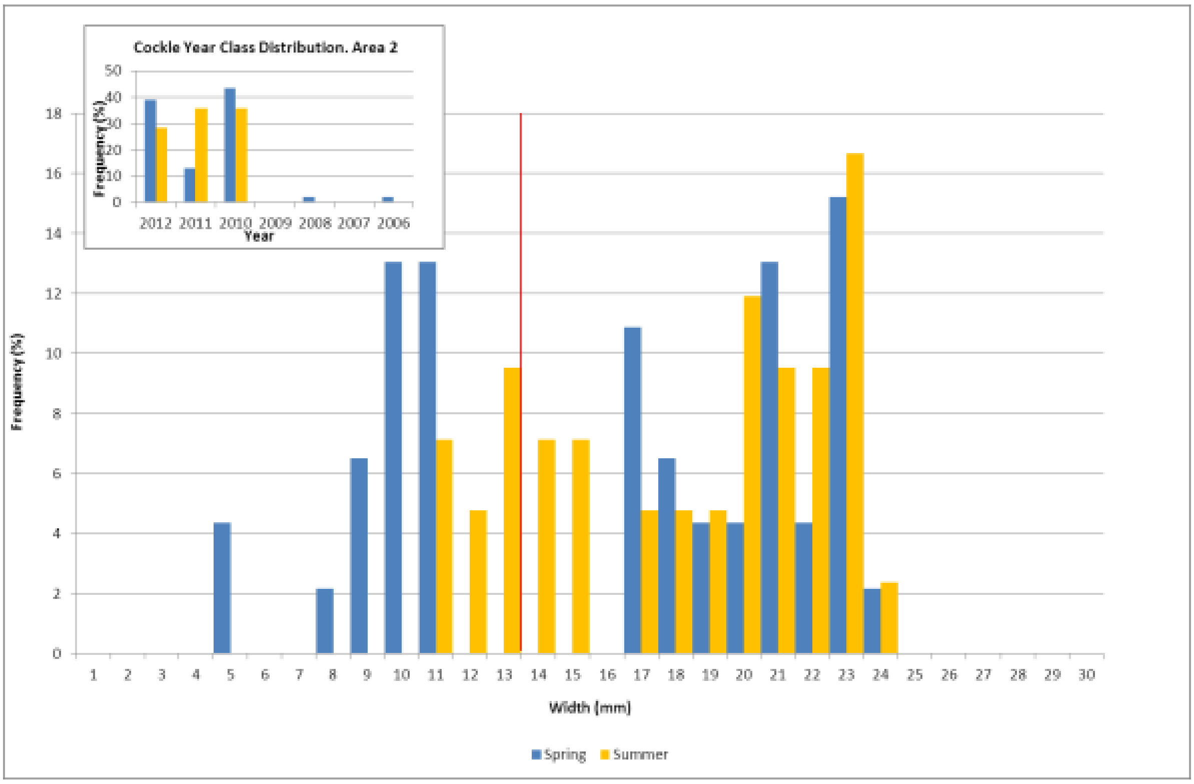


Figure 3.6.12 – Chart showing the cockle size frequency at Zone 2 in April and June

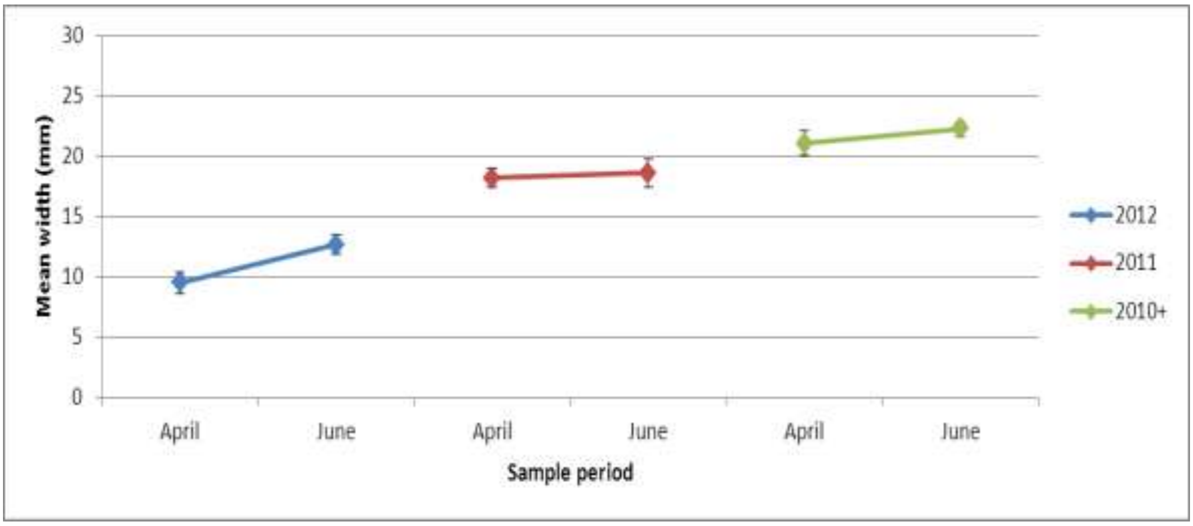


Figure 3.6.13 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 2 in April and June

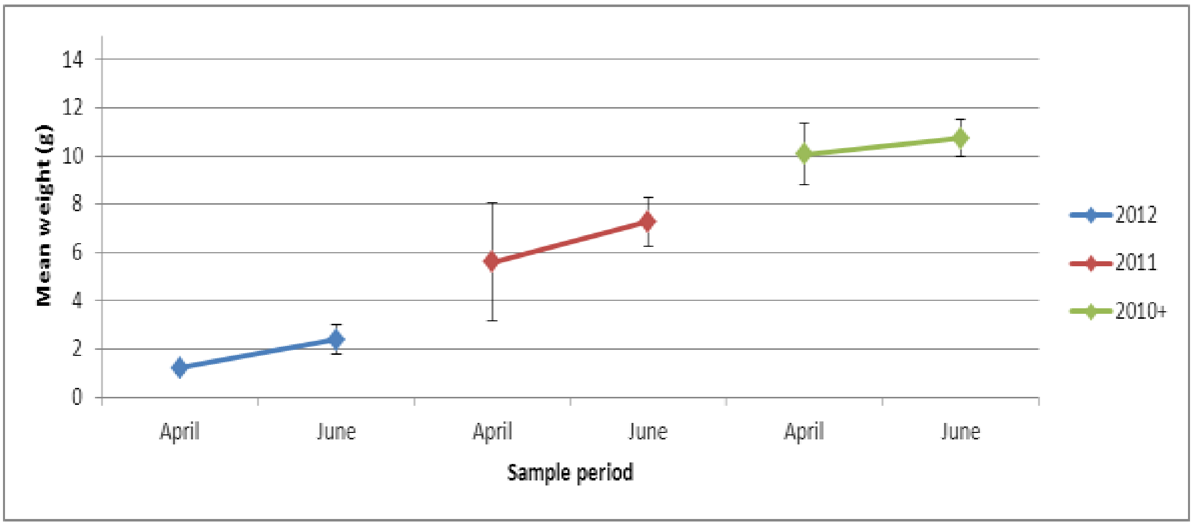


Figure 3.6.14 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 2 in April and June

Zone 3 - Butterwick

Figures 3.6.15 to 3.6.17 show the 2012 year-class cockles in Zone 3 had grown well between April and June but had not attained 14mm width during this period. Little growth was evident among the older cockles from this zone. The 95% confidence limits in figure 3.6.16 are narrow, enabling assessments of increases in mean width to be conducted accurately. Figure 3.6.17 shows a slight decrease in mean weight for the 2011 cohort between sampling occasions, but this difference is possibly due to the wider 95% confidence limits in the April sample from this group rather than an actual decrease in weight.

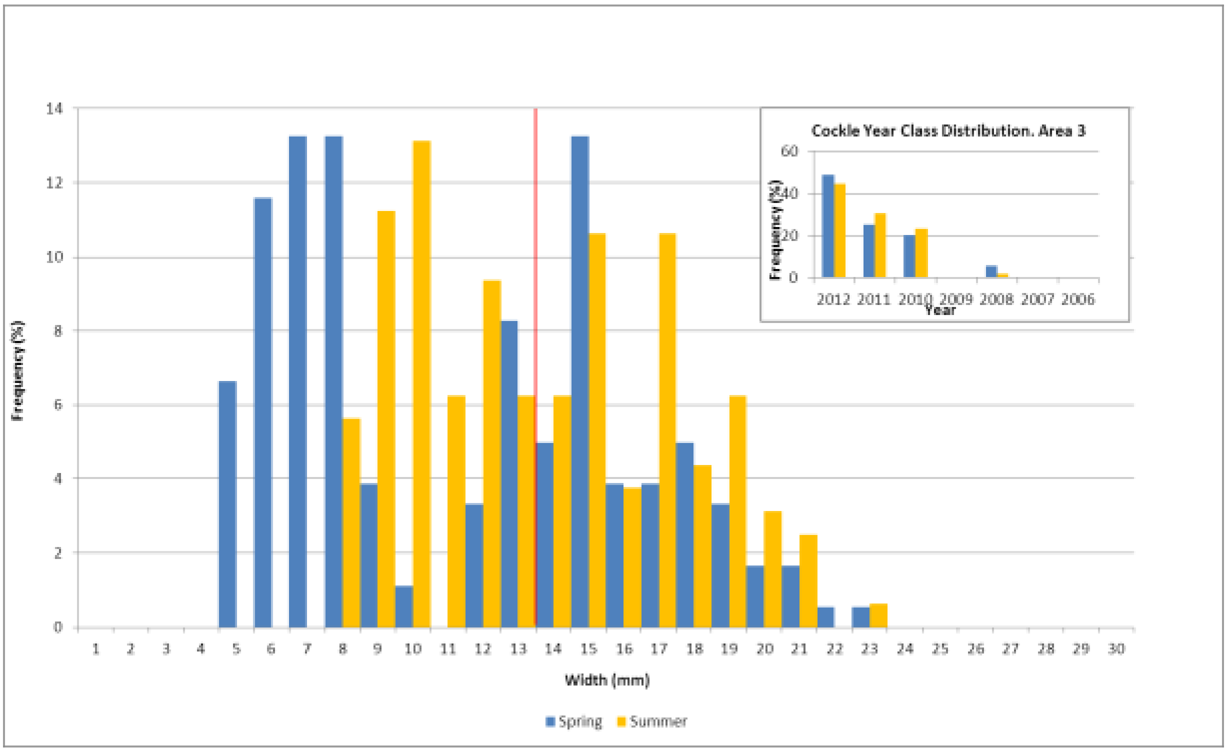


Figure 3.6.15 – Chart showing the cockle size frequency at Zone 3 in April and June

Overall, the mean weight of the cockles sampled from Zone 3 was found to have increased 26.4% from 2.67g to 3.37g. If this figure is applied to the 1,143 tonnes of cockles estimated to be present in this zone in April, the biomass would have increased to 1,433 tonnes (again, assuming no mortality had occurred). Because the cockles <14mm width had grown at a faster rate than those ≥14mm width, and none had attained 14mm width between sampling occasions, the proportion biomass of ≥14mm cockles in the population had declined slightly from 70.6% to 68.5%.

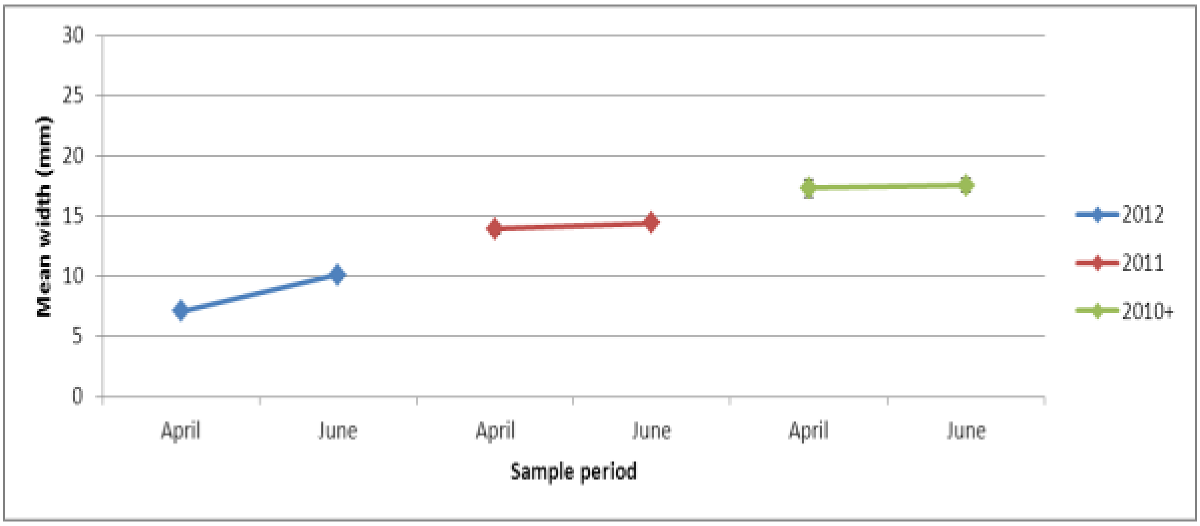


Figure 3.6.16 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 3 in April and June

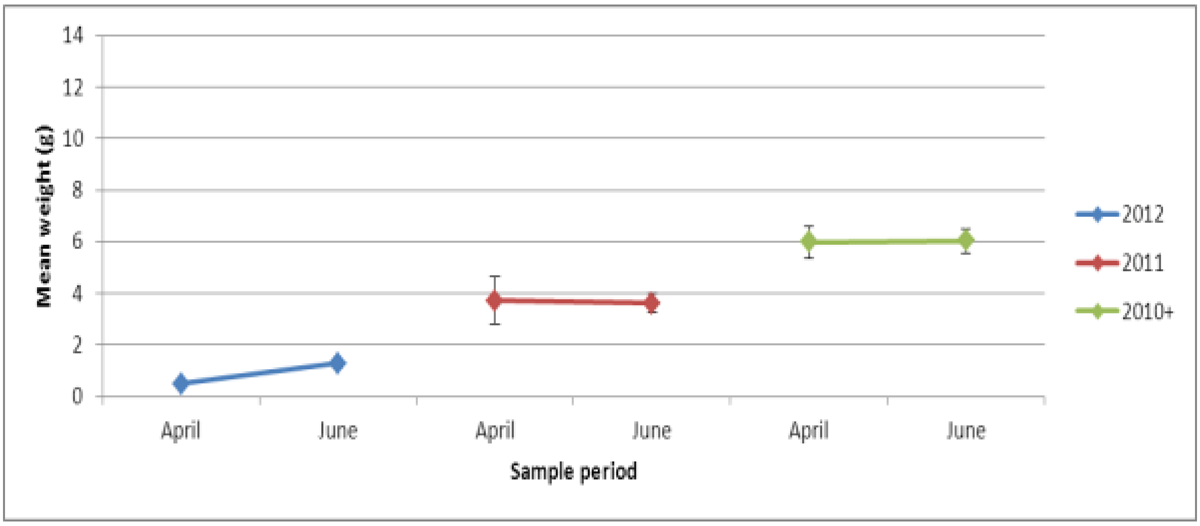


Figure 3.6.17 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 3 in April and June

Zone 4 – Black Buoy, Roger, Gat

From figure 3.6.18 it can be seen that the cockles collected from this zone are dominated by individuals from the 2011 cohort. Because large numbers of cockles were sampled from this cohort, the 95% confidence limits for the mean width and weight estimations are good. Figures 3.6.19 and 3.6.20 show that growth was poor among this group between April and June. Growth appeared better among the other two cohorts from this area, but because of the low cockle numbers in the samples, their 95% confidence limits are poor.

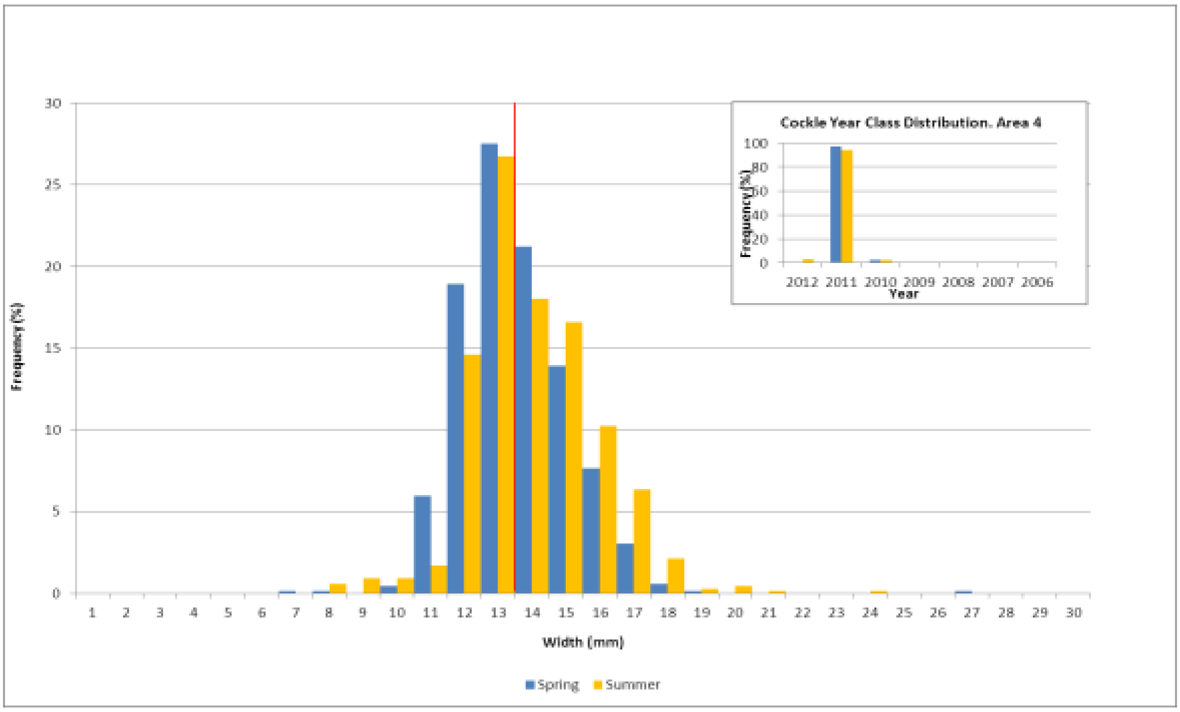


Figure 3.6.18 – Chart showing the cockle size frequency at Zone 4 in April and June

The mean weight of the whole population was found to have increased from 3.15g to 3.58g, a gain of 13.8%. If this figure is applied to the 3,049 tonnes of cockles estimated to be present in this zone in April, the biomass would have grown to 3,469 tonnes. This figure assumes no mortality had occurred between surveys. In April the proportion biomass of cockles that had attained 14mm width was 35.7%. Although growth had been relatively poor on this bed, because some of the 12-13mm cockles had attained 14mm width by June, this proportion had increased to 45.4%.

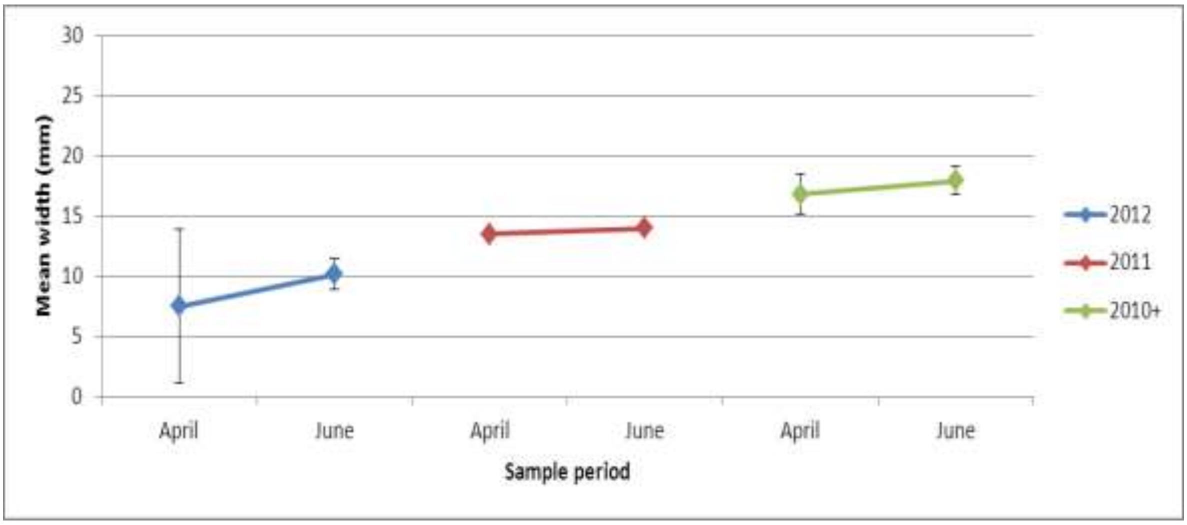


Figure 3.6.19 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 4 in April and June

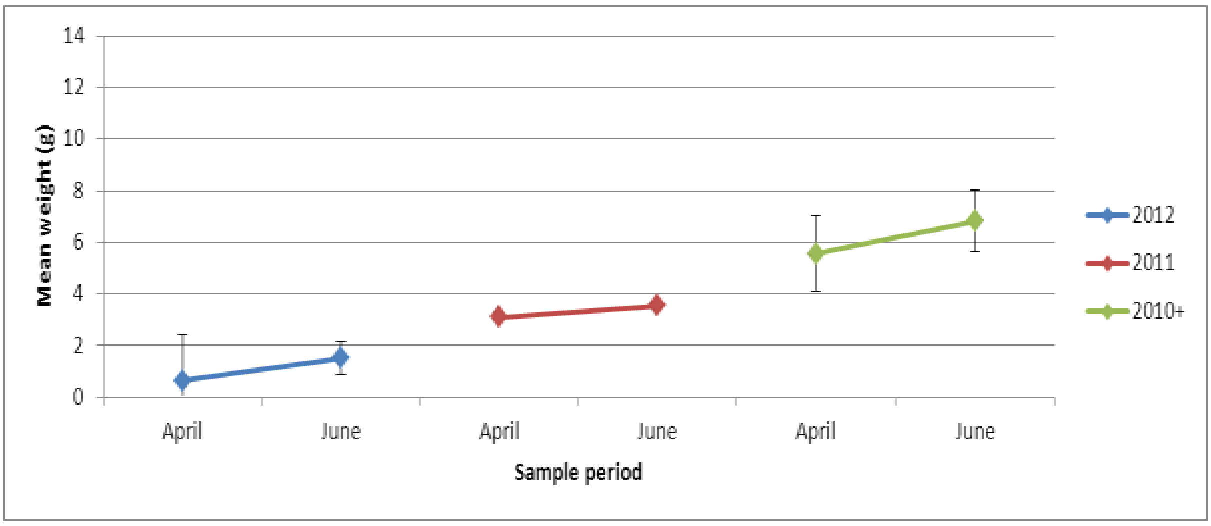


Figure 3.6.20 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 4 in April and June

Zone 5 – Mare Tail

Figure 3.6.21 shows the cockles collected from Zone 5 were dominated by individuals from the 2012 and 2010+ cohorts, with few 2011 year-class cockles present. The large numbers of 2012 and 2010+ cockles provided good 95% confidence limits when estimating their mean widths and weights. These limits were poorer for the 2011 cohort, whose numbers were much lower. Figures 3.6.22 and 3.6.23 shows that while there had been growth to the 2012 year-class cockles, the 2010+ cohort had actually decreased in mean width and weight. This is possibly due to some of the larger cockles from this cohort dying between April and June. These two figures show that the 2011 year-class individuals had grown well, but the 95% confidence limits for this cohort are poor.

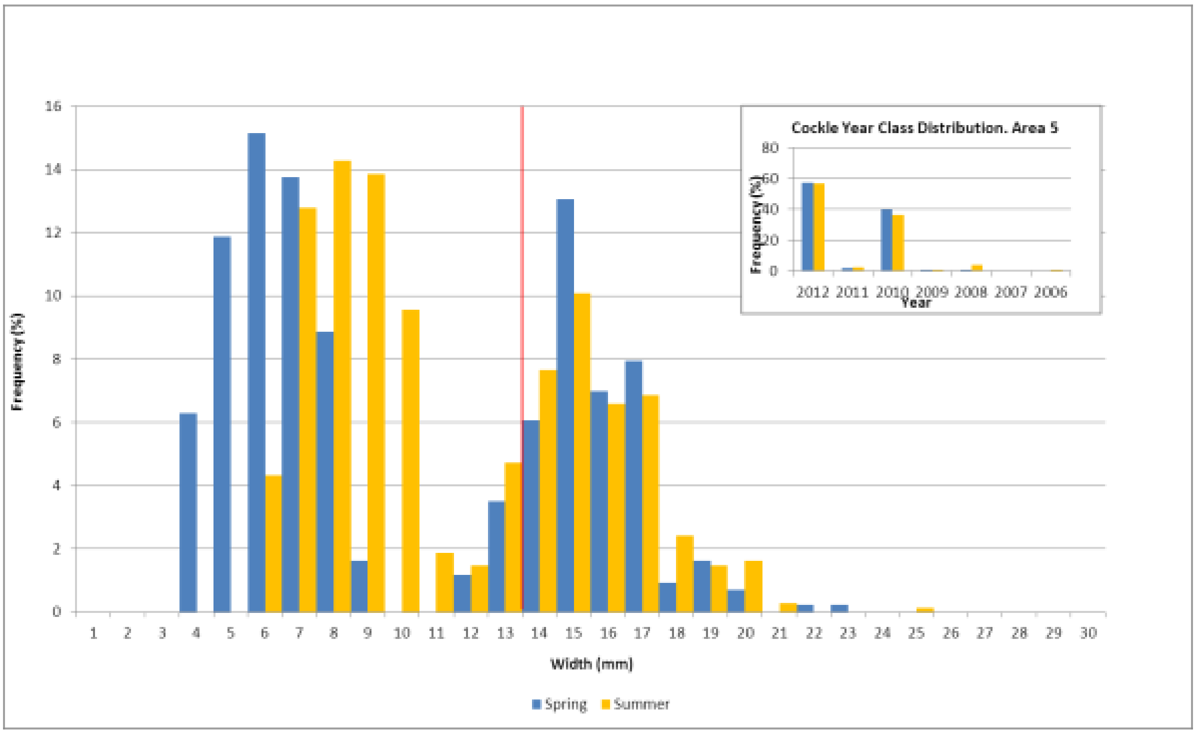


Figure 3.6.21 – Chart showing the cockle size frequency at Zone 5 in April and June

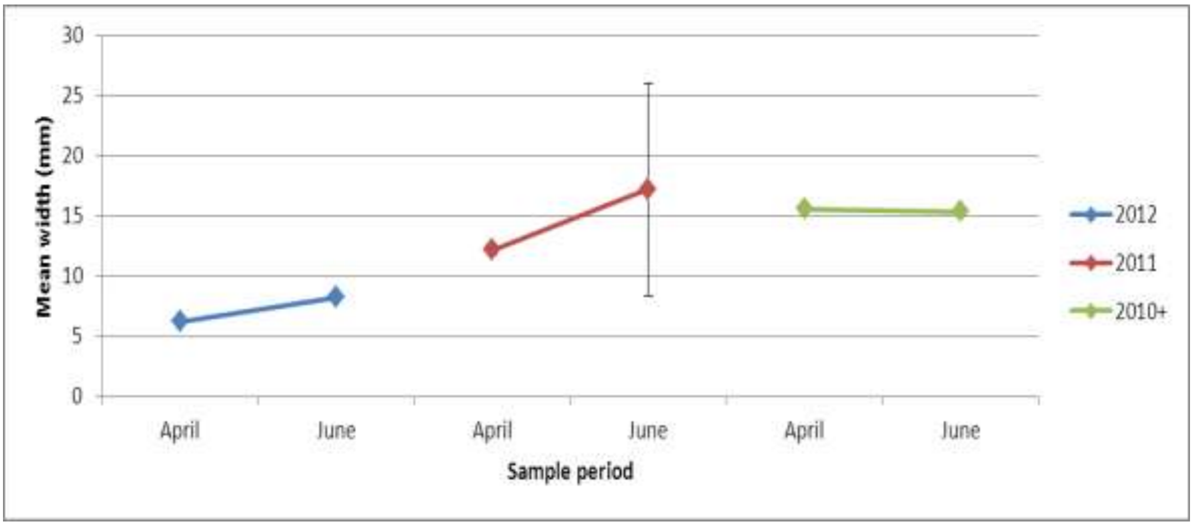


Figure 3.6.22 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 5 in April and June

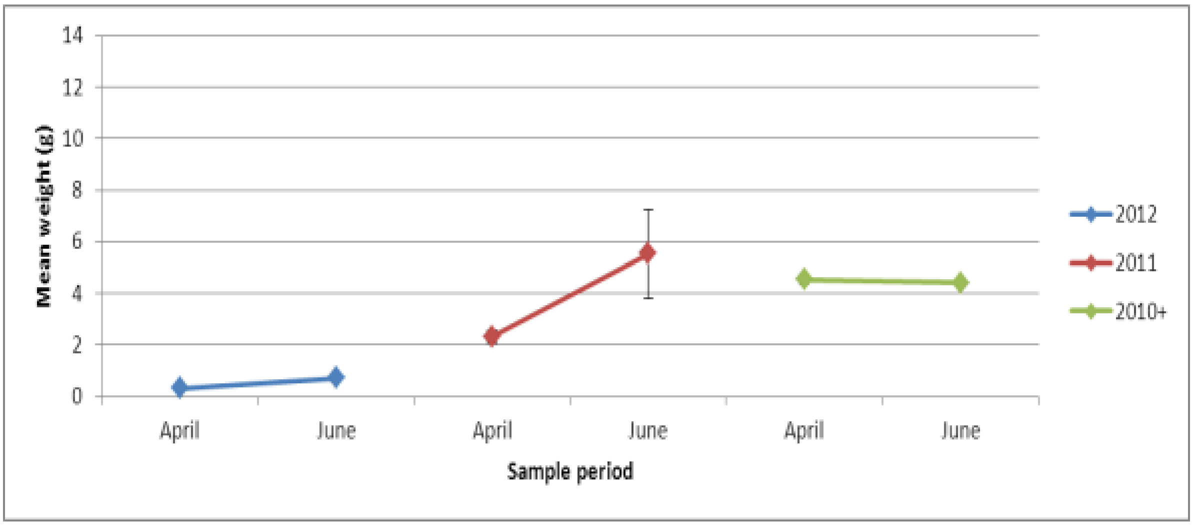


Figure 3.6.23 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 5 in April and June

When taking the whole population from this zone into account, their mean weight remained unchanged at 2.47g. Because there had been some growth among the smaller cockles, and possible mortality among the larger cockles, the proportion biomass of those cockles that had attained 14mm width was found to have decreased from 47.9% to 33.7%.

Zone 6 - Holbeach

Figure 3.6.24 shows that the cockles collected in the samples from this zone were dominated with individuals from the 2011 year-class cohort. Figures 3.6.25 and 3.6.26 show that growth had been poor among this cohort, but that the individuals in the 2012 cohort had grown well. These figures suggest that the 2010+ cohort had decreased in mean size between surveys, but this may be due to the poor 95% confidence limits for this group.

Overall, the mean weight of the population from this zone had increased 20.7% from 2.39g to 3.88g. If these figures were applied to the cockle stock of 3,161 tonnes estimated to be present in April, the population is estimated to have potentially increased to 3,815 tonnes by June (again, assuming no mortality had occurred between surveys). The recruitment of some of the <14mm width 2011 year-class individuals to the ≥14mm width population assisted the proportion biomass of ≥14mm width cockles to increase from 44.1% to 51.5%.

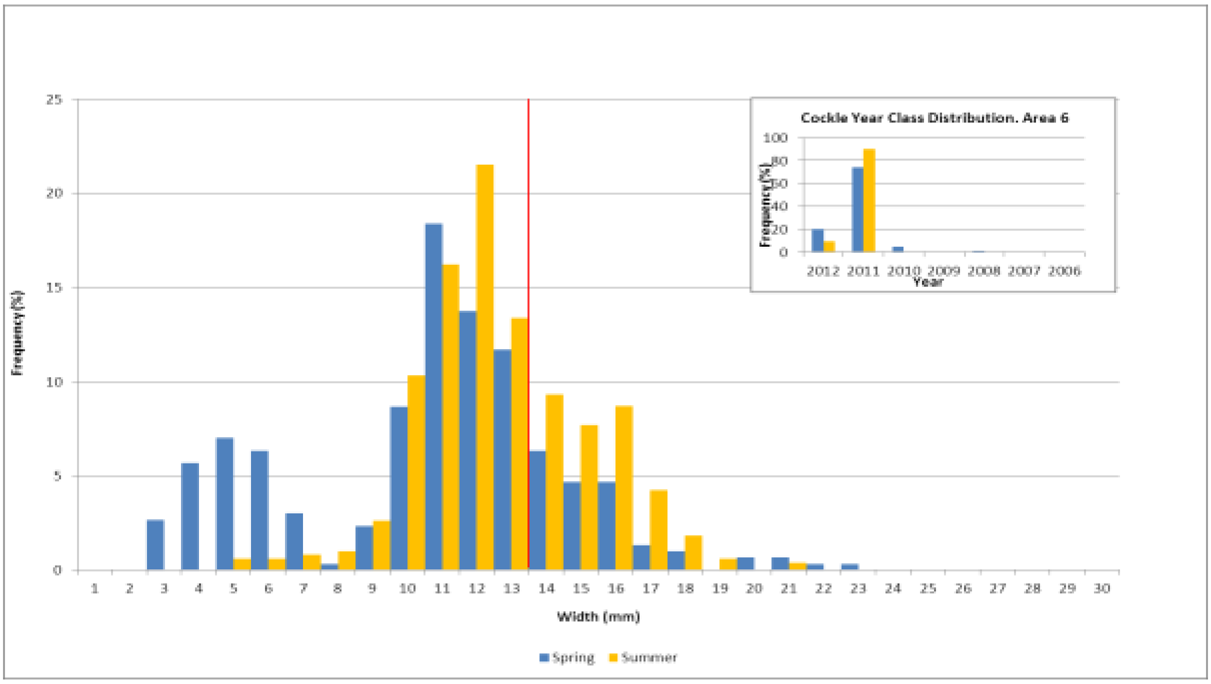


Figure 3.6.24 – Chart showing the cockle size frequency at Zone 6 in April and June

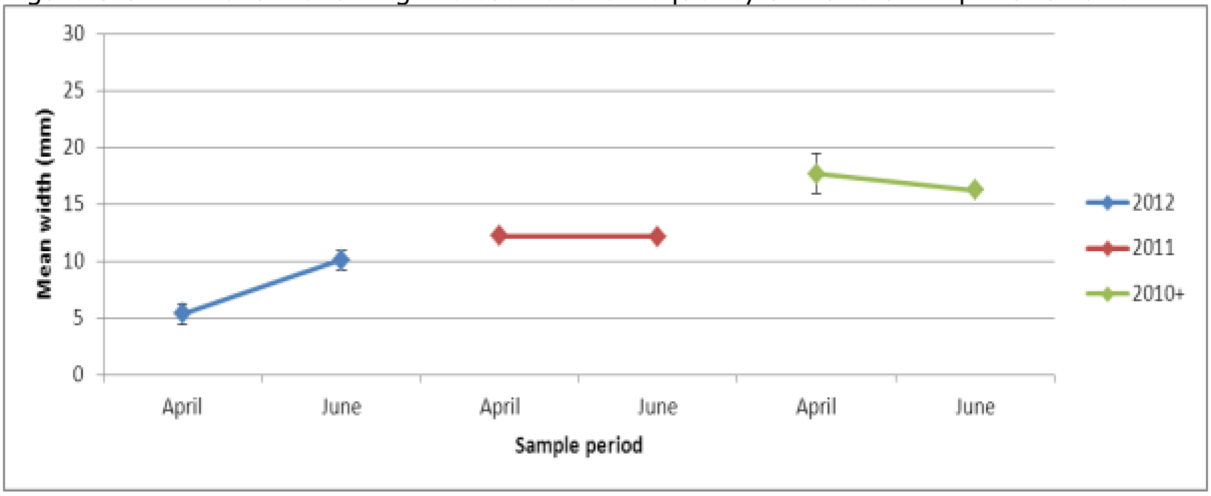


Figure 3.6.25 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 6 in April and June

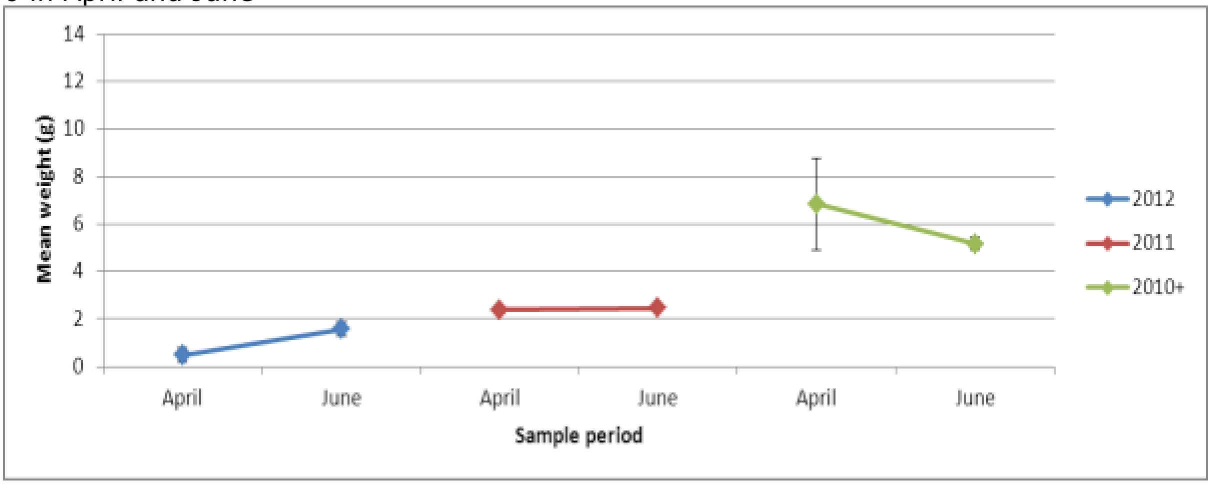


Figure 3.6.26 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 6 in April and June

Zone 7 – Inner Westmark Knock

Figure 3.6.27 shows the samples collected from Zone 7 were dominated by the 2011 and 2010+ cohorts. This and figures 3.6.28 and 3.6.29 show that growth had been good within all of the cohorts on this sand. Due to the large numbers of cockles collected in the samples from this zone, the 95% confidence limits were good.

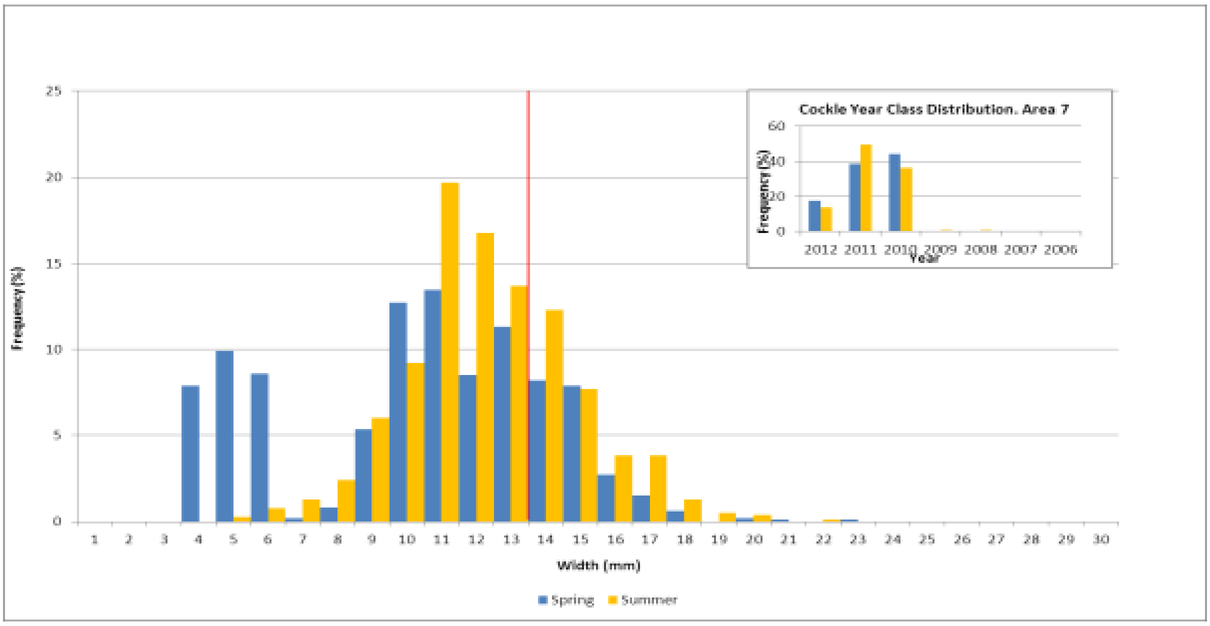


Figure 3.6.27 – Chart showing the cockle size frequency at Zone 7 in April and June

Across the whole population the mean weight was found to have increased 45.6% from 1,71g to 2.48g. If no mortalities had occurred, this increase would have helped the stocks in this zone to have increased from an estimated 2,252 tonnes in April to 3,279 tonnes. The proportion biomass of ≥14mm width cockles in this zone was found to have increased from 58.4% to 62.0%.

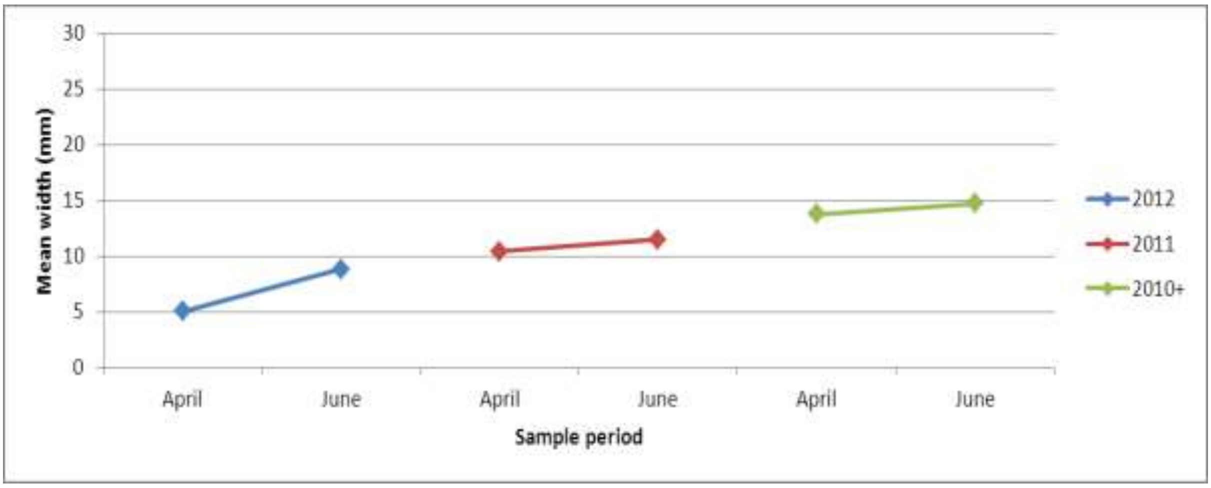


Figure 3.6.28 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 7 in April and June

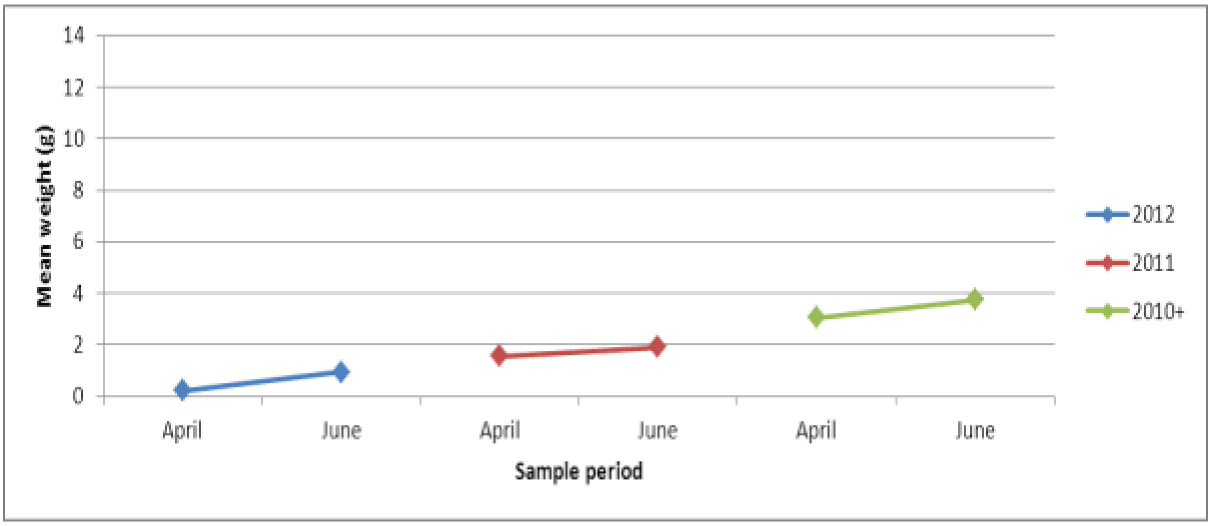


Figure 3.6.29 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 7 in April and June

Zone 8 – Breast sand

Figure 3.6.30 shows that the cockles collected from Zone 8 were dominated by individuals from the 2011 year-class cohort. Figures 3.6.31 and 3.6.32 indicate that the three age cohorts experienced differing growth effects on this sand. While the dominant 2011 cohort had increased slightly in mean width and weight, the mean sizes of both the 2012 and 2010+ cohorts were found to have decreased. These declines could be an artefact of the smaller numbers of cockles collected from these latter two cohorts or a result of mortality among the larger individuals between surveys.

Overall the mean weight of the cockles from this zone was found to have increased 13.8% from 2.64g to 3.00g. If these figures are applied to the stock of 3,473 tonnes estimated to be present in this zone in April, had there been no mortality, the stock could have grown to 3,951 tonnes.

The proportion biomass of ≥14mm width cockles on this bed was found to have declined slightly between surveys from 58.9% to 58.5%.

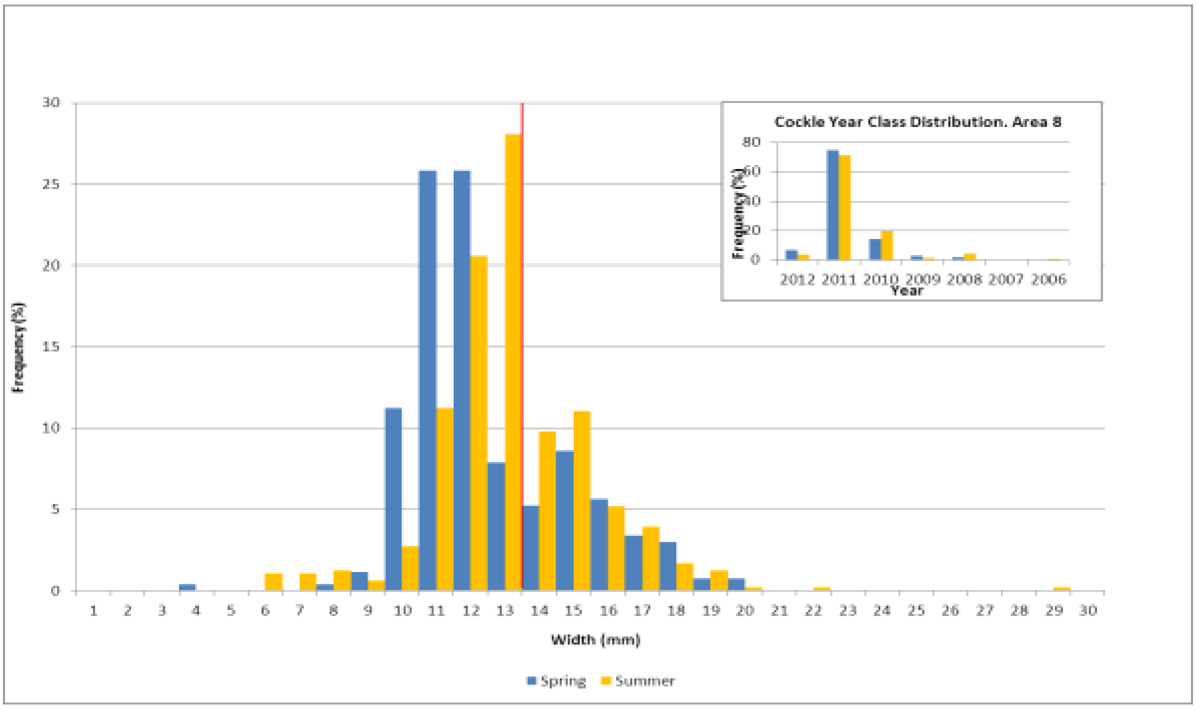


Figure 3.6.30 – Chart showing the cockle size frequency at Zone 8 in April and June

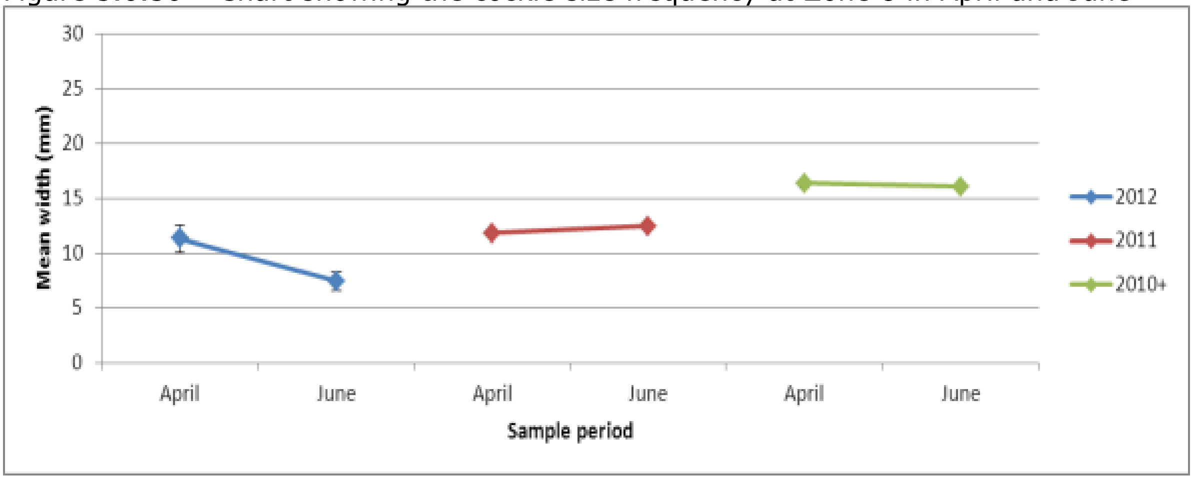


Figure 3.6.31 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 8 in April and June

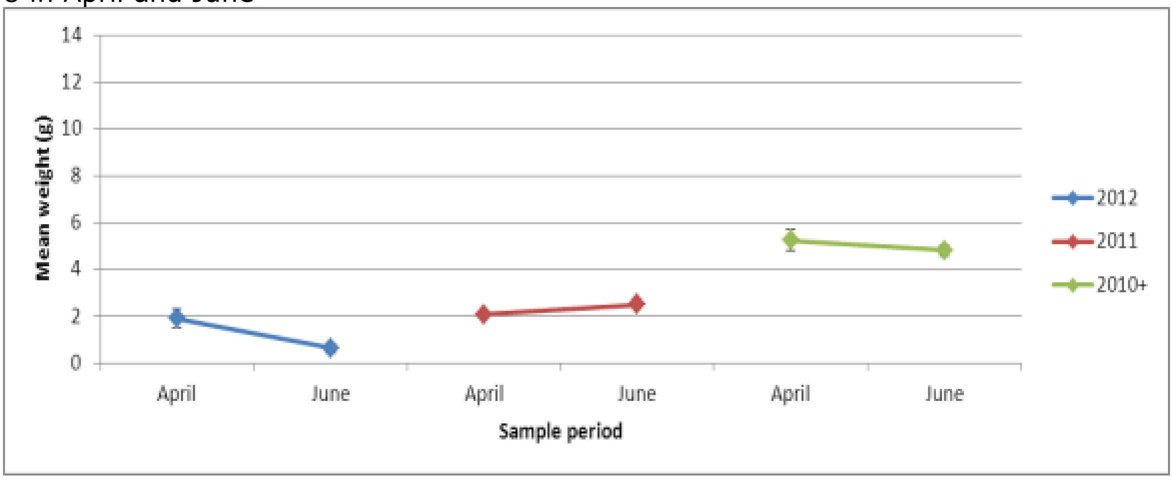


Figure 3.6.32 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 8 in April and June

Zone 9 – Whiting Shoal, Thief

The cockle densities were so low in this zone, only 26 cockles were found in the samples over the course of both surveys. Figure 3.6.33 shows that the majority of these were surviving remnants from the 2006 year-class cohort. Insufficient cockles from the 2012 and 2011 cohorts were found to enable an estimation of their growth rates. Figures 3.6.34 and 3.6.35 suggest that the mean size of the 2010+ year-class cockles had declined. Due to the low numbers of cockles in this dataset, however, the 95% confidence limits are poor.

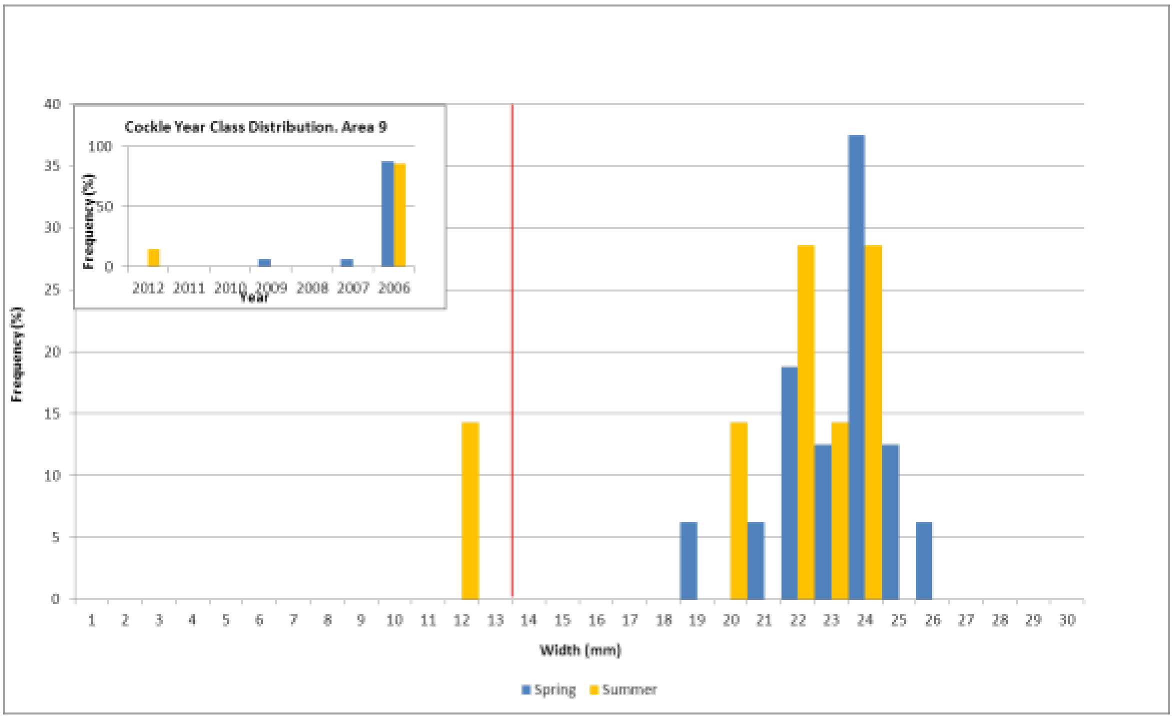


Figure 3.6.33 – Chart showing the cockle size frequency at Zone 9 in April and June

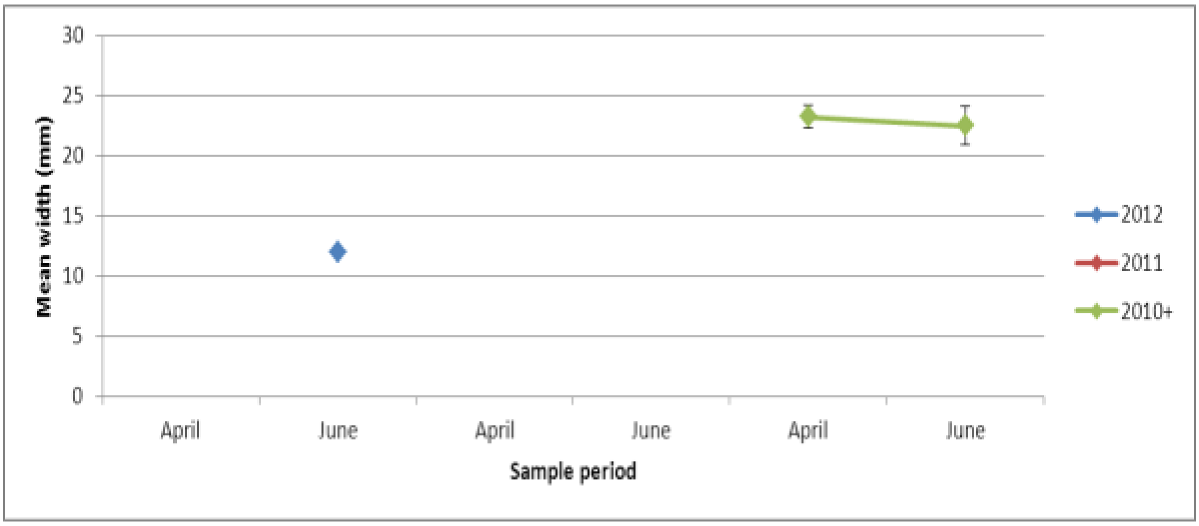


Figure 3.6.34 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 9 in April and June

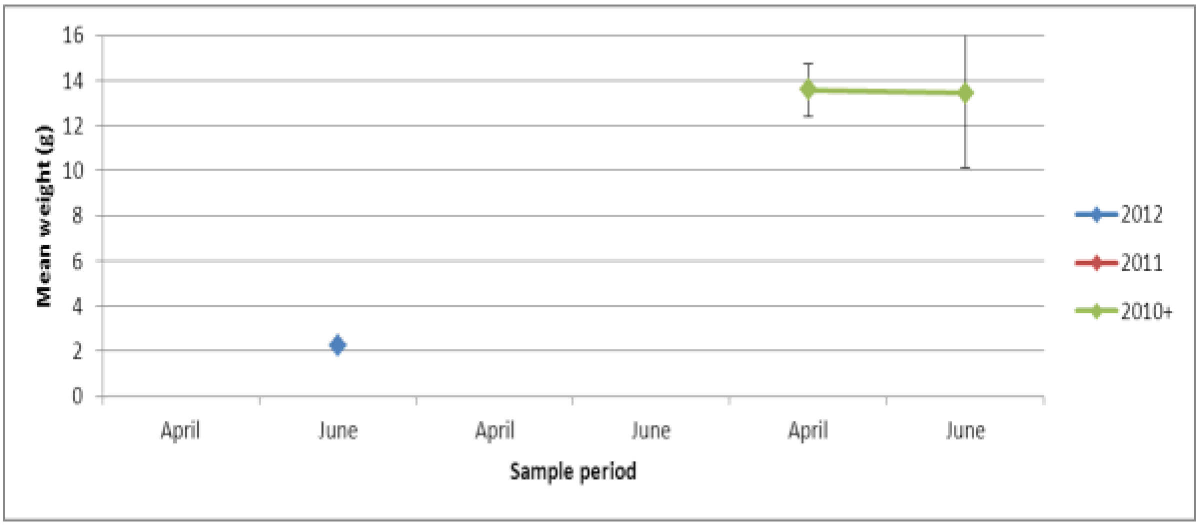


Figure 3.6.35 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 9 in April and June

Bearing in mind the low confidence in this small dataset, the mean weight of cockles from this zone was calculated to have declined 12.9% from 13.59g to 11.83g. If these figures were to be applied to the biomass of 164 tonnes estimated to be present in April, the stock may have declined to 143 tonnes. This figure does not take into account any further losses that may have occurred as a result of possible mortalities.

Zone 10 – Daseley's

Figure 3.6.36 shows the stocks on this bed are dominated by the 2011 year-class cohort. These were present in sufficient numbers for an accurate estimation of their growth rate to be made (figures 3.6.37 and 3.6.38). Insufficient samples were collected from the 2012 cohort to make an estimation of growth. While there were sufficient 2010+year-class cockles to indicate this cohort had grown well, the 95% confidence levels were poor.

Across the whole population, the mean weight of the cockles on this bed was calculated to have grown 18.0% from 2.53g to 2.99g. Ignoring any impact from possible mortality, if these figures were applied to the stock of 2,721 tonnes estimated to be present in April, the stock would have grown to 3,212 tonnes. Because part of the population had attained 14mm width between the surveys, the proportion biomass of ≥14mm cockles had increased from 46.0% to 70.0%.

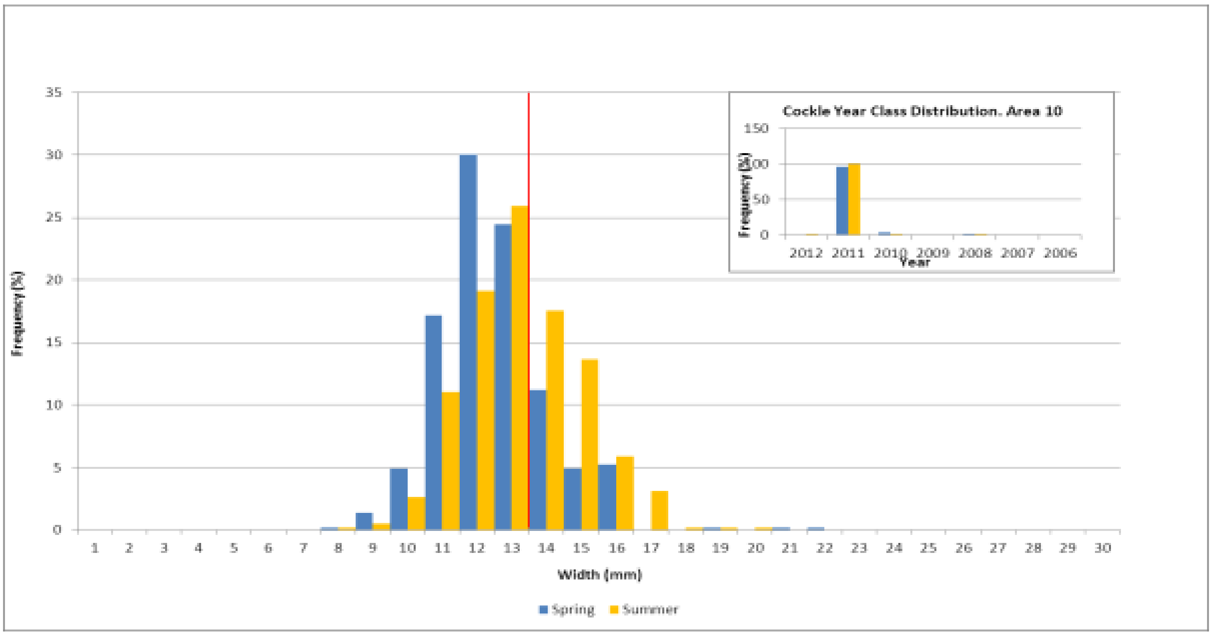


Figure 3.6.36 – Chart showing the cockle size frequency at Zone 10 in April and June

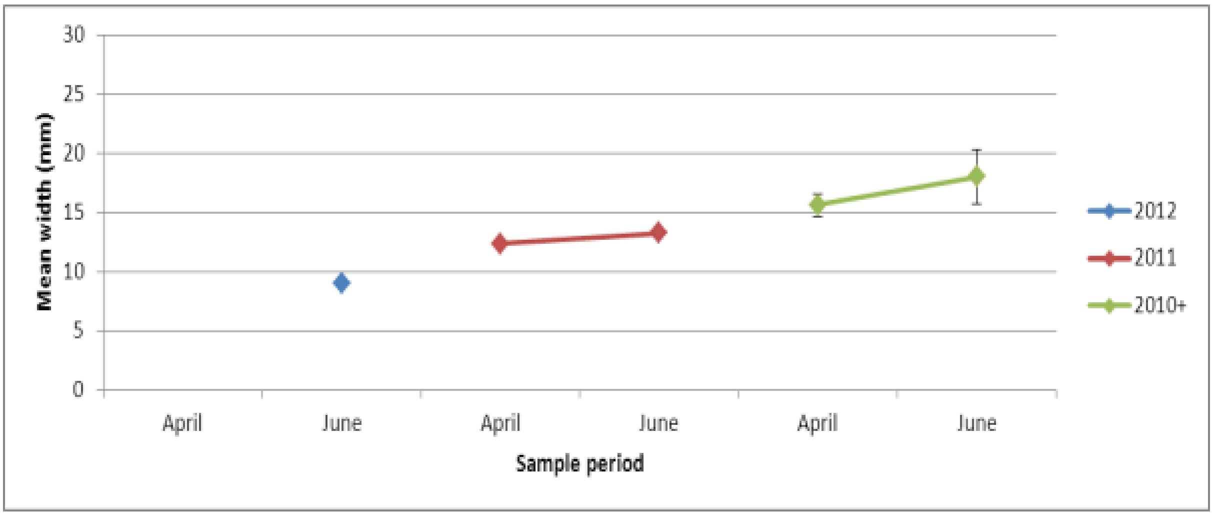


Figure 3.6.37 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 10 in April and June

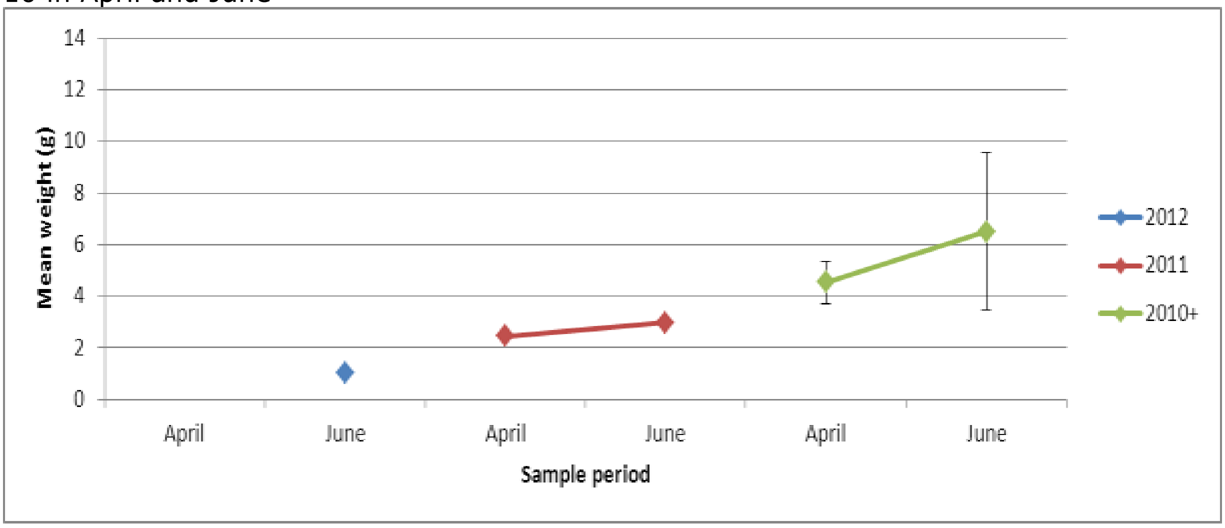


Figure 3.6.38 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 10 in April and June

Zone 11 – Pandora, Peter Black, Styleman's

This zone was found to only support low densities of cockles. Figure 3.6.39 shows these to be from a spread of age classes. Figures 3.6.40 and 3.6.41 suggests that growth had occurred in this zone, but the 95% confidence limits for the 2012 and 2010+ cohorts are poor. Although the confidence levels are poor, the mean weight of the whole population in this zone was estimated to have increased 31.7% from 2.87g to 3.78g. Ignoring the impact that possible mortalities may have had, if these figures were applied to the stock of 511 tonnes estimated to be present in April, the stock would have grown to 673 tonnes. Because part of the population had attained 14mm width between the surveys, the proportion biomass of ≥14mm cockles had increased from 54.8% to 87.0%.

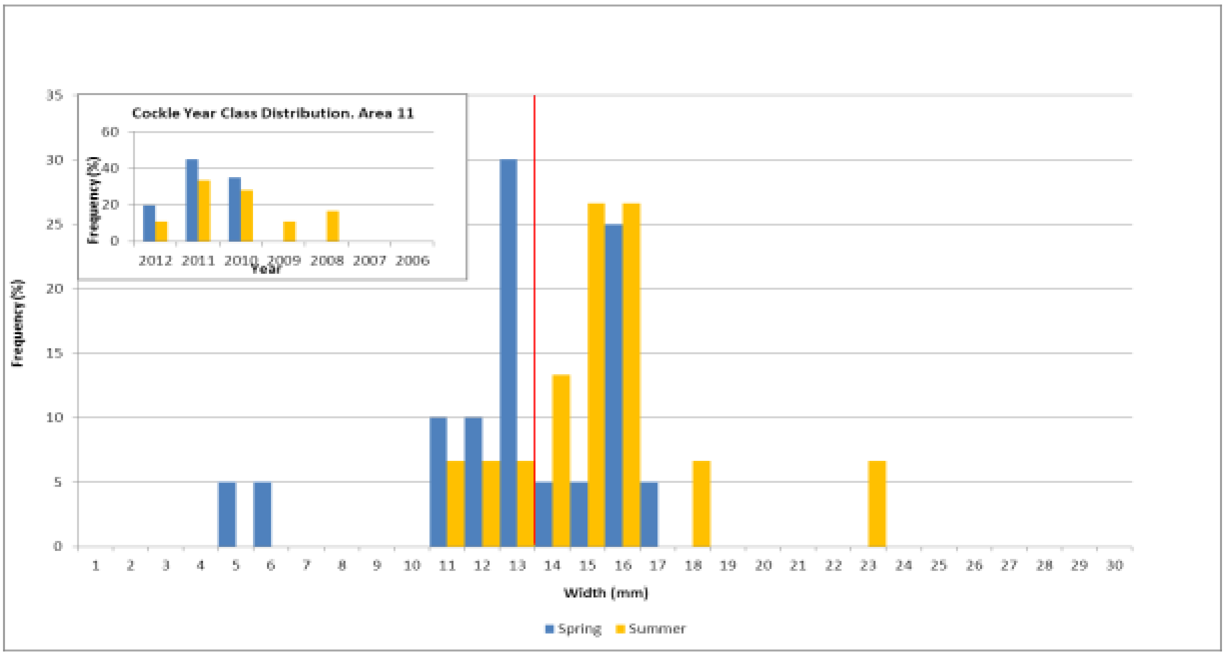


Figure 3.6.39 – Chart showing the cockle size frequency at Zone 11 in April and June

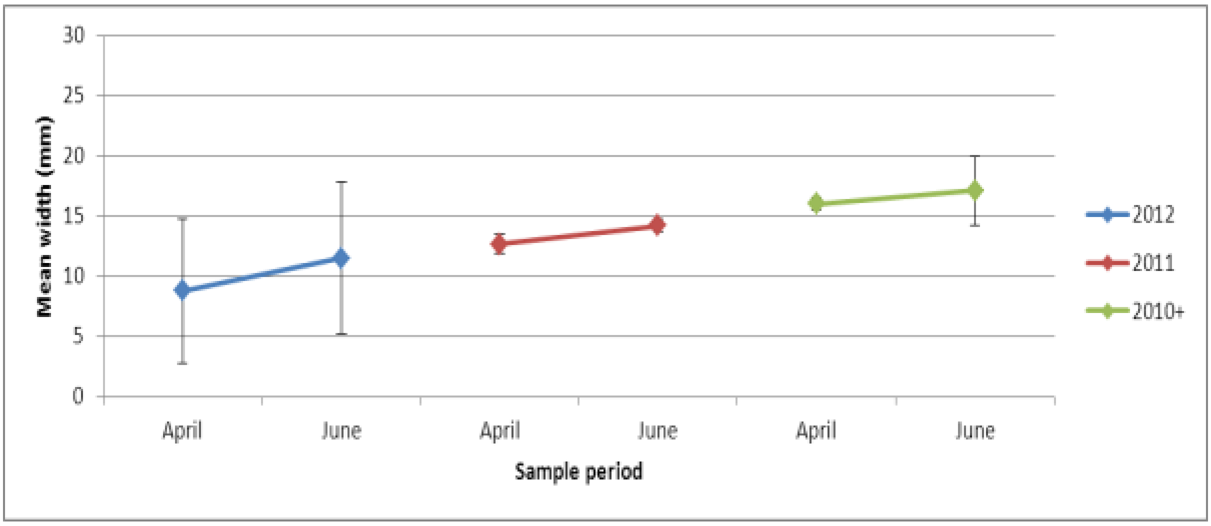


Figure 3.6.40 – Chart showing the mean width of cockles from the 3 age cohorts in Zone 11 in April and June

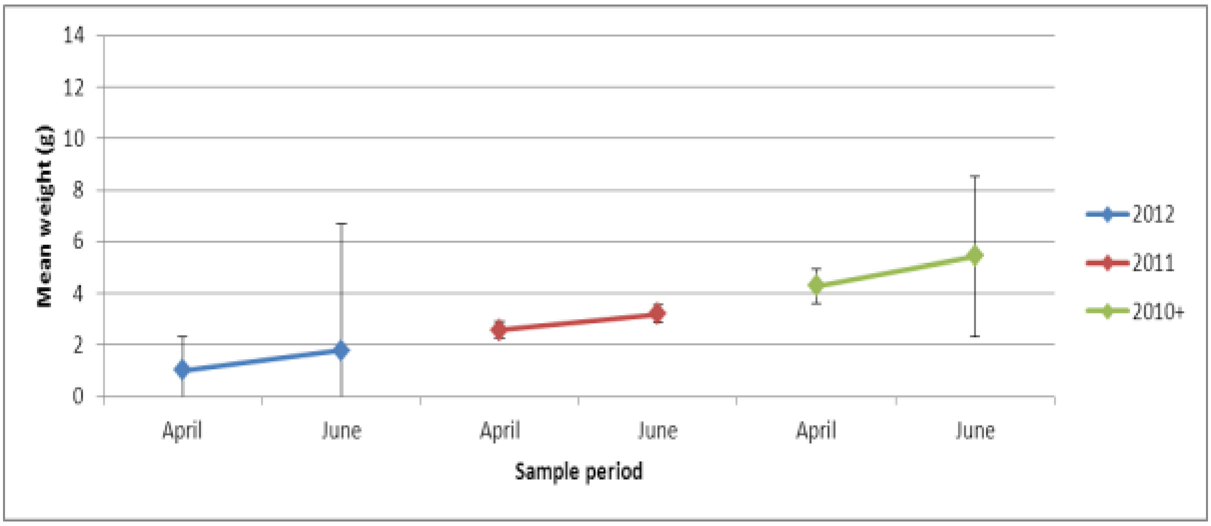


Figure 3.6.41 – Chart showing the mean weight of cockles from the 3 age cohorts in Zone 11 in April and June

Table 3.6.2 – Summary of the growth study data

		Mean weight (all ages) (g)			Stock biomass (t)		Proportion ≥14mm (%)	
Area	Sands	April	June	% Change	April	June	April	June
1	Friskney + Ext	7.23	9.48	31.0	566	742	92.2	99.2
2	Wrangle + Ext	6.03	7.12	18.2	808	955	92.1	93.7
3	Butterwick + Ext	2.67	3.37	26.4	1134	1433	70.6	68.5
4	BBuoy, Roger, Gat	3.15	3.58	13.8	3049	3469	35.7	45.4
5	Mare Tail	2.47	2.47	0.0	1976	1973	47.9	33.7
6	Holbeach	2.39	2.88	20.7	3161	3815	44.1	51.5
7	IWMK	1.71	2.48	45.6	2252	3279	58.4	62.0
8	Breast	2.64	3.00	13.8	3473	3951	58.9	58.5
9	Whiting, Thief	13.59	11.83	-12.9	164	143	100.0	97.3
10	Daseley's	2.53	2.99	18.0	2721	3212	46.0	70.0
11	Pandora, PBlack, Style	2.87	3.78	31.7	511	673	54.8	87.0
*	Herring Hill	Not Assessed			1117	1117	54.3	54.3
	Total				**20932**	**24760**		

3.6.4 Discussion

Although the surveys were only conducted two months apart, measurable levels of cockle growth were detected using the described methodology. In areas where the cockles were present in high densities, thus providing large numbers in the samples, their mean sizes and weights could be determined with high confidence. Where densities were low the data had poor levels of confidence and should be used cautiously.

In areas that supported mixed age groups of cockles, the younger cockles were found to grow at significantly faster rates than the older cohorts. Apart from the Breast sand, where the mean size of the 2012 cohort had decreased, the mean weight of this cohort had increased at rates of between 75% (Zone 11) and 336% (Zone 7). In five of the nine zones that were found to support this cohort, the individuals had more than doubled in weight during the two month study period. Only in areas where members of this cohort had been relatively large at the start of the study (>1g) were growth rates lower. Of the nine zones found to support cockles from the 2011 age group, eight showed measurable increases in mean weight. Apart from one that had increased by 3% (Zone 6) and one that had increased by 137% (Zone 5), their rates of growth ranged between 20.5% and 29.6%. Growth rates among the 2010+ group were mixed. Four of the eleven zones showed declines in mean weight, but it is difficult to determine whether this is a real effect due to mortality among larger individuals or whether it is an artefact of the lower numbers of these cockles in the samples reducing the confidence of the data. The other seven zones exhibited growth among this cohort at rates between 0.9% and 43%. These differing growth rates between cohorts are an important factor that would need consideration if it was ever attempted to set and apply a fixed "growth co-efficient" to future survey results.

If the growth rates measured at each site were applied to the total biomass of cockles estimated to be in the Wash following the April surveys, the stock would have grown from 20,932 tonnes to 24,760 tonnes, an increase of 18.2%. This figure does not take into account any impacts from mortality that may have occurred during this period. It is estimated that 14,117 tonnes would have attained a size of 14mm width by June. This is a 26.5% increase on the 11,159 tonnes estimated to have attained 14mm width in April. The population of ≥14mm stocks increased at a greater rate than the stock as a whole because in addition to increasing in weight, some of the cockles that had been less than 14mm width in April had recruited into the ≥14mm width population. This can be seen in figure 3.6.42, where the proportion of 14-17mm width cockles throughout the Wash sites had increased.

The TAC for the fishery is traditionally calculated as being 33.3% of the biomass of cockles that have attained 14mm width. Based on the April stock assessment surveys, the TAC for the 2013 fishery was 3,720 tonnes. Should the TAC have been calculated from the estimated stock in June following growth, the TAC would have been 4,706 tonnes.

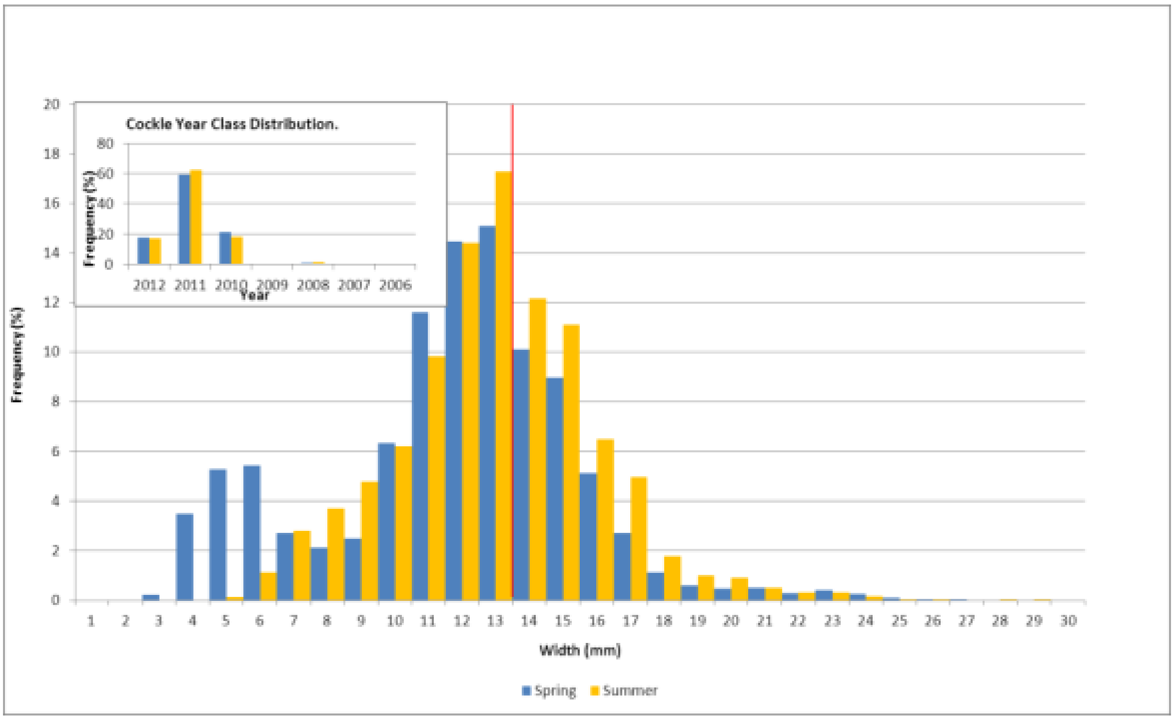


Figure 3.6.42 – Chart showing the cockle size frequency over all of the sites in April and June

All of the above stock calculations have assumed no mortality had occurred between April and June. Although the cockle stocks at this time of the year tend not to be subject to the large-scale mortalities associated with losses from winter storms or warm weather phenomena like "ridging-out" events or "atypical" mortality, bird predation and other natural losses would have occurred. It was hoped that this study would provide a means to measure natural losses in addition to cockle growth, but even though replicates were taken at each station, localised variability in cockle densities proved too high for these estimations to be made. This was evidenced by overall cockle numbers in the samples increasing 23% between April and June rather than decreasing. Although over-all this increase was not statistically significant at a $p<0.05$ level of confidence, it is still of concern that such large differences could occur between two surveys. Taking more replicates at each station would increase the accuracy of these surveys, but doing so would significantly increase the time and resources required to conduct such a study. Faced with increasing workloads and research demands, this would not be possible within the current EIFCA research plan.

The impact of localised variations will also bring into question the accuracy of the actual annual stock assessment surveys that underpin the management of the fishery. These surveys provide details of cockle stock levels on the various beds in the Wash and charts showing interpolated models of the cockle distributions. As 1,250+ stations are sampled during the course of these surveys, there should be sufficient samples collected to provide good confidence levels in the data for the Wash as whole. For individual beds, however, where only a fraction of this number of stations are sampled, confidence levels will be much lower. This means that while the estimation of total stock (and thus, the TAC calculation) will be reasonably accurate, charts showing the densities of cockles on individual beds will be of lower confidence and occasionally a poor reflection of the actual cockle distributions. This is an important consideration that should be remembered whenever micro-management of individual beds is attempted.

This study was undertaken in order to determine the feasibility of adopting a methodology that could be used to assess the growth of cockles during the period between the stock assessment survey being conducted and the commencement of the fishery. Some methodologies rely on determining average levels of annual growth based on spring and winter surveys. These methods tend to estimate a growth co-efficient based on average growth rates measured over several years. These, however, seldom provide an accurate measure of growth for specific years and can lead to overfishing in years when actual growth is below average. Instead of estimating an average growth co-efficient, this method was designed to measure the actual growth that had occurred between sampling occasions. The study successfully achieved this aim, although in areas where cockle densities were low, the confidence levels were poor. Because there are numerous conditions that can affect growth rates, this assessment would need to be conducted every time an assessment of growth was required. This is particularly the case as the number of <14mm width cockles that recruit into the ≥14mm width population between surveys will change from year to year depending on frequency of 12 and 13mm width cockles in the population. Faced with increasing workloads and demands on research time, regular assessments would prove a large commitment on Authority resources and would need to compete with other projects for available resources. Additionally, because it was not possible to accurately assess mortality rates during this study, adjusting stock levels for growth without taking account of mortality would lead to an over-estimation of stocks. If the TAC for the fishery were to be calculated from figures that took into account growth but not mortality, it could easily lead to over-exploitation of the stocks. This might not only endanger the sustainability of the stocks but could also have a detrimental impact on the conservation status of the site.

4.0 CRAB/LOBSTER STOCK ASSESSMENT

4.1 Introduction

Potting fisheries targeting crustaceans are of importance throughout the EIFCA district, primarily landing edible crab (*Cancer pagurus*) and lobster (*Homarus gammarus*).
These fisheries are mostly aggregated along the North Norfolk coast with strong associations with the coastal towns of Cromer and Wells however; potting activities are carried out to a lesser extent throughout the Authority's district.

Landings figures taken from Monthly Shellfish Activity Returns (MSAR) reveal average annual landings (2006-2011) of ~700 tonnes averaging a value of £2.2 million.
This represents a valuable contribution to local and national economies from landings alone. In addition these fisheries play an important role in defining the identity of coastal towns in the district, undoubtedly contributing to the tourist trade in a manner that has yet to be quantified.

As with any fishery, potting relies on healthy stocks to ensure a viable industry. Care must be taken to ensure the sustainability of this industry through proactive management based on best available evidence.

This need was first recognised by the authority (then ESFJC) in 1997 when a program of studies to carry out lobster stock assessments was initiated. In 2004 this was extended to include some edible crab and velvet crab (*Necora puber*) data and in 2007 even greater emphasis was put on edible crab populations. In 2010 a feasibility study was carried out to investigate methods to identify instances of scrubbing (the practise of removing eggs from berried lobsters, the landing of which is prohibited under byelaw 6) using portable test kits, and to review the research program. Due to staff changes no substantial work was carried out on the project throughout 2011-2012 however; 2013 has seen the projects resurrection.

Due to the timing of new staff recruitment and constraints on officer time a fully realised biosampling regime has not been achieved for 2013. However time series data of landings and effort from MSAR has been used to pull out information on how and where the major fisheries operate and to make initial attempts at modelling the districts fisheries. This has allowed some basic inferences to be made on how the fisheries stand in terms of maximum sustainable yield (MSY) and optimum fishing effort ($_f$Opt). It is hoped that continuation of the project will allow data gaps resulting from insufficient biosampling to be addressed through the implementation of a regular sampling schedule.

4.2 Biology

Homarus gammarus and *Cancer pagurus* are crustaceans belonging to the order Decapoda. Animals of this order share a number of common characteristics; as the name infers all decapods have ten legs known as periopods. In some species, including those mentioned, the front pair of periopods develop into claws (chelae) and are referred to as chelipeds. These modified limbs are used for defence, in territorial encounters and for crushing and dismembering prey.

As with all Crustacea, crab and lobsters have a tough exoskeleton which provides the animal with a level of protection from predators. In order to grow, this hard shell is shed (a process called ecdysis) at intervals, growth is therefore determinate with the animal increasing in size only immediately after moulting. Ecdysis typically occurs more frequently in younger animals with the moult rate decreasing over time as they mature.
During ecdysis water is absorbed causing the animals body to swell. This causes the old shell to split along definable weak points (found at the back of the cephalothorax in crabs and between the carapace and abdomen in lobster). Once the old shell has split the animal gently withdraws itself, at this point the new shell is soft and pliable. Further uptake of water expands the soft shell to its new size before it starts to harden again. In-between moults water taken up to expand the new shell is gradually replaced by body tissues, essentially the animal uses this time to grow into its new shell, once its capacity is reached ecdysis begins anew.

Crabs and lobsters are fairly hardy animals, and are able to sustain injuries that would debilitate other animals. Lost limbs resulting from encounters with predators or territorial conflict with conspecifics are commonly observed; indeed animals have been known to readily shed limbs as an escape response. Limbs lost in this fashion can be regenerated through successive moults, growing in increments with each successive moult until they are of normal size.

4.2.1 European Lobster (*Homarus gammarus*)

Homarus gammarus is one of the highest value/kg, commercially exploited shellfish species found in UK waters. Its distribution extends from the Arctic Circle and into the Mediterranean but is mainly centred on the British Isles where a high proportion of landings originate (MAFF 1996).

Figure 4.1 A juvenile European Lobster (*Homarus gammarus*) found on chalk reef at sheringham .

Lobsters favour rocky reef and rough ground where they typically shelter in crevices between rocks and boulders. The availability of suitable habitat of this type has been postulated as a factor influencing the carrying capacity and size structure of lobster populations. The Norfolk population for example has been noted as being comprised of individuals that are on average smaller than those found in other areas. An early investigation explored the idea that this was due to genetic isolation resulting in a "dwarf race" emerging (Graham 1949) however; this was dismissed and a later study by Howard (1980) instead suggested that a lack of suitable refugia for larger animals was a more likely cause of this phenomenon.

From hatching it takes ~5 years for a lobster to reach the minimum landing size (MLS) of 87mm. By this time the animal has few natural predators and will have moulted several times. On average a lobster will increase in carapace length by ~10% each moult and by ~50% in weight although this does decrease with age.

Moulting of males and females tends to be staggered, with males shedding earlier in the year than females. This facilitates the mating process which generally occurs between a newly moulted female and a hard shelled male. At this time the male passes a spermatophore to the female which she retains until she is ready to extrude her eggs, usually one month to two years after mating has occurred. The female extrudes her eggs from oviducts found at the base of the third set of periopods, passing over the retained sperm to be fertilised. They are then retained in the tail where they attach to hairs (setae) on the pleopods. This affords the eggs some level of protection as they are carried by the female for up to 12 months before hatching and being released as planktonic larvae. The larval phase lasts ~10 -35 days, during which time they go through three stages of development before settling to the benthos. Despite extensive studies (Linnane et al 2001) very little is known about the natural behaviour of juveniles after settling and they are rarely observed in the wild.

Lobsters feed on a varied diet including fish, shellfish and marine worms. Eyesight is poor however; sensitive antennae located at the front of the carapace allow the detection of food by smell. Like many marine organisms lobsters are opportunistic feeders and will readily scavenge carcasses making them susceptible to traps baited with dead fish.

4.2.2 Edible Crab (*Cancer pagurus*)

While sharing a similar geographic range as the European lobster this crustacean is found on a wider range of habitat types, ranging from rocky reefs to soft mud and sand. As with lobster, studies have revealed a smaller average size in edible crabs in North Norfolk when compared to adjacent areas. Unlike lobster however this has not been associated with habitat limitations but rather as a consequence of migration patterns and recruitment regimes (Eaton 2003). This smaller average size is reflected in a lower MLS in the Authority's district compared to the rest of the country.

Edible crabs take approximately four years to reach the MLS of 115mm carapace width increasing in size by 20-30% with each moult. As with other crustaceans moult frequency and resulting size increase decrease with age. Similar to lobsters, moulting is staggered between the sexes to allow for mating between soft shelled females and hard shelled males. Moulting tends to occur through the summer months and into autumn. As with lobsters the female will carry the eggs throughout incubation (7-9 Months) releasing the young as larvae into the plankton. Once released the larvae remain in the plankton for around two months before settling into the intertidal benthos (Bennett 1995). During the incubation period it is believed that females cease active feeding and consequently are only rarely caught in pots (Howard 1982). As a consequence of this seasonal variation in the sex ratio of catch occurs, with females generally more abundant in spring and early summer before males begin to dominate in late summer-autumn as the females commence their moult (Brown & Bennett).

Figure 4.1 Edible crab (*Cancer pagurus)* caught by fishermen operating from Cromer. Image Courtesy of Ady Woods

Edible crabs feed on a similar range of organisms as lobster and are active predators, their powerful claws are employed in breaking open the shells of bivalve molluscs such as mussels, clams and cockles. Occurring in much higher densities than lobsters and with a more active foraging strategy, edible crabs are often caught in much greater densities than lobster. In this way what they lose in value they more than make up for in numbers caught, making them the principle target of pot fishermen in the district.

4.3 Fishing

Potting fisheries operate throughout the EIFCA district from Saltfleet in Lincolnshire down through Norfolk and as far as Felixstowe Ferry at the Authority's southern limits in Suffolk. The majority of this activity however is concentrated along a relatively small stretch of coastline along the North Norfolk coast with ~95% of reported annual landings coming from fisheries operating between Brancaster and Great Yarmouth. This area has a long tradition of fishing for crab and lobster with earliest recorded accounts of the fishery dating back to the early part of the 18^{th} century (MAFF 1966). Many of the towns and ports in this area have such a strong association with crab and lobster fisheries that they have become an intrinsic part of their culture; Sheringham for example hosts an annual festival to celebrate the fishery, while Cromer crab is renowned across the country for its quality.

All of the vessels regularly active in the fishery fall into the <10m category the major differences being between those that are beach launched and those that operated out harbours. Beach launched vessels (typically found between Wells and Great Yarmouth on the Norfolk coast) are generally more restricted in their ability to get to sea by weather conditions. Heavy seas and pounding surf can make it difficult to launch and recover these vessels from the beach without incurring damage; essentially limiting the days they are able to spend fishing.

Traditionally the potting fishery has operated within 2nm being more accessible to vessels without the capacity to fish further out. Advancements in technology including the introduction and advancement of motor engines, improved vessel design and fishing gear steadily increased the range that potters could operate. In the present day some of the more robust and mobile vessels operate out to ranges of up to 40nm (Jessop et al 2009) however a significant number of operators still fish traditional grounds often within sight of the shore.

The main fishing season for crab commences around late March to early April with peak landings in May and June before dropping off through to late September/early October. Lobster season tends to follow closely behind crab with the season getting to a start mid-May/ June, peaking in June/July before again dropping off through autumn and into winter.

Crab and lobster are specifically targeted through the deployment of static gears consisting of a string or "shank" of 20-30 pots baited with dead fish. This gear is typically left to soak for 24-48 hours before being hauled, cleared and reset. Each vessel will fish a number of shanks checked on a rotational basis, hauling between 100 – 500 pots depending on the capabilities of the vessel and number of crew. Catch is sorted at sea with any undersize or poor quality animals being returned immediately, the rest is landed before being sold either to processing factories, private orders or direct to the consumer.

Due to the nature of the gear, mortality rates of bycatch (i.e. unlandable target species or non-commercial species) are incredibly low in pot fishing when compared to other fishing gears. Consequently those animals discarded back into the sea have a good chance of survival allowing them to grow on to a size where they will recruit to the fishery or improve in condition.

Catch value varies throughout the year, with lobster fetching the highest average price from October /November through to March presumably when demand is high due to the festive season. Crab prices show a converse seasonal fluctuation to lobster, with peak prices occurring throughout the summer. This coincides well with the summer holiday period and is undoubtedly linked to increases demand and direct sales to tourists visiting the area.

4.4 Management measures

Crustacean fisheries are currently managed at a national level through MMO licencing. No new licence entitlements are currently being authorised so this effectively limits entry into the fishery to those already in possession of or able to procure an existing licence entitlement. International level EU regulations on minimum landing sizes regulate the removal of animals from the fishery; These MLS are set at 115mm carapace width (CW) for edible crab and 87mm carapace length (CL) for lobster. The 115mm MLS for edible crab was nationwide; however reviews in 1986 and 1990 saw this raised in other districts to between 130-160mm. EIFCA district was given derogation to retain the smaller MLS to reflect the smaller individuals typical of the Norfolk population and to mitigate potentially debilitating effect that changing MLS would have on this fishery (Addison & Bennett 1992).

In addition to MLS lobsters are afforded additional protection under The Lobsters and Crawfish (Prohibition of Fishing and Landing) Order 2000. This prohibits the fishing for or landing of lobsters bearing a V-notch; or that have been mutilated in such a manner as to obscure a V-notch. V-notching is a voluntary activity in the EIFCA district aimed at preserving brood stock and involves cutting a V-shaped notch into the tail of a lobster (usually berried females). This animal is then effectively protected from fishing allowing it to reproduce several times over 2-3 years until the notch grows out.

At district level EIFCA manage crustacean fisheries through a number of byelaws which protect shellfish at particular stages in their life cycle or under certain conditions:

- Byelaw 5:- Prohibition on the use of edible crab for bait.
- Byelaw 6:- Prohibition on the landing and requirements for the immediate return to the sea of any egg-bearing or soft shelled crab and lobster.
- Byelaw 7:- Prohibition of the removal from the fishery of parts of shellfish (e.g. claws) that cannot be measured to ensure compliance with MLS.
- Byelaw 9:- Re-deposition of any shellfish, the removal of which is prohibited, to the sea immediately and as nearly as possible to the place from which they were taken.
- Byelaw 10:- Prohibition on the landing of whitefooted edible crab (Those crabs that have not fully regained condition and meat yield after moulting) between the 1st of November and the 30th of June (inclusive).

(Note: These are paraphrased from the EIFCA Byelaws; for full wording please consult the EIFCA website or apply to the office for a written copy)

Local fishermen have always been keen to be involved in the sustainable management of their fishery (Jessop et al 2009); indeed the first statutory regulation for the management of a crab fishery was born out of the desire for Norfolk fishermen to protect the stocks upon which their livelihoods depended (MAFF 1966). Today many industry members are happy to assist in the development of new methods of assessing and preserving stocks and EIFCA aims to maintain this relationship. Close consultation and engagement with stakeholder groups ensures that a balance is struck between maintaining sustainable stocks and encouraging a viable industry.

4.5 Defining the fishery

The aim of this section is to define the crab and lobster fisheries operating in the EIFCA district in quantifiable terms using data from MSAR forms. These returns detail information about daily fishing activities including; Port of landing, area fished (categorised by ICES statistical area), gear set/hauled and landed catch (kg/species). The resulting dataset (covering 2006-2013) has yielded information that can be used to facilitate the assessment of the fishery and provide focus for the study.

4.5.1 Data Reliability

The number of fishing days annually reported has remained consistent over the years (Figure 4.3) with a mean of 5658 fishing days reported each year (2006-2013); submissions do fluctuate throughout the year, reflecting peak periods of fishing activity. Analysis of Variance (ANOVA) testing revealed no significant differences between the number of submissions received each year ($p=0.995$) Consistency in the number of returns received each year gives confidence that any trends identified are likely due to tangible changes in the fishery, rather than changes in the number of returns submitted.
It remains to be noted that information generated through the analysis of this data is only as reliable as its source. MSAR forms are often filled in from estimates rather than precise figures. False reporting, either accidentally or with intent can also cause issue in the data. During the course of this analysis any obvious discrepancies in the data have been investigated and any exclusion/alteration of such entries to address this has been documented.

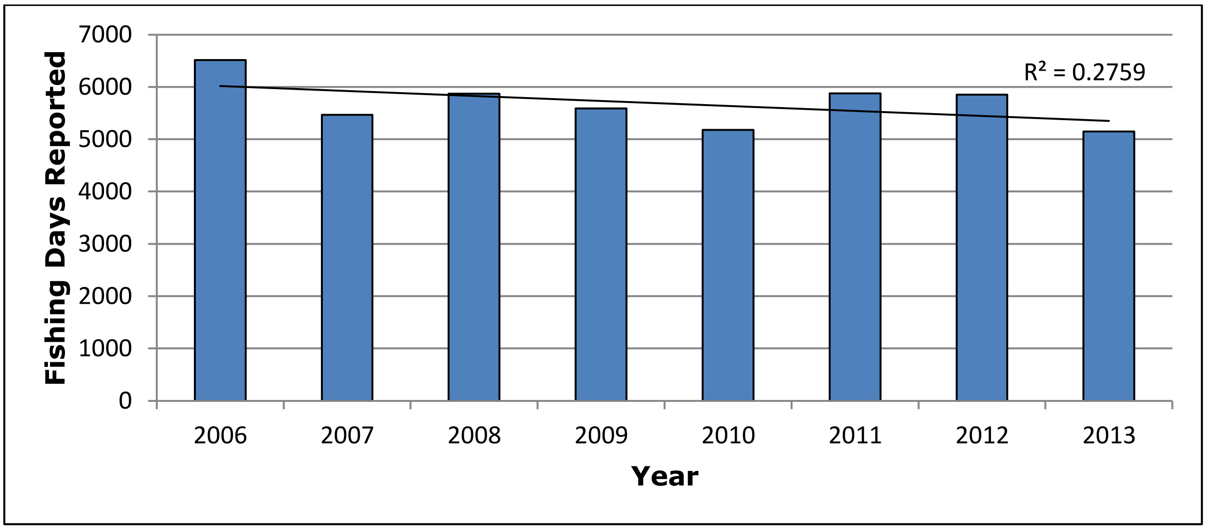


Figure 4.3 Annual fishing days reported by MSAR form 2006-2013. Source - EIFCA MASR Database

4.5.2 EIFCA District Landings

Catches of edible crab account for the majority of total annual crustacean landings in the district (mean 86.4%) with lobster accounting for less than a quarter of total landings each year (mean 13.6%). Despite significant difference in landed weight, contribution to estimated value of the two species are more similar (mean crab 53.5%, mean lobster 46.5%) due to the higher market value of lobster.

Landings for the fishery have remained relatively stable throughout the period of the dataset however; there is some variability in crab landings (Figure 4.4) with a peak in landings in 2008 followed by a gradual decline through to 2013. Despite this ANOVA testing revealed no significant difference in crab landings between years (P=0.9409) for the district as a whole.

Isolating the data from 2008 to 2013 (Figure 4.5) highlights the trend in declining catch from 2008 however; landings do not drop below the lowest reported annual catch in the dataset and a separate ANOVA test for this period again found no significant differences between years (P= 0.9488).

Despite the lack of significance this sudden increase in catch in 2008 followed by gradual decline is still interesting though its cause is uncertain. Local Fishermen have suggested that landings of crab follow a cyclical pattern with particularly good years occurring on a roughly decadal basis. This type of phenomenon has been hypothesised for a number of fisheries where particularly good recruitment years sustain the fishery for a number of years while being gradually fished down. This may go some way to explaining the observations made by fishermen and this dataset and it will be interesting to see if this is reflected in the data in subsequent years.

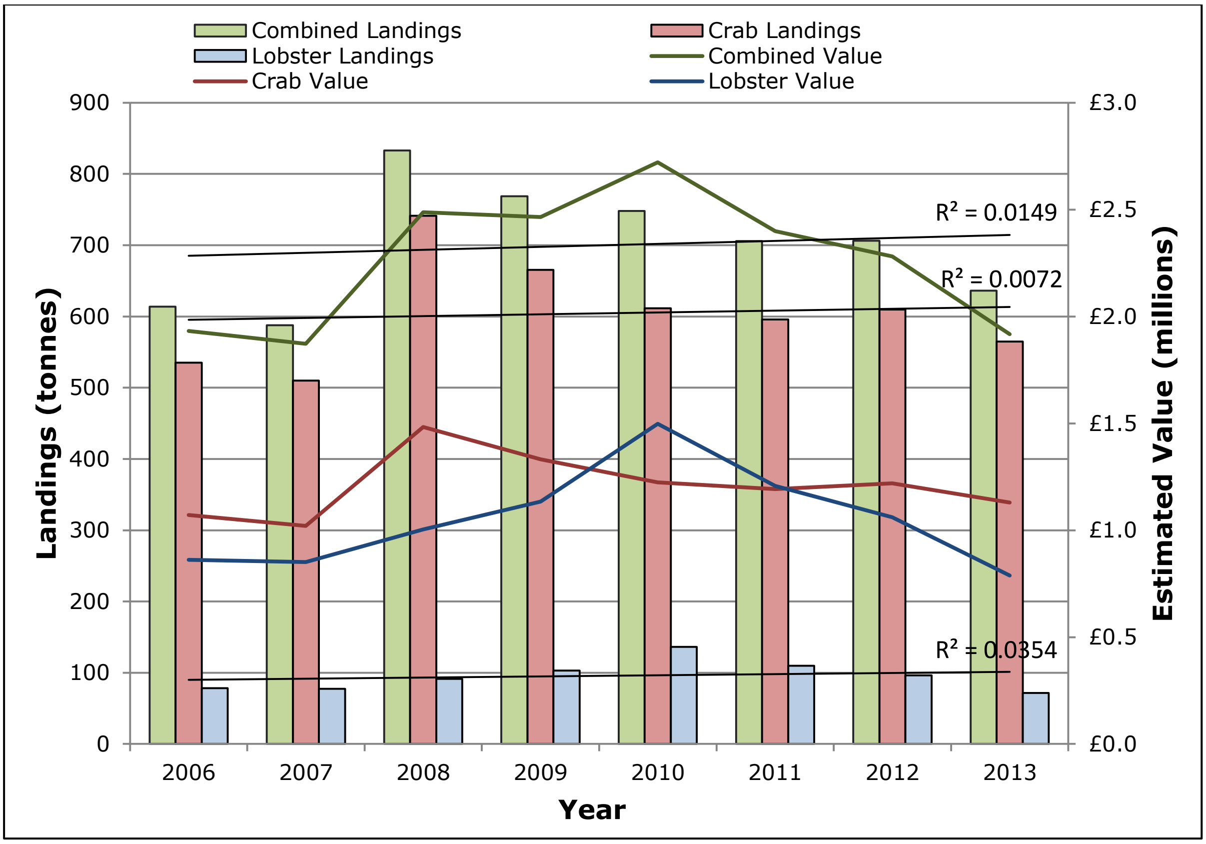


Figure 4.4 - EIFCA District crab and lobster landings by weight and estimated value (2006-2013). Source - EIFCA MSAR Database

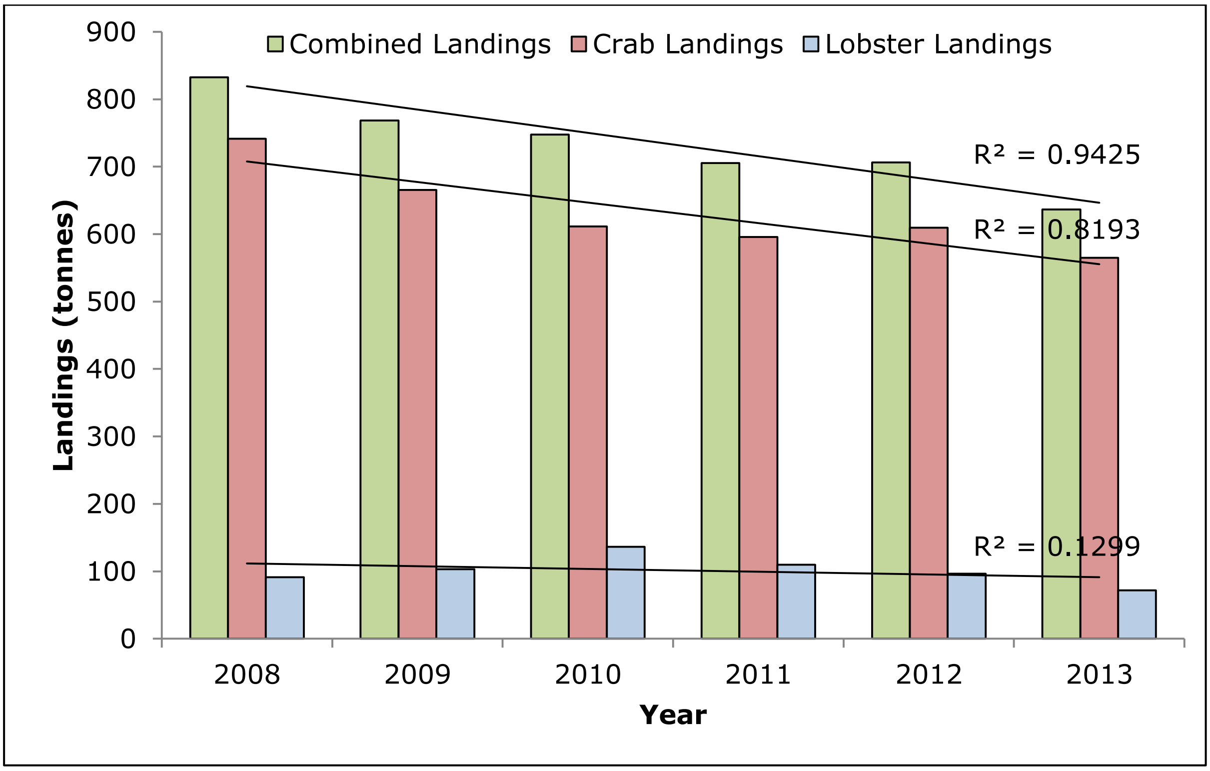


Figure 4.5 - EIFCA District crab and lobster landings by weight (2008-2013). Source - EIFCA MSAR Database

4.5.3 EIFCA District Effort

Individual vessel effort is recorded as both pots set and pots hauled on MSAR forms, for the purposes of this report only the latter have been considered due to a lack of consistency in the way that pots set is reported. Some forms report only the pots set on the day of fishing, others report all pots that are set and fishing in the water creating an unrealistic figure when the two are combined. Pots hauled are reported much more consistently with only pots actually hauled and cleared on the day being recorded. Using pot hauls also allows for catch per unit effort (CPUE) to be quantified as kg/100 pot hauls.

Annual effort for the district is summarised in Figure 4.6 along with CPUE for each species both separately and combined. Effort fluctuates around a mean of 8900 (100 pot hauls) with a relatively large reduction in effort from 2006 to 2007. Despite this ANOVA detected no significant difference in effort between years (p=0.9309).

As with landings, effort in terms of annual pot hauls has remained relatively constant across the period of the dataset. Assuming no major changes in the efficiency of gears used in the fishery this bodes well, indicating that stocks are not being subjected to increasing fishing pressure and that nothing major is restricting the ability for fishermen to set and haul there pots (e.g. economic downturn, prohibitive fuel prices etc.).

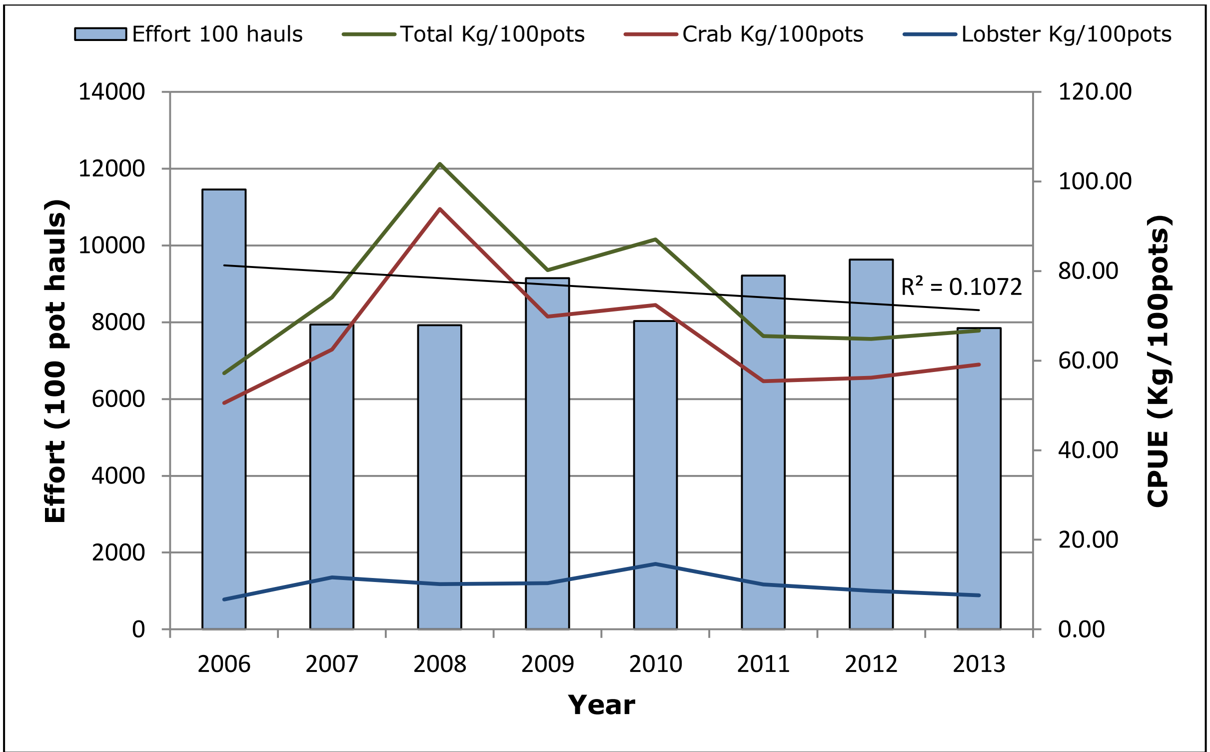


Figure 4.6 - EIFCA District annual effort and CPUE (by total catch and by species) 2006 - 2013. Source EIFCA MSAR Database

4.5.4 Ports Engaged in Crustacean Fisheries

Pot fishing for crab and lobster is carried out throughout the EIFCA district however this activity is not evenly distributed being primarily concentrated along the North Norfolk coast.

Norfolk ports make up a significant proportion of all ports operating in the fishery with 64% situated in Norfolk compared to 24% in Suffolk and 12% in Lincolnshire. Of this 64% only Great Yarmouth is not situated on the North Norfolk coast. Considering North Norfolk on its own these ports still represent 60% of all ports operating in the EIFCA district.

Table 4.1 lists those ports that have submitted MSAR forms over the period of the data set and includes information on the number of vessels submitting returns for each of those ports. Again north Norfolk is most heavily represented in terms of vessels deployed with Wells and Cromer deploying the most vessels in the county.

Trends in total crab and lobster landings can be seen in figures 4.7 with figure 4.8 giving greater resolution for those ports landing less than 100 tonnes on average across the dataset.

Distribution of productivity is far from even with Wells and Cromer being the major producers, each contributing in excess 100 tonnes to total landings each year (Figure 4.7). Wells evidently contributes the most to landings in the district accounting for an average of 49% of total landings (mean = 342 tonnes/year); Wells contribution to landings is so high that they strongly influence the records for district total landings. When compared to each other total landings for Wells and the district as a whole share a very similar pattern of trends as a result of Wells heavy involvement in the fishery.

Cromer records the second highest annual landings (22% of total landings, mean = 152 tonnes/year), but still contributes less than half the landings of Wells despite deploying more vessels.

Looking at Wells and Cromer the discrepancy between vessels engaged in the fishery and total landings can be explained by the way that vessels from these ports operate. Vessels fishing out of Cromer are all beach launched and in the most part smaller Coble style boats operated by a single fisherman. These vessels are restricted in their operation by both environmental conditions and the amount of time they can spend at sea. Poor conditions can prevents these vessels from launching essentially preventing them from fishing during unfavourable weather conditions and tidal states; additionally the open design offers very little in the way of comfort preventing them from spending any great amount of time fishing. Consequently these vessels operate close to shore often launching and beaching on a single tide restricting the amount of pots they can haul and clear on any given days fishing.

Table 4.1 – Ports and vessels operating in the potting fishery in EIFCA's District 2006 - 2013.

Port	County	2006	2007	2008	2009	2010	2011	2012	2013	Max	Min
Skegness	Lincs	0	1	1	0	0	0	1	2	2	0
Kings Lynn	Lincs	1	0	0	0	0	1	2	3	3	0
Boston	Lincs	0	0	0	0	0	1	4	7	7	0
Wells	Norfolk	9	8	11	9	9	9	14	8	14	8
Cromer	Norfolk	13	14	17	14	15	17	16	18	18	13
Morston	Norfolk	2	2	5	5	5	4	2	1	5	1
Brancaster	Norfolk	3	2	3	4	3	3	4	3	4	2
Weybourne	Norfolk	2	2	2	2	2	2	2	2	2	2
Sea Palling	Norfolk	2	2	2	2	2	2	5	3	5	2
Great Yarmouth	Norfolk	5	7	8	7	6	8	10	8	10	5
Overstrand	Norfolk	3	3	2	2	2	2	2	2	3	2
Sheringham	Norfolk	8	6	5	6	6	6	7	6	8	5
Mundesley	Norfolk	3	3	2	2	2	3	1	1	3	1
Blakeney	Norfolk	2	2	3	1	2	3	2	1	3	1
West Runton	Norfolk	2	0	1	1	1	1	1	1	2	0
Cley	Norfolk	1	1	1	0	0	2	4	5	5	0
East Runton	Norfolk	2	2	1	2	1	2	3	3	3	1
Bacton	Norfolk	2	1	2	2	2	1	1	1	2	1
Stiffkey Freshers	Norfolk	0	0	0	0	0	1	1	1	1	0
Felixstowe Ferry	Suffolk	10	8	9	6	3	9	10	10	10	3
Southwold	Suffolk	5	3	4	1	3	5	7	6	7	1
Lowestoft	Suffolk	6	5	2	2	2	4	3	6	6	2
Sizewell	Suffolk	1	1	1	1	1	1	1	1	1	1
Harwich	Suffolk	0	6	4	0	2	1	0	5	6	0
Aldeburgh	Suffolk	6	5	5	7	5	5	7	7	7	5
Orford	Suffolk	4	4	3	3	4	2	3	2	4	2
Unidentified	N/A	2	0	1	0	1	0	3	0	3	0
Total		94	88	95	79	79	95	116	113		

In contrast Wells boats operate out of Wells harbour allowing them to get to sea on days that would be too rough for beach launching as long as tidal states are favourable. In addition these vessels are generally larger than the Cromer vessels with more powerful engines, covered wheelhouses and more crew members. This allows their operators to cover more ground and spend longer at sea fishing, while additional crew allows them to haul and clear pots quickly and more efficiently.

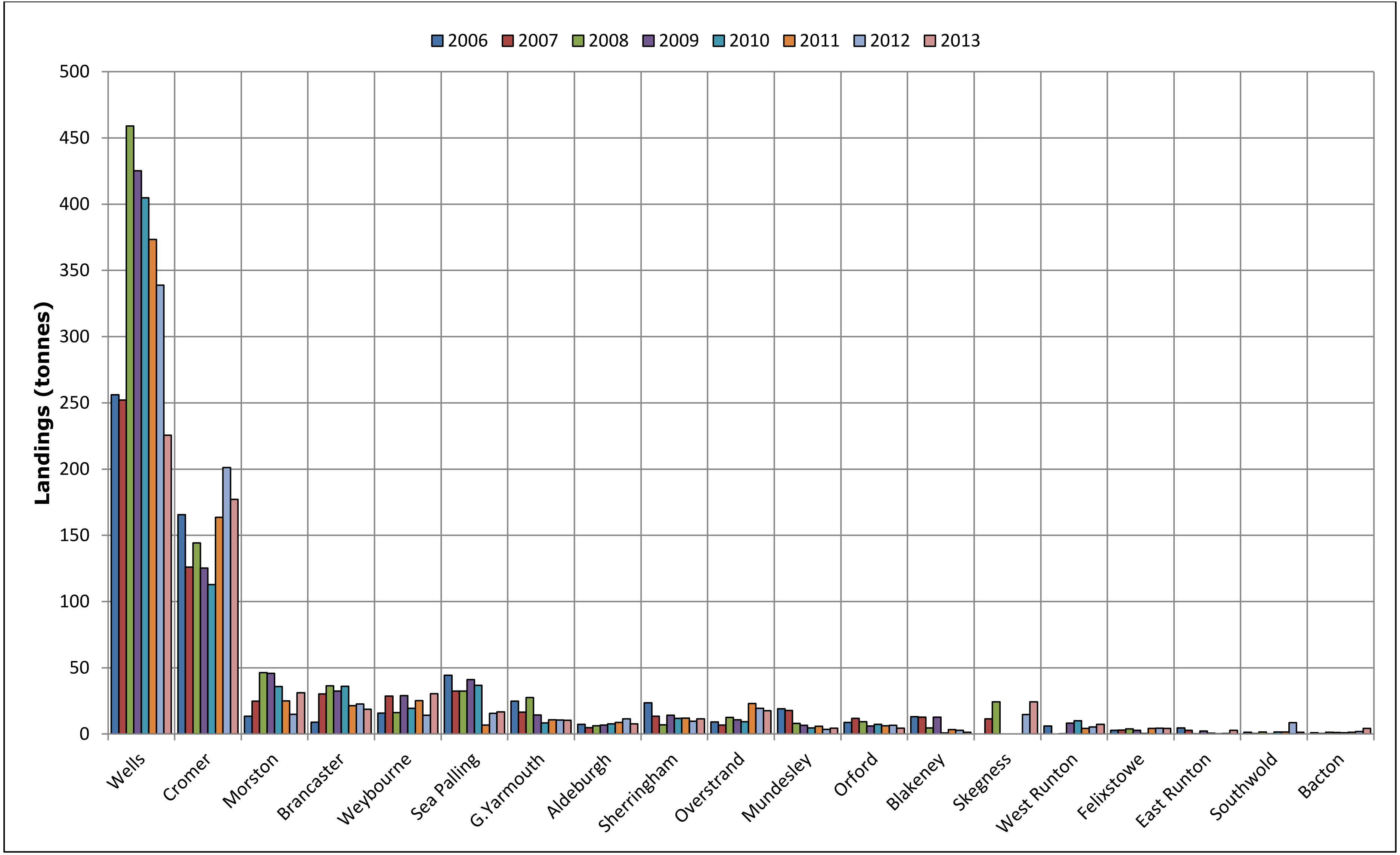


Figure 4.7 - Annual Landings (mean >1 tonne) by Port (2006-2013).

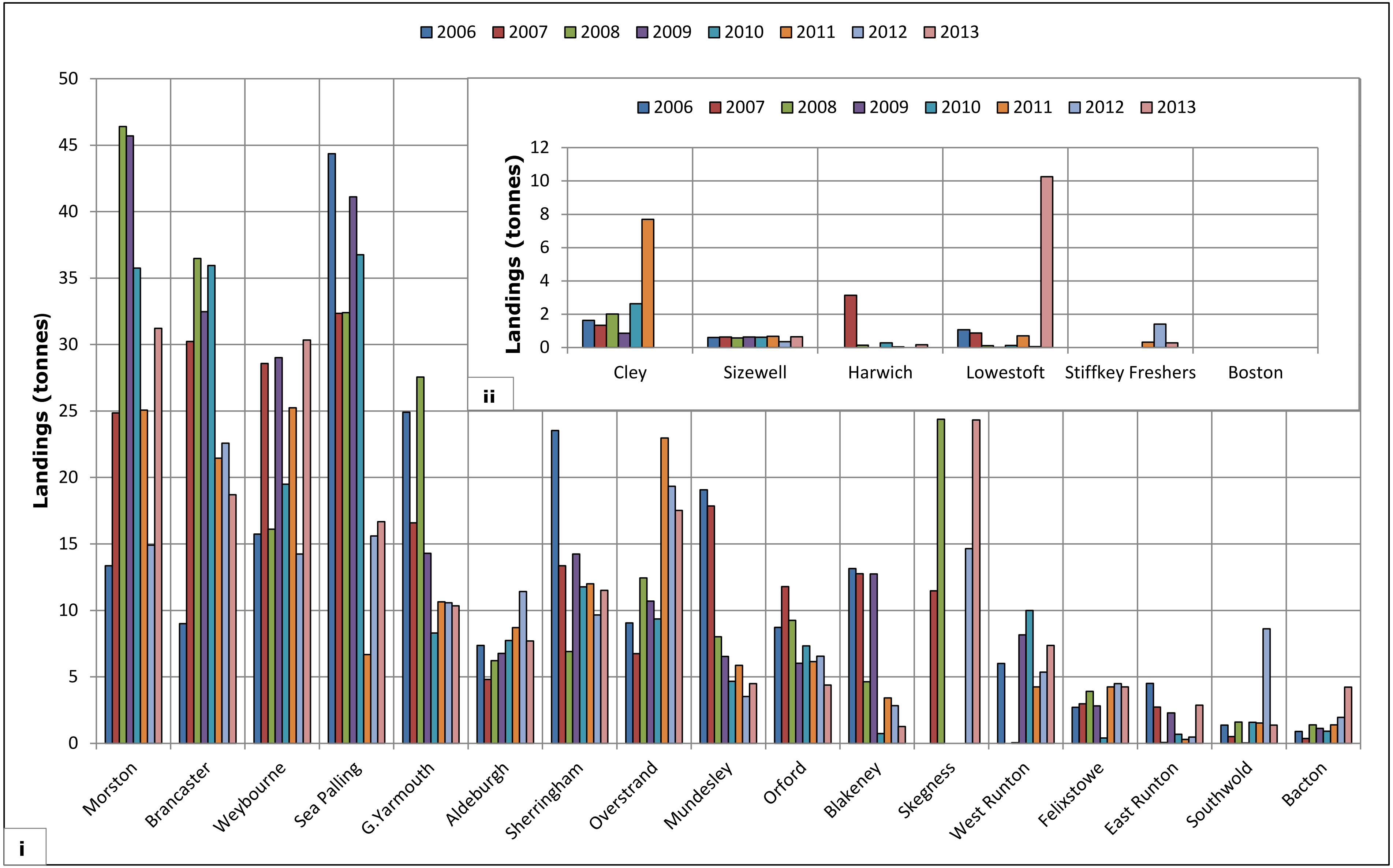


Figure 4.8 - Annual Landings by Port (i) mean >1 tonne < 100 tonne (ii) > 1 tonne (2006 - 2013).

While the contribution of the remaining ports operating in the district may seem inconsequential when considered against Wells and Cromer their combined contributions is still significant, particularly those from the North Norfolk coast.

Figure 4.9 divides the district by county to show where the major potting fisheries are located. Figures are based on mean annual landings converted to percentages to visually describe where the majority of landings are taking place by county.

The chart to the left of the diagram shows how contribution to mean annual landings is divided amongst the three counties of the Authority's district. From this it is immediately apparent that the majority of landings of crab and lobster are occurring in Norfolk, accounting for 96% of mean annual landings (~670 tonnes) for the district.

The chart to the right shows the contribution to district landings of Wells, Cromer and the remainder of North Norfolk's ports to district landings. This highlights the role of not only Wells and Cromer but also the smaller ports such as Brancaster and Sheringham which are dotted along the North Norfolk Coast. Individually these smaller ports may only make small contributions to landings however; when their landings are combined their contribution to landings becomes much more significant at ~160 tonnes on average each year.

When it is considered that the ports operating on the North Norfolk coast are generally fishing the same grounds it is practical to combine them in this way and treat them as a single fishery for the purposes of carrying out monitoring and assessment.

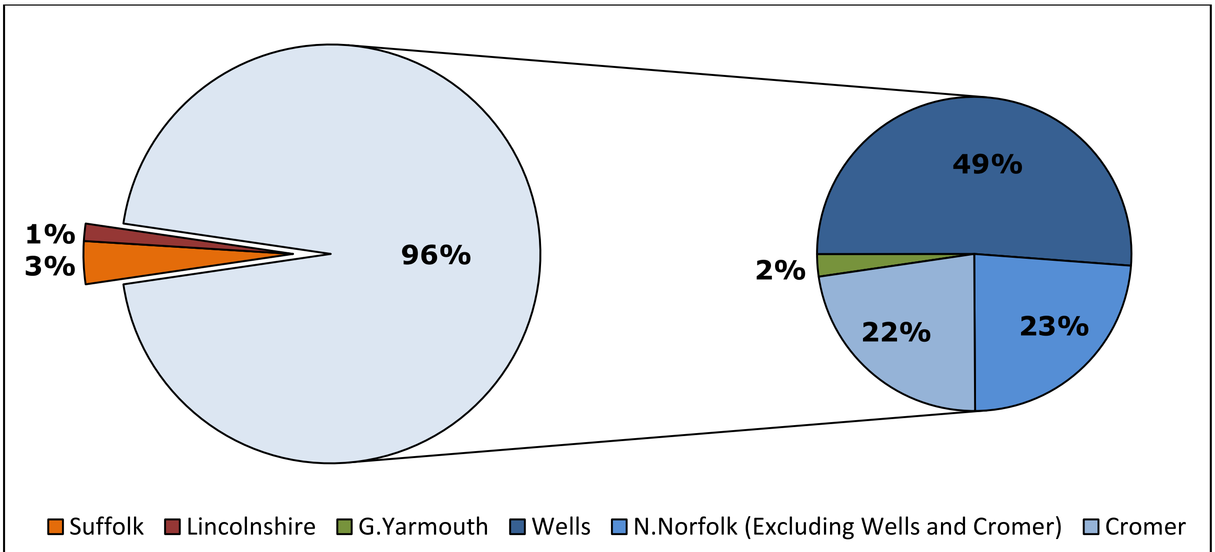


Figure 4.9 Relative contribution to total landings for each county within the district including a break down of ports operting out of N.Norfolk

4.5.5 Grounds Fished

While the previous sections addressed how much is being caught in the fishery and where this catch is landed, this section begins to look at where the catch is coming from and where effort is focused.

For the purposes of visualisation and facilitating the analysis and assessment of fished stocks ICES divide the North Sea into 3 broad areas; IVa being the northern limits, IVb the middle and IVc being the southern North Sea which includes the area for which EIFCA is the relevant authority. To provide greater resolution these areas are further divided into Statistical Rectangles arranged in a grid.

In this study Statistical Rectangles have been used to define the boundaries of grounds fished by operating in the district and carry out analysis on a site by site basis. This delineation is facilitated by the requirement for fishermen to report ICES Statistical Areas they have fished on any given day. Those areas falling within the boundaries of EIFCAs authority are presented below (Figure 4.10).

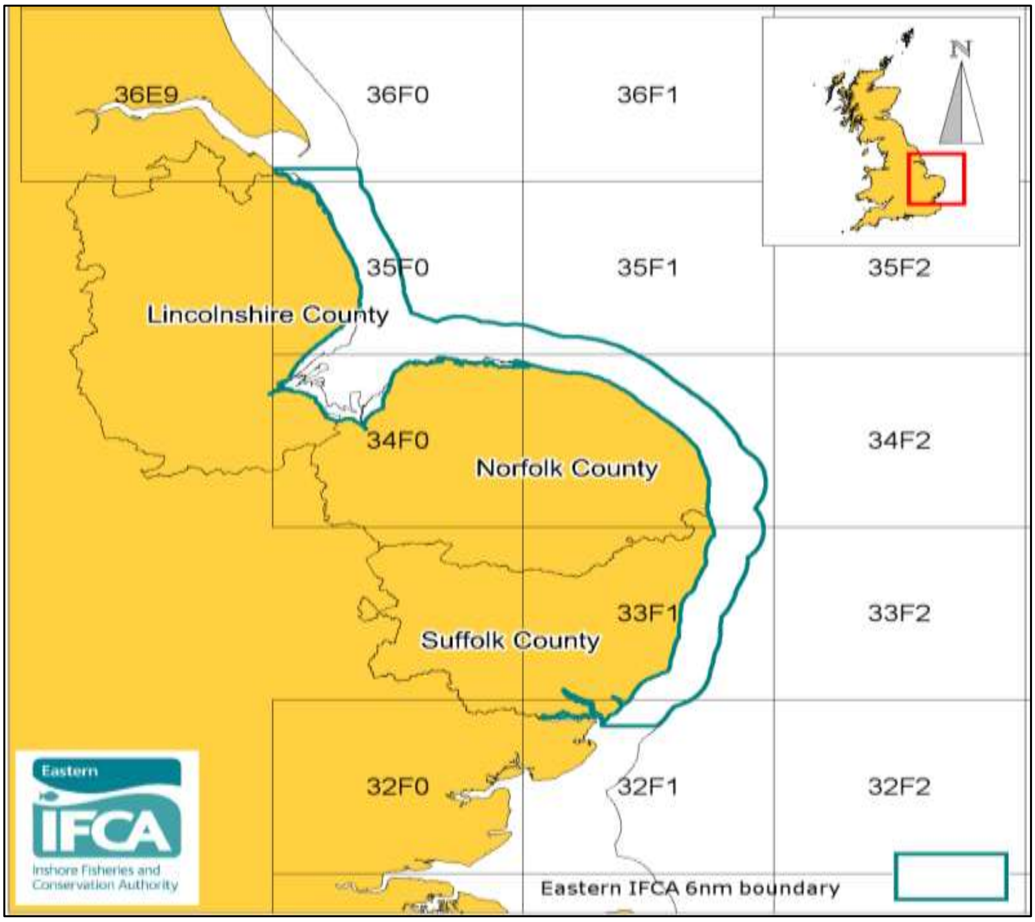


Figure 4.10 Counties and ICES Statistical rectangles falling within the EIFCA district boundaries.

As with port of landing, effort and catch is not evenly distributed throughout all fishing grounds within the district’s boundaries but is concentrated on certain areas. As would be expected these areas correspond with the position of the major contributing ports, with key production areas being situated off the North Norfolk coast.

Figure 4.11 shows landings and effort data for those grounds falling within the bounds of the EIFCA district, highlighting where effort is concentrated and where the majority of landings originate. From this it is clear to see the importance of areas 34F1, 35F0 and 35F1 of the North Norfolk coast which each contribute on average >100 tonnes to combined landings annually.

Statistical analysis of mean annual landings and effort revealed significant differences in effort for all areas (Two tailed t-test P = <0.05) and in combined landings for most areas. The exception to this are areas 32F1 and 34F0 which have statistically similar means for combined landings (P = 0.672).

Crab accounts for the bulk of landings for those grounds off the North Norfolk coast (34F1, 35F0 & 35F1) and strongly influences the trends seen in combined landings with lobster obviously playing a supplementary role to the fishery in these areas. In contrast the difference between catches of crab and lobster is much less pronounced in Suffolk (32F1 and 33F1) and the Wash (34F0).

Two sample t-tests of the differences between crab and lobster landings in each area revealed statistically significant differences between means for all grounds except 32F1 and 34FO which returned p values of 0.08 and 0.40 respectively indicating that these areas operate as more of a mixed fishery relying less on large catches of crab.
Crab is therefore of much greater importance than lobster in the majority of fishing grounds in the district however; despite appearing to play an ancillary role to their main crab catch, more lobster is still produced from the North Norfolk coast grounds than the other areas defined here. This is likely as a consequence of the higher levels of effort that occur there.

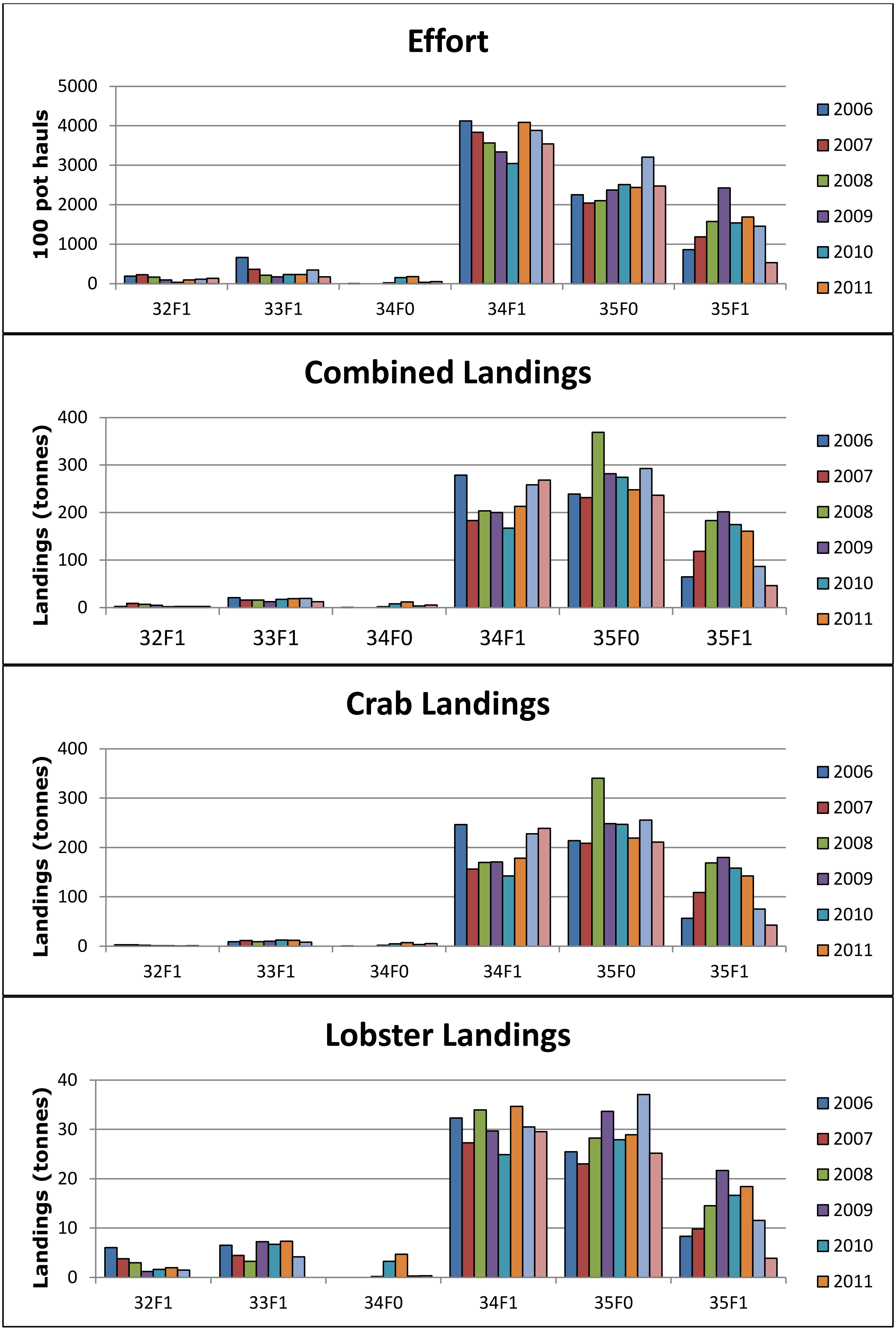


Figure 4.11 Effort and landings for the main potting fishery grounds

4.5 Fisheries Assessment

In addition to defining basic characteristics, MSAR data has been used to construct surplus yield models of grounds fished; providing estimates of Maximum Sustainable Yield (MSY) and optimum fishing effort ($_f$Opt). This has been carried out based on the same delineation of fishing grounds as previously described (i.e. by ICES statistical rectangles). This section will also go into greater detail of the activities occurring in these areas providing at glance statistics regarding landings and effort on an annual basis.

<u>4.5.1 32F1</u>

4.5.1.1 Overview

This area overlaps significantly with Kent & Essex IFCA being located at the southern limits of the EFICA district. It is fished by a relatively small number of ports and vessels from our district which is reflected in effort and landings (Table 4.2).

Lobster accounts for a greater proportion of catch in this area than crab; however this difference is not significant, indicating that this area operates as more of a mixed fishery than areas such as those along the North Norfolk coast that are more reliant on a single species.

Table 4.2 Statistical Rectangle 32F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	11	189	2.1	0.7	1.4
2007	3	13	223	8.8	2.8	6.0
2008	5	13	165	6.6	2.8	3.8
2009	2	6	96	4.6	1.7	2.9
2010	5	7	36	1.7	0.5	1.2
2011	1	6	95	2.2	0.6	1.6
2012	1	8	112	2.3	0.4	1.9
2013	2	10	134	2.1	0.7	1.5
Mean	**3**	**9**	**131**	**3.8**	**1.3**	**2.5**

There appears to be some correlation between landings and effort as indicated in Figure 4.12; particularly in the period covering 2007-2010 where landings are seen to decrease relative to effort. This trend is observed for both crab and lobster (Fig 4.12 (ii)) indicating that the decline in landings is not related to changes in abundance of one species relative to the other.

Of some concern is the time period from 2010 onwards, where effort is seen to increase again without a corresponding increase in landings. It is apparent that something is having a negative effect on the fishery from this point limiting productivity relevant to previous years. The cause of this uncertain at this point and will require further investigation.

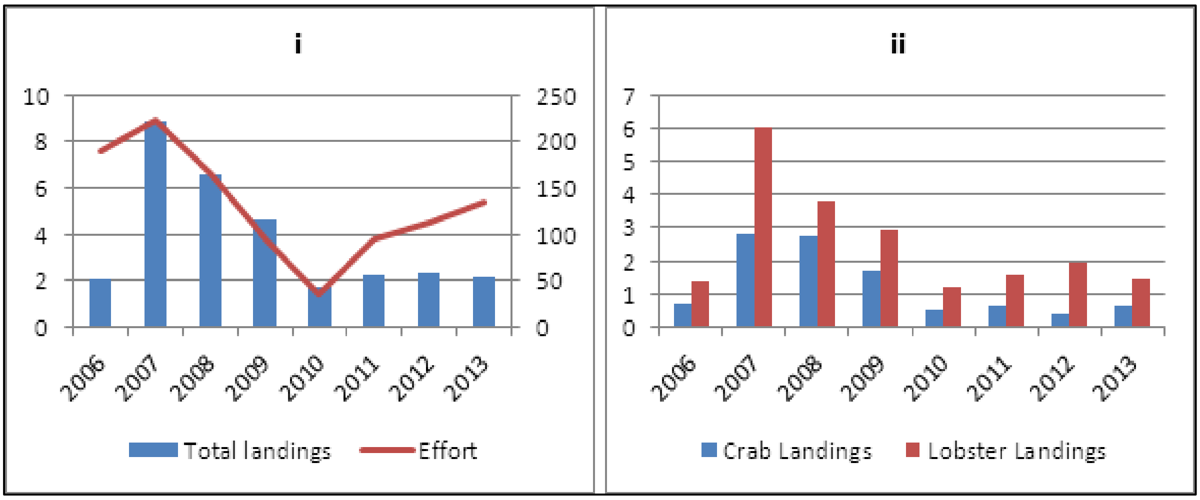


Figure 4.12 Statistical Area 32F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

4.5.1.2 CPUE

Regression analysis of CPUE (catch per unit effort) against effort highlights the disparity between pre and post 2010 data (Fig 4.13) which falls into two distinct groups when plotted (2006 appears to be an outlier in this data set). CPUE remains fairly constant throughout the period between 2007 and 2010 indicating that at this point fishing activity is not having a detrimental effect on abundance (CPUE would be expected to fall as effort increased if this was the case).

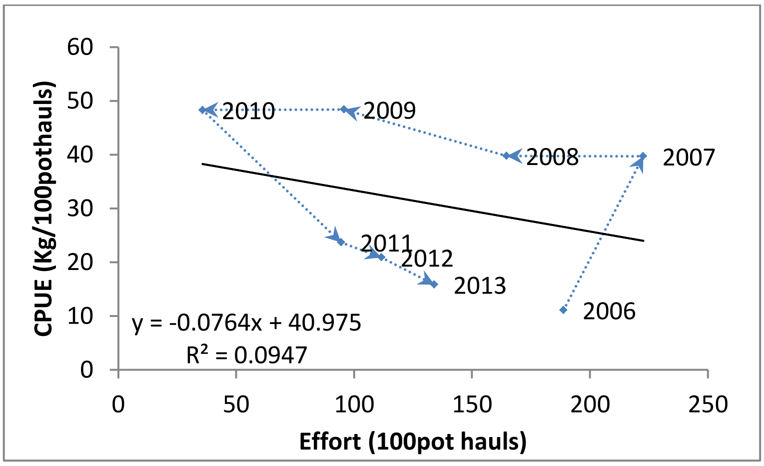


Figure 4.13 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 32F1 2006-2013

CPUE drops dramatically from 2010 to 2011 suggesting that some event has occurred between these points that has either had a negative impact on the abundance of animals on the ground or has reduced the efficiency of the fishery. This is followed by a steady decline in CPUE despite increasing effort which should have seen landings returning to 2008/2009 levels.

4.5.1.3 Surplus Yield Models

Due to the grouping of data points and disparity between those groups, three surplus yield models have been created for this area utilising parameters derived the different groups of data.

Using parameters derived from the complete data set creates the catch curves in Figure 4.14. This model represents the middle ground between the years where CPUE was high (2007-2010) and after CPUE had drastically dropped (2011-2013). Fit of data to this model is fairly poor (R^2 =0.09) making its reliability as an indicator of fOpt and MSY questionable. It has been included here for comparison with Figures 4.15 & 4.16.

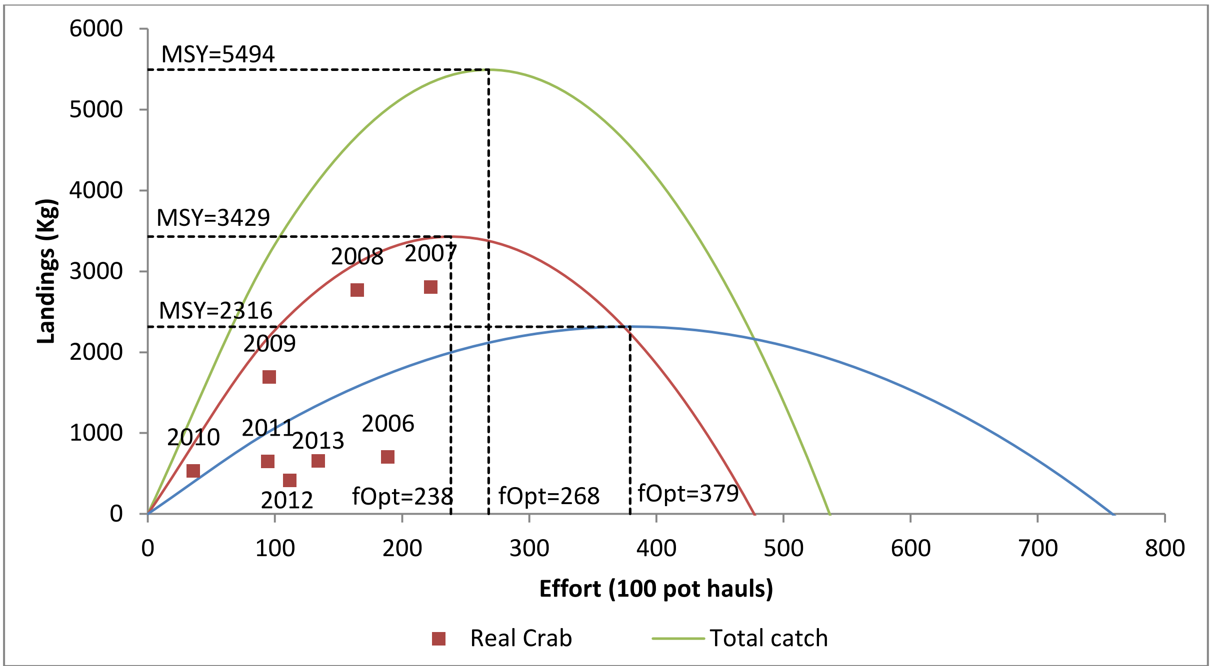


Figure 4.14 Statistical Rectangle 32F1 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2013)

Figure 4.15 presents a surplus yield model based on parameters generated from 2007 to 2010 and indicates that at this point in time the fishery was far from being overexploited. With an estimated total catch MSY of ~12 tonnes and fOpt of 462000 pot hauls compared to observed means of 3.8 tonnes and 131000 the fishery at this point appears to be able to support an increase in effort and landings without adversely affecting the populations ability to replace losses resulting from fishing mortality. Fit of regression data to this model is high (R^2=0.82) which would make it a reliable indicator for the management of the fishery had conditions remained constant in subsequent years. Unfortunately the reduction in CPUE in subsequent years makes it inadvisable to use figures generated from this model as a basis for management as these would tend to overestimate MSY in light of later years data.

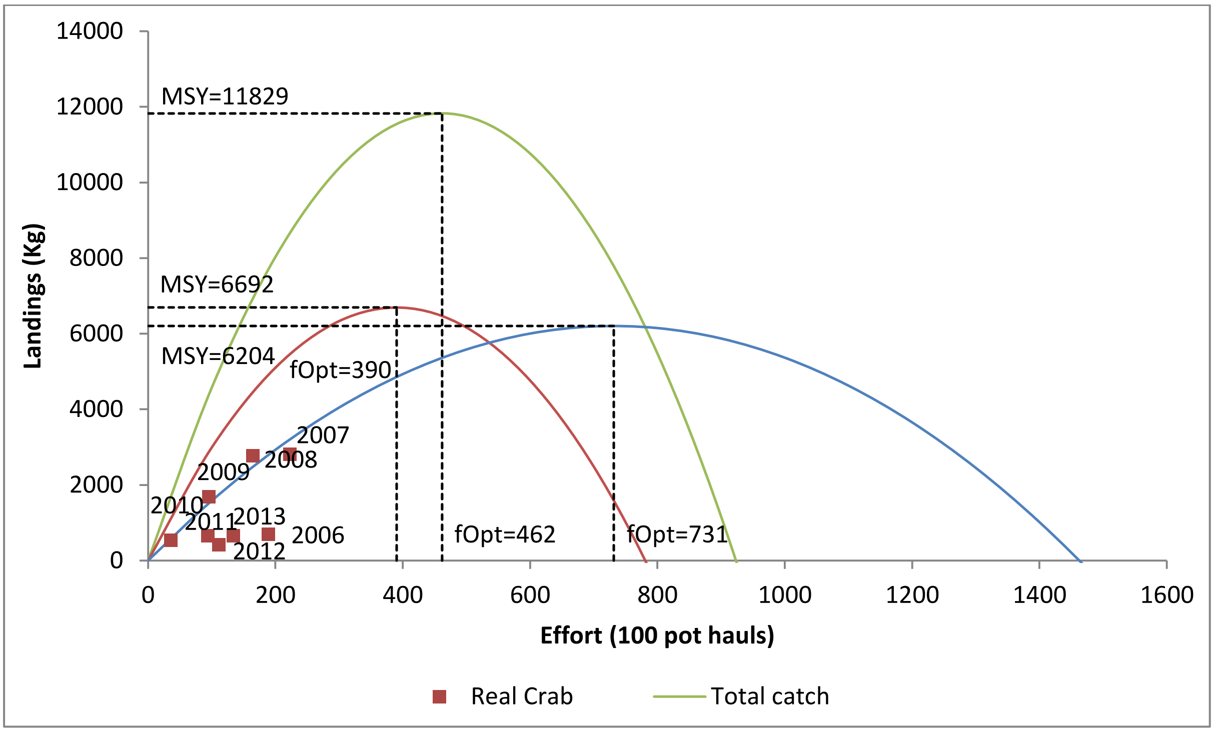


Figure 4.15 Statistical Rectangle 32F1 Surplus Yield Model Using Parameters Derived from Regression of Data Points 2007- 2010

Parameters derived from 2011 to 2013 data have been used to construct the model presented in Figure 4.16 and indicate the effect on MSY that the sudden decrease in CPUE occurring after 2010 has had on the area. MSY and fOpt are greatly reduced compared to the other models with indications that MSY was reached in 2011 for lobster which is the limiting species in this fishery and has since been pushed beyond the capacity of the population to fully replenish losses occurring through fishing mortality. Fit of data to this model is high (R^2=0.99) however; it is important to note that this is based on a very limited data set (3 data points) and consequently reliability may be questionable; it does however provide a precautionary estimate of yields on which to base management.

The disparity between models makes it difficult to make recommendations with any confidence for this area. Indications are that this fishery has gone through a dramatic shift in productivity which early models would indicate is not related to over exploitation. This change could be a consequence of a number of things including to poor recruitment, changing environmental influences or development on or near key fishing grounds. With no information to verify any of these it would be wise investigate this further while taking a precautionary approach to managing this fishery by restricting effort at current level and monitoring catch for any change over time. It may be beneficial to liaise with Kent and Essex IFCA regarding this area due to the significant level of overlap with their district.

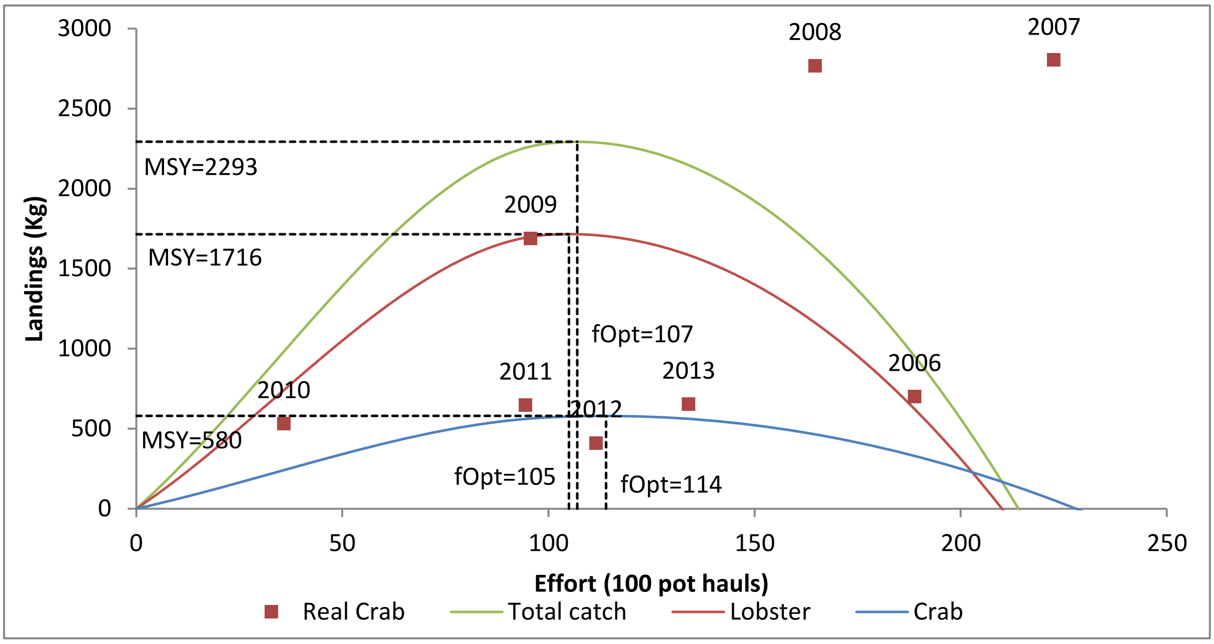


Figure 4.16 Statistical Rectangle 32F1 Surplus Yield Model Using Parameters Derived from Regression of Data Points 2011- 2013

Indications are that this area has been underexploited in the past and could have been subjected to higher levels of effort however; it is apparent that something has had an effect on the productivity of the fishery in recent years reducing its capacity. Whether this is environmental or anthropogenic in cause is unclear at this point and would be worthy of further investigation however; caution should be exercised in the continued exploitation of crustaceans in this area as indications are that populations in this area could now be exceeding sustainable levels of exploitation.

4.5.2 33F1

4.5.2.1 Overview

This area is situated off the Suffolk coast covering an area between the Orford and Lowestoft. Again it is fished by a small number of ports and vessels compared to other areas in the district which is reflected in landings and effort (Table 4.3). Landings have remained fairly stable across the period of the dataset however there is an observable reduction in effort between 2006 and 2009(Fig 4.17 i). Crab composes the majority of catch in this area with lobster playing a lesser role (fig 4.17 ii).

Table 4.3 Statistical Rectangle 33F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	8	19	665	20.9	11.5	9.4
2007	7	20	364	15.5	9.0	6.5
2008	7	17	215	15.9	11.4	4.4
2009	7	14	170	12.0	8.8	3.2
2010	7	18	230	17.2	9.9	7.2
2011	6	16	232	18.8	12.1	6.7
2012	8	21	344	19.1	11.8	7.3
2013	8	20	171	12.2	8.0	4.2
Mean	**7**	**18**	**299**	**16.4**	**10.3**	**6.1**

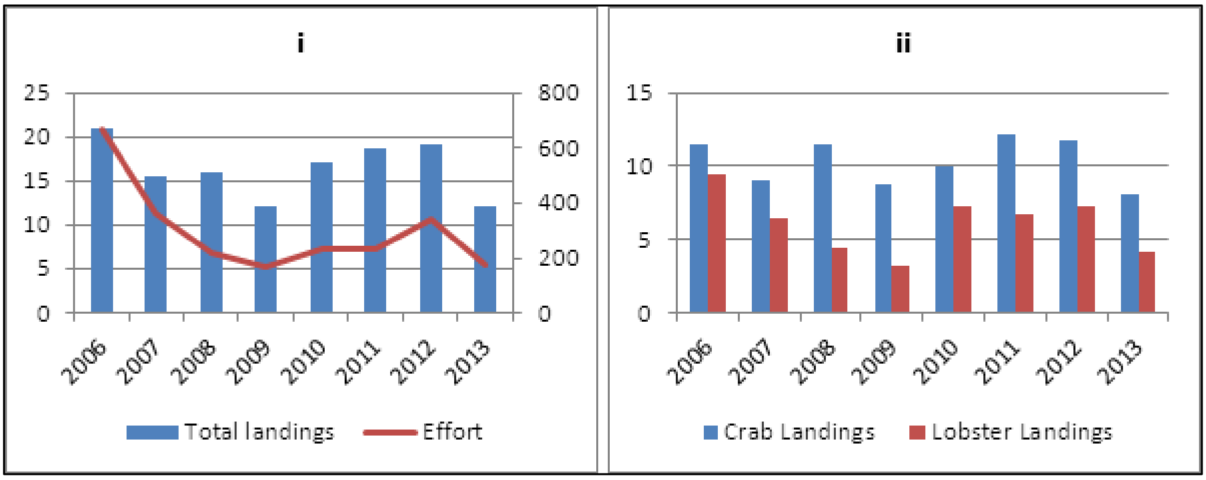


Figure 4.17 Statistical Area 33F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

4.5.2.2 CPUE

Regression analysis revealed a strong negative correlation between increasing effort and CPUE (R^2=0.72) with all data points falling into one group along the regression line and no apparent outliers (Fig 4.18). The spread of data provides good coverage of different levels of effort and CPUE for this area and a good fit of the regression line (R= 0.7255) gives confidence in the reliability of the models generated from it.

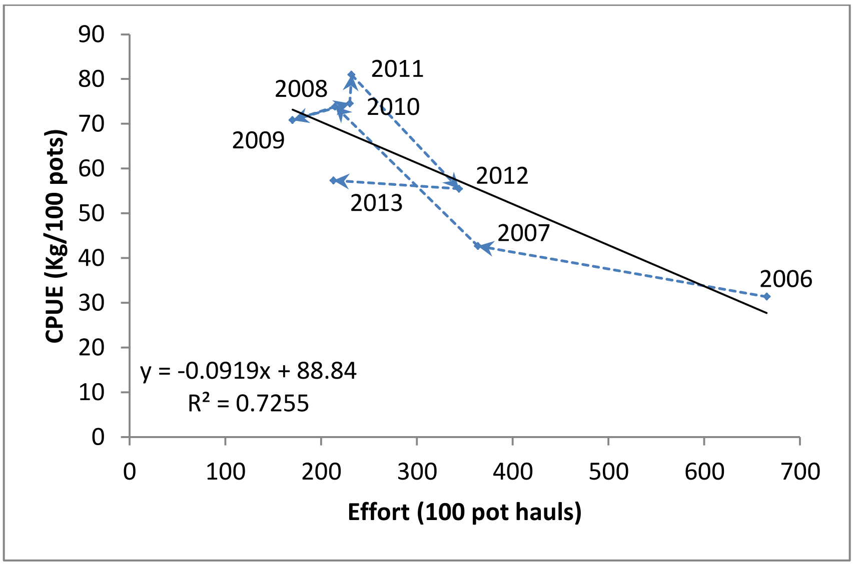


Figure 4.18 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 33 F1 2006-2013

4.5.2.3 Surplus Yield Model

Figure 4.19 presents catch curves for this areas fishery generated from all points on the regression analysis. Indications are that this fishery has been subjected to unsustainable levels of effort (2006 data point) but that a subsequent roll back of effort has brought exploitation levels down below the recommended MSY of ~21.5 tonnes preventing any long term damage to the viability of stocks.

Effort and landings have fluctuated over consecutive years falling to levels that do not result in the maximum sustainable economic gain from the fishery. 2012 stands out as the year that would likely have produced the optimum economic yield from the fishery and should be considered a goal/cut off point for future exploitation of this fishery.

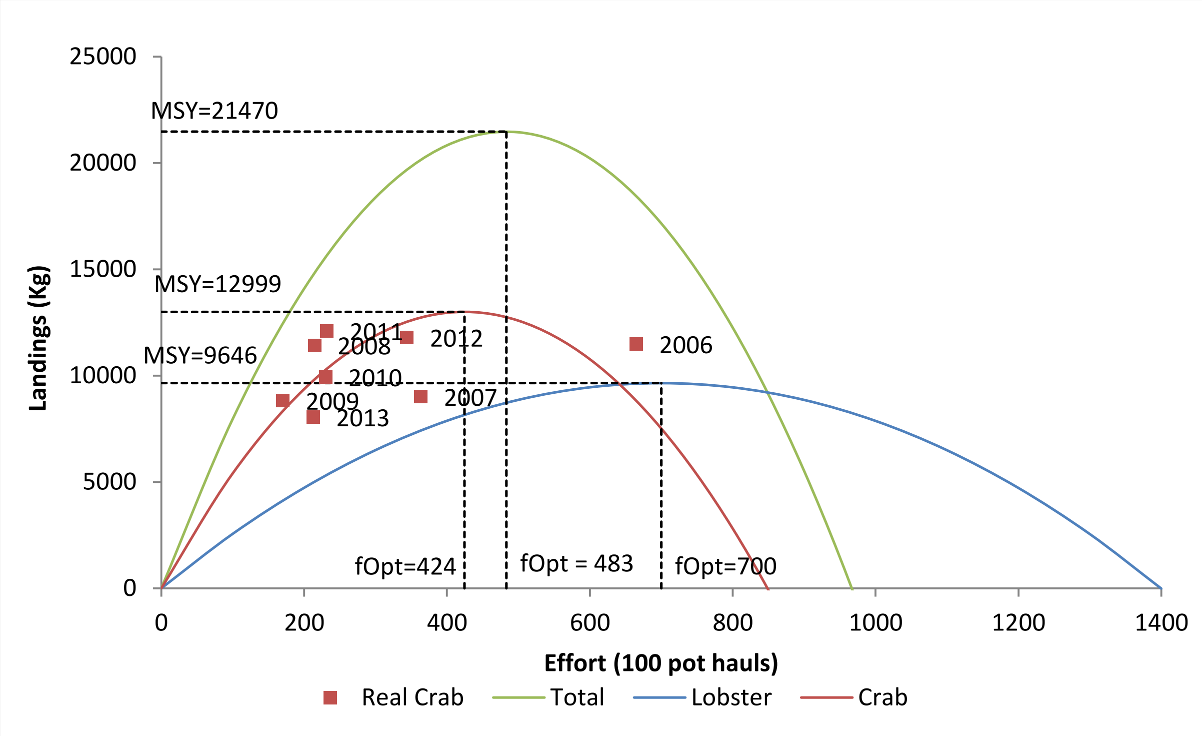


Figure 4.19 Statistical Rectangle 33F1 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2013)

4.5.3 34F0

4.5.3.1 Overview

This area straddles the border between Norfolk and Lincolnshire and is composed mainly of The Wash and a short section of the North Norfolk coast. It represents a developing fishery with very little in the way of effort currently dedicated to crab and lobster fishing (Table 4.4). Crab constitutes the majority of the catch however the difference between crab and lobster catch is not statistically significant (Figure 4.20).

Table 4.4 Statistical Rectangle 34F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	1	1	0	0.0	0.0	0.0
2007	0	0	0	0.0	0.0	0.0
2008	1	1	0	0.0	0.0	0.0
2009	2	3	22	1.8	1.6	0.2
2010	3	3	151	7.7	4.5	3.2
2011	5	7	176	11.5	6.9	4.7
2012	6	6	31	3.3	3.0	0.3
2013	5	5	49	5.2	4.9	0.3
Mean	**3**	**3**	**54**	**3.7**	**2.6**	**1.1**

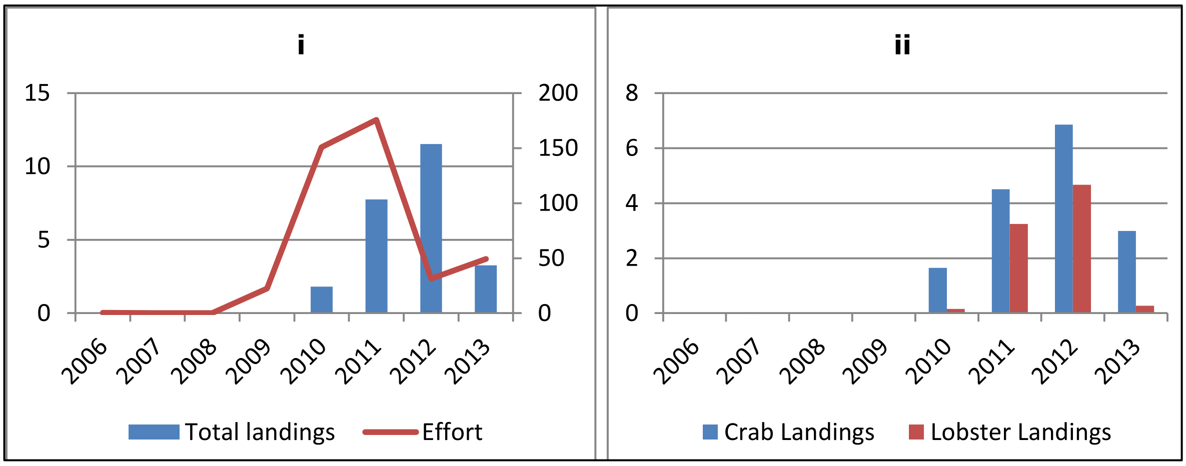


Figure 4.20 Statistical Area 34F0 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

4.5.3.2 CPUE

Unlike other areas in the data set fishing activity has only been recorded for five years starting in 2009. Regression of CPUE against effort does reveal a negative correlation between the two (Figure 4.21) however this is only apparent for crab. Regression of CPUE against effort for lobster reveals a positive correlation (Fig 4.22) which suggests that the fishery has not yet been fully or over exploited for this species at this time. While this is good news in terms of the fishery likely having no negative effect on populations of lobster in the area as of yet it does mean that this data cannot be used to model the fishery, as this type of model relies on parameters from a negative correlation to function correctly. For this reason only the crab fishery has been modelled for this area.

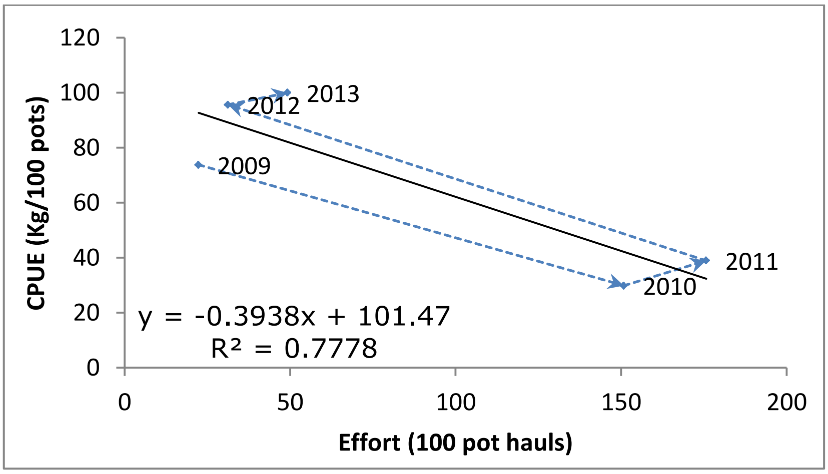


Figure 4.21 Regression Analysis of Crab CPUE vs. Effort for Statistical Rectangle 34F0 2009 -2013

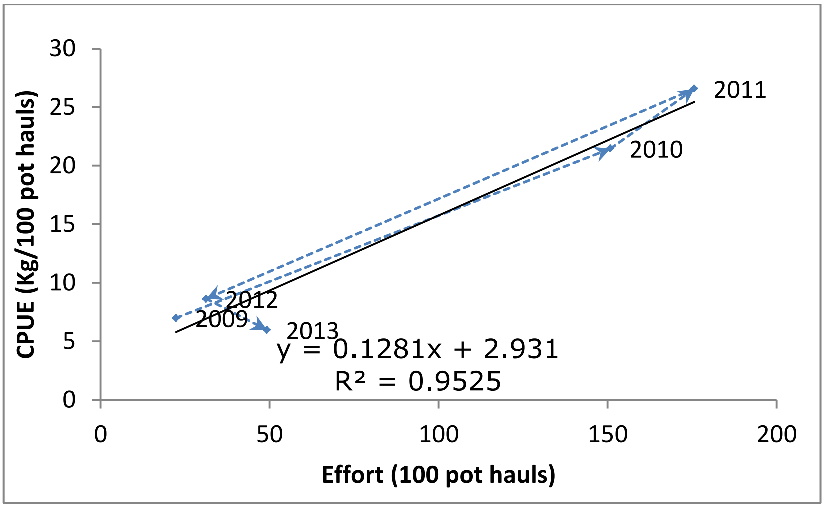


Figure 4.22 Regression Analysis of Lobster CPUE vs. Effort for Statistical Rectangle 34F0 2009 -2013

4.5.3.3 Surplus Yield Model

The catch curve in Figure 4.21 models the fishery for crab only based on data points from 2009 to 2013. Fit of data to the left hand side of the curve is good for this model with landings increasing towards MSY as effort increases. The right hand side however is less accurate, 2010 displays the drop in landings with effort increasing beyond MSY as should be expected however further increase in effort in 2011 sees an increase in landings which is contrary to the predictions of the model. Looking again at the regression analysis (Figure 4.22) it can be noted that a small increase in CPUE occurred at the same time as the increase in effort between 2010 and 2011 which would explain this. At present levels of effort this anomaly is of little concern, especially when the limited availability of data for this area is considered. As a developing fishery it is possible/ probable that this area has not yet been fully exploited and is still being explored by fishermen to determine the best areas to deploy gear. Consequently it would be unwise to consider this model entirely accurate at this point until further years fishing have been added to the data set. That said the MSY and fOpt levels generated by the model could be considered precautionary for management of this area with a softly softly approach to the exploration of the fishery advisable until its full potential is ascertained.

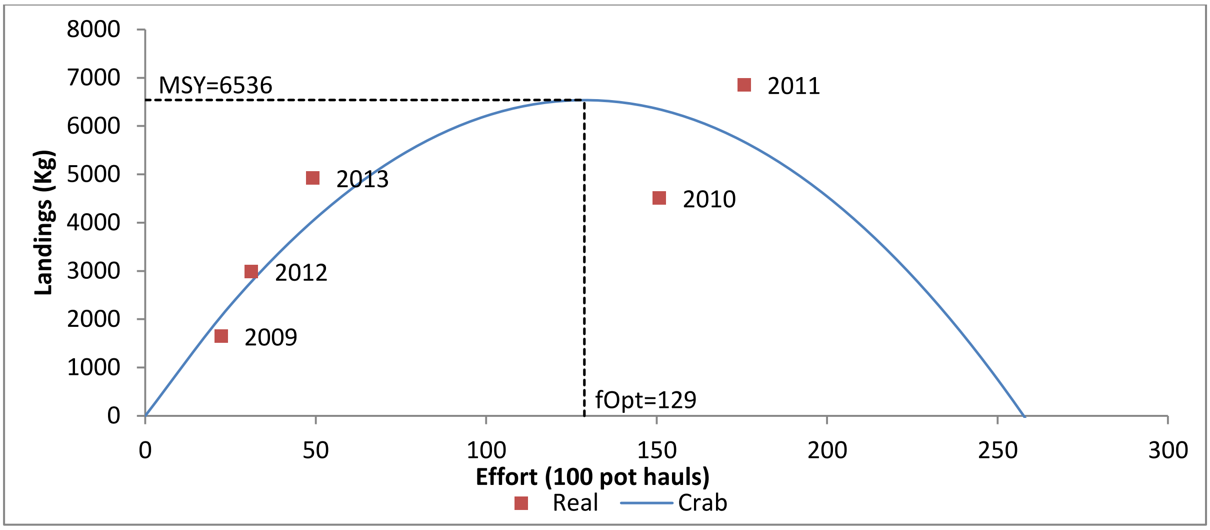


Figure 4.212 Statistical Rectangle 34F0 Surplus Yield Model for Crab Using Parameters Derived from Regression of Data Points 2009 – 2013.

4.5.4 34F1

4.5.4.1 Overview

This area is one of the most productive for potting in the EIFCA district. Situated off the North Norfolk coast it is the primary fishing ground for vessels operating out of Cromer. This area is fished by a large number of vessels from numerous ports along the North Norfolk coast, mainly consisting of day going vessels launching from beaches and fishing close to shore. The high number of vessels fishing this area is reflected in the effort and landings which are the second highest for any area in the district (Table 4.5). This fishery is very much centred on fishing for crab with large numbers of these animals being landed each year. Landings of lobster are significantly lower than crab in this area (Figure 4.22) however; lobster landings are still significantly higher here than in most other areas in the district.

Table 4.5 Statistical Rectangle 34F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	17	49	4123	278.8	246.5	32.3
2007	12	37	3837	183.3	156.0	27.3
2008	13	35	3564	203.7	169.8	33.9
2009	14	37	3339	200.1	170.4	29.7
2010	13	35	3046	167.3	142.5	24.9
2011	12	42	4088	213.0	178.4	34.6
2012	13	41	3881	258.1	227.6	30.5
2013	14	44	3543	268.3	238.7	29.5
Mean	**14**	**40**	**3677**	**221.6**	**191.2**	**30.3**

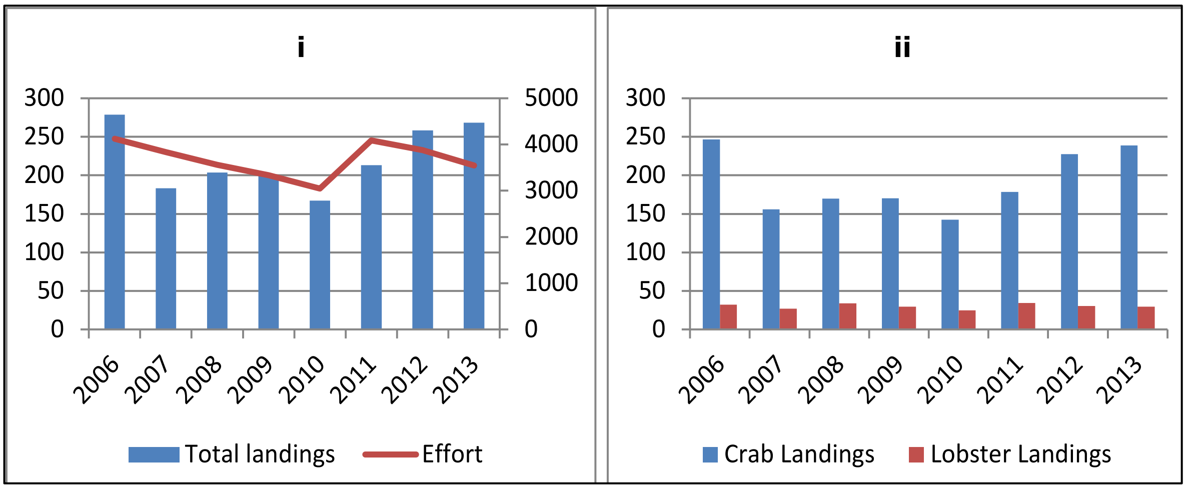


Figure 4.22 Statistical Area 34F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

4.5.4.2 CPUE

Regression analysis of all data points results in a positive correlation between effort and CPUE (Figure 4.23). This appears to be due to a few exceptional years (2006, 2012 and 2013) where CPUE has increased without any appreciable change in effort. In order to identify the negative trend required to produce surplus yield curves these exceptional years were excluded from the analysis and only those data were a negative correlation could be detected was used (Figure 4.24). While this may discount good years in the fishery, for the purpose of this analysis this is still acceptable. The resulting model can be considered precautionary, where effort and MSY are set at lower levels to protect stocks but still allow for bonus catch in those years when productivity is exceptionally high.

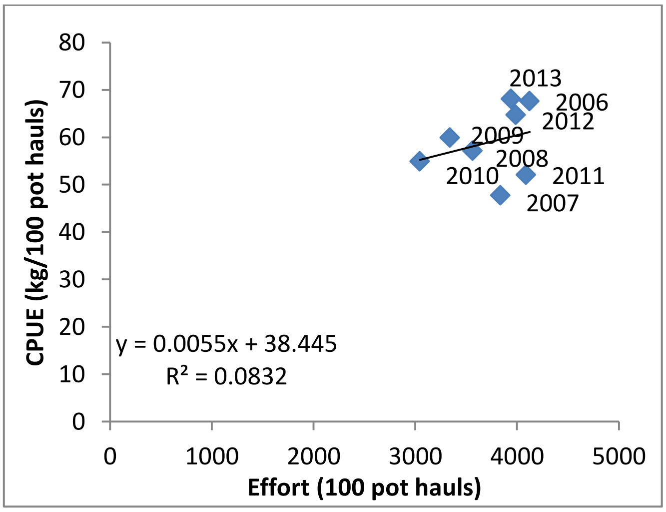


Figure 4.23 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 34F1 2006-2013.

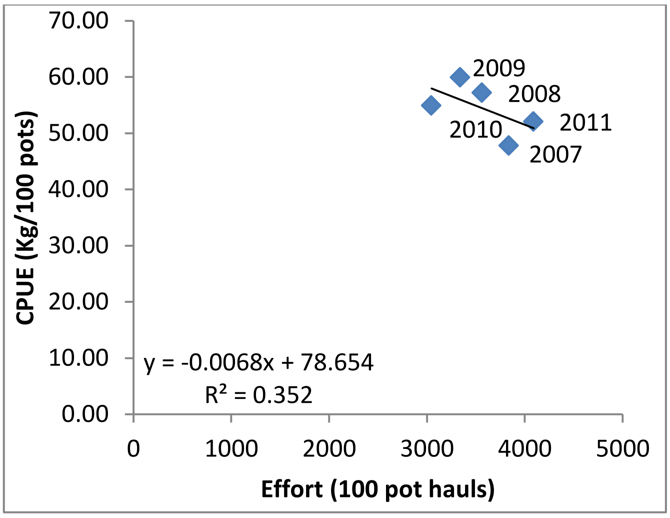


Figure 4.24 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 34F1 2008-2011

4.5.4.3 Surplus Yield Model

Using parameters derived from 2008-2011 data produces the model presented in figure 4.25 It is apparent that crab is the limiting species in this fishery despite having a higher MSY than lobster. Crab is highly abundant in this area and makes up a high proportion of the catch with large numbers being removed annually. Despite this it does not appear that this fishery has yet reached unsustainable levels of exploitation however; the model suggests that current effort is approaching the maximum recommended levels. 2006, 2012 and 2013 appear to be exceptional years for this fishery, where no appreciable increase in effort has produced higher yields than in other years. This may be explained by good years of recruitment, where large numbers of moulting animals have increased in size to meet MLS or some other environmental variation that has proved beneficial for fishing. It is not clear from the available data as to what is causing these exceptional years or if indeed they are part of a natural pattern of abundance within the fishery that cannot be detected within the scale of data being analysed; further investigation and monitoring of the fishery would be recommended to fully explore what is happening.

This Fishery appears to be relatively stable at present and offers little of concern in terms of management requirements. That said it would be advisable to monitor effort in this fishery as it does appear to be approaching the maximum recommended levels based on available data. As this is one of the most economically important crustacean fisheries in the district further study to monitor effort and investigate population dynamics in the fishery would be recommended allow more reliable assessment methods to be employed.

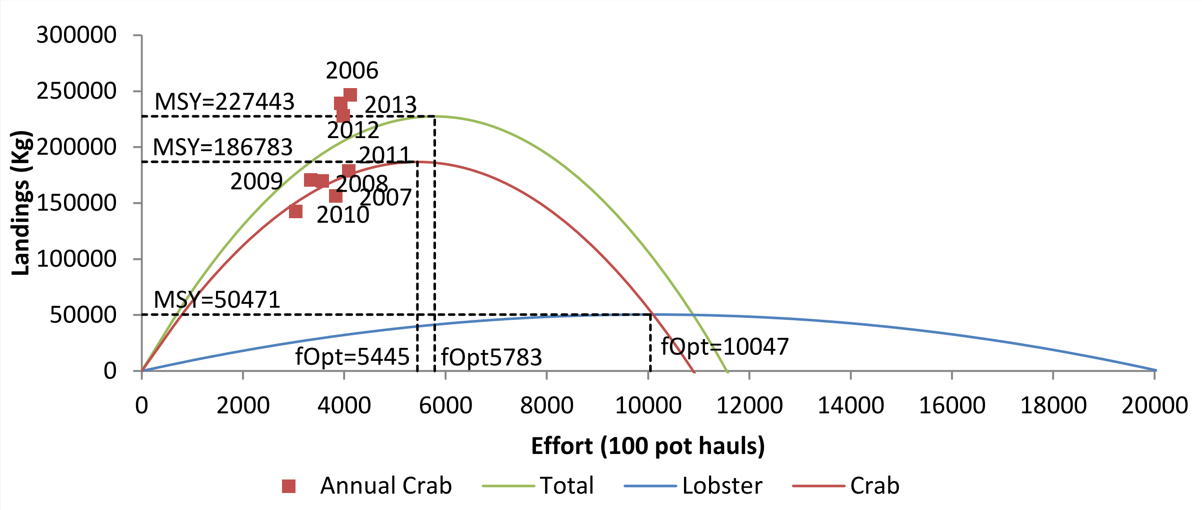


Figure 4.253 Statistical Rectangle 34F1 Surplus Yield Model Using Parameters Derived from Regression Data Points 2007-2011.

4.5.5 35F0

4.5.5.1 Overview

This area is the most productive for potting fisheries in the district with the highest annual landings despite only being fished by a small number of ports (Table 4.6). This is the main fishing area for vessels operating out of Wells and is where much of the districts offshore potting occurs. As shown in figure 4.26 crab constitutes the majority of the catch for this area being significantly higher than lobster. Despite being ancillary to the main crab catch however; as with 34F1 lobster landings are still significantly higher from this area than most others in the district. Landings are fairly consistent and appear to follow effort quite closely with changes in effort coinciding with a related change in landings. 2008 is the only point that contradicts this trend, with a noticeable increase in landings that does not coincide with any appreciable increase in effort.

Table 4.6 Statistical Rectangle 35F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	13	2251	239.2	213.7	25.4
2007	4	12	2040	231.4	208.4	23.0
2008	3	14	2105	368.8	340.6	28.2
2009	3	13	2374	281.8	248.2	33.6
2010	3	14	2507	274.5	246.7	27.9
2011	4	15	2439	247.7	218.8	28.9
2012	4	18	3207	292.6	255.6	37.0
2013	4	13	2471	236.2	211.1	25.1
Mean	**4**	**14**	**2424**	**271.5**	**242.9**	**28.7**

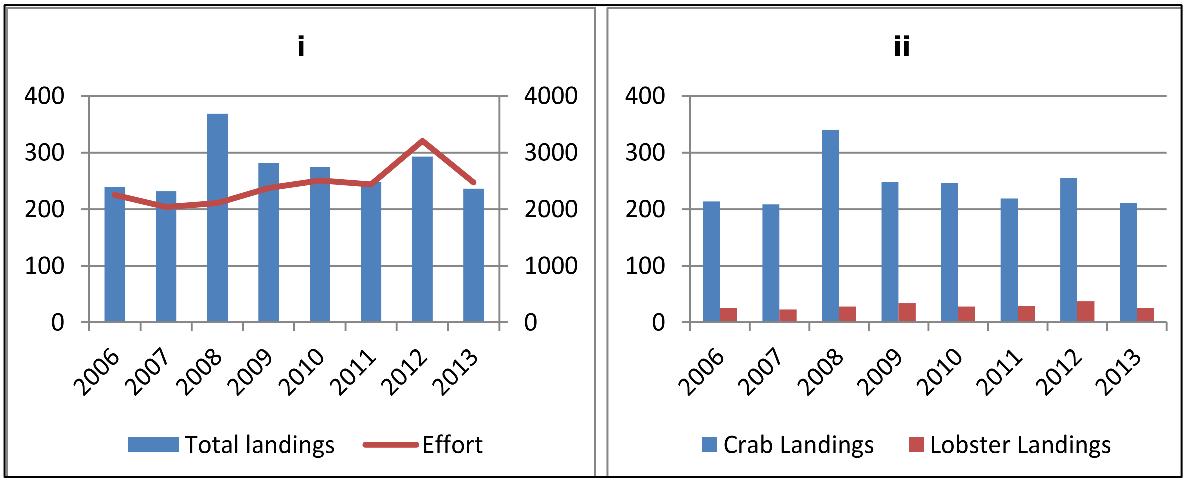


Figure 4.26 Statistical Area 35F0 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

4.5.5.2 CPUE

At recent levels of effort, CPUE is observed to decrease as effort increases giving a negative correlation to the regression line (Figure 4.27 & 4.28). 2008 appears to be an outlier in this regression with a noticeable spike in CPUE compared to similar effort in other years (Figure 4.27). Removal of the 2008 outlier flattens the regression line reducing the degree to which increasing effort has effect on the trend line. For the purposes of constructing a surplus yield model 2008 has been considered an outlier and parameters from the regression in figure 4.28 have been used.

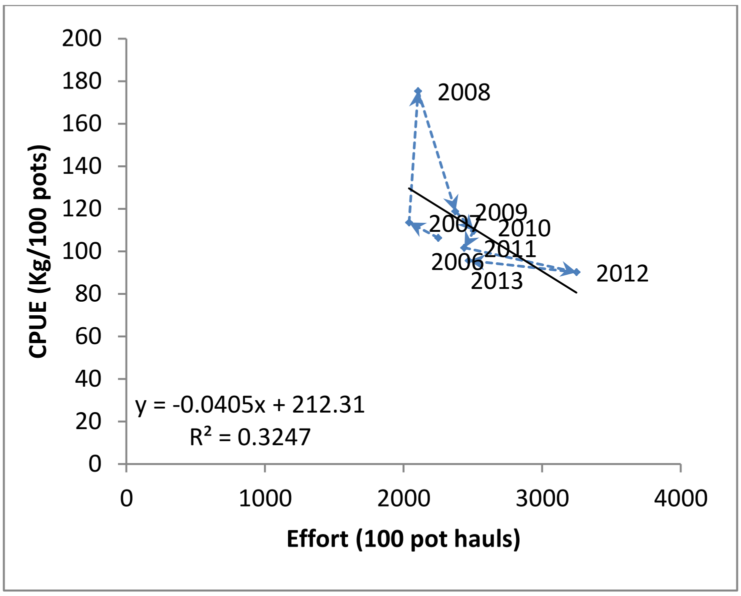


Figure 4.27 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 35F0 2006-2013

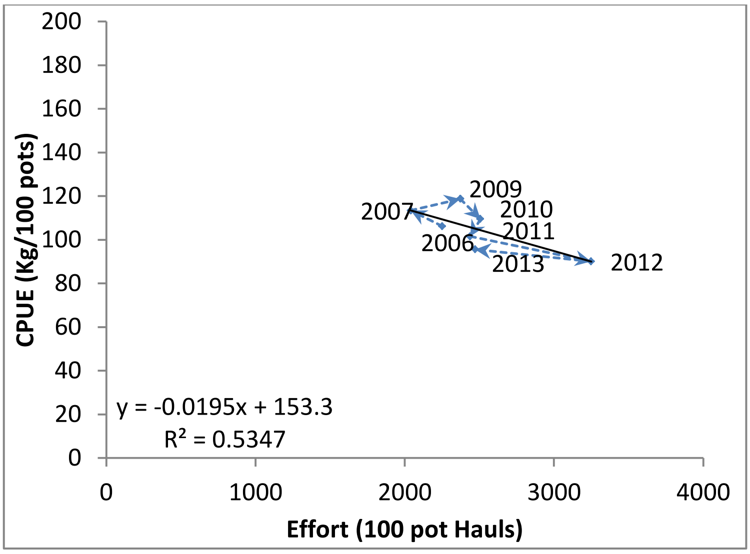


Figure 4.28 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 35F0 excluding 2008

4.5.5.3 Surplus Yield Model

The model presented in figure 4.29 indicates that crab is the limiting species in this fishery. Despite this MSY for crab is significantly greater than for lobster at ~260 tonnes compared to ~7.5 tonnes. The fishery does not appear to have been fished at unsustainable levels throughout the history of the dataset but as with area 34F1 it is apparent that fOpt is not far off being met for crab.

Lobster appears to be able to sustain much higher levels of effort than crab in this model and this is likely explainable from the regression of CPUE against effort for this fishery. The trend line for this regression shows a positive correlation between CPUE and increasing effort for this species, indicating that lobster has not been fully exploited as of yet. This trend produces parameters that do not result in a reliable model for this species in this area, but despite this it would be likely that the lobster fishery would benefit from increased effort; however any increase in effort to increase lobster landings would result in increased pressure on the crab stock. This would be unadvisable given how close that fishery is to producing MSY.

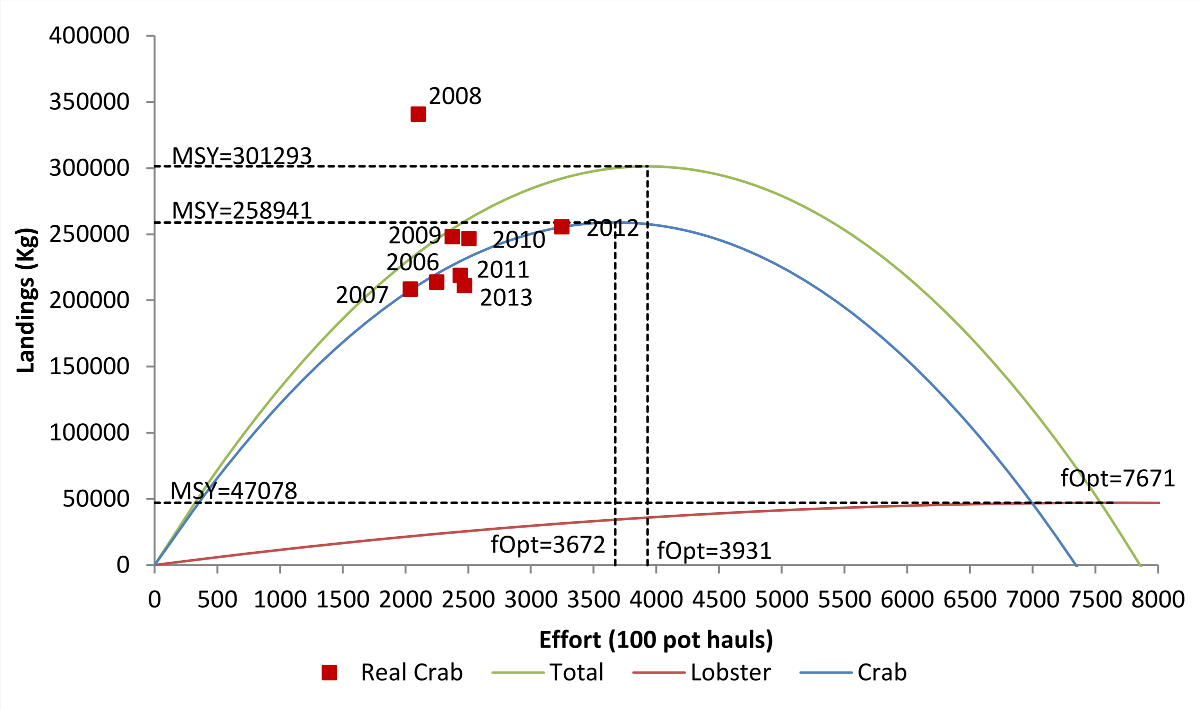


Figure 4.29 Statistical Rectangle 35F0 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2013)

<u>4.5.6 35F1</u>

4.5.6.1 Overview

This is the third most productive area fished in the district and is situated to the north of the main Cromer fishing ground (34F1). This area is primarily offshore with the majority of it falling outside of the 6nm district limits, despite this it is still considered in this assessment as it is likely that the stock associated with this area is part of a larger stock that includes inshore areas.

Effort and landings have seen a steady increase from 2006 to 2009 with landings increasing by ~50 tonnes each year, before steadily falling back down to 2006 levels again in 2013. Crab constitutes the main catch from this area being significantly greater than catch of lobster (Figure 4.30).

Table 7 Statistical Rectangle 35F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	7	11	861	64.6	56.3	8.3
2007	7	10	1187	118.6	108.8	9.8
2008	10	17	1575	183.1	168.6	14.5
2009	9	16	2427	201.3	179.7	21.6
2010	9	17	1539	174.8	158.2	16.6
2011	6	13	1691	160.9	142.4	18.4
2012	6	12	1454	86.7	75.2	11.5
2013	6	8	529	46.2	42.3	3.9
Mean	**8**	**13**	**1408**	**129.5**	**116.4**	**13.1**

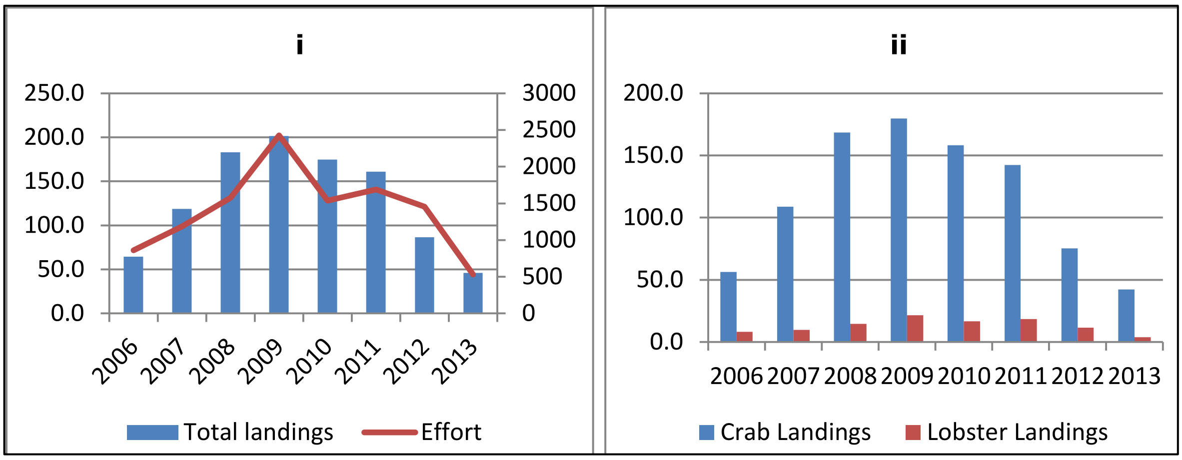


Figure 4.30 Statistical Area 35F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

4.5.6.2 CPUE

Regression analysis of CPUE against effort for total catch (Figure 4.31) revealed a positive relationship between increasing effort and CPUE however this correlation is very weak (R^2 = 0.0153). This same relationship is evident for the regression of crab and lobster data. CPUE does not vary greatly with changes in effort suggesting that this fishery has not yet reached a level of effort that the local stock cannot sustain. Typically a change in effort would be reflected by an increase or decrease in CPUE however in this instance this relationship is not evident. Although CPUE does show some variability it is very small (<1 tonne between the maximum and minimum CPUE reported) and could be accounted for by naturally occurring variability in catchability. The lack of relationship between effort and CPUE indicates that fishery in this area has not yet reached levels of effort that are having any appreciable effect on local stocks.

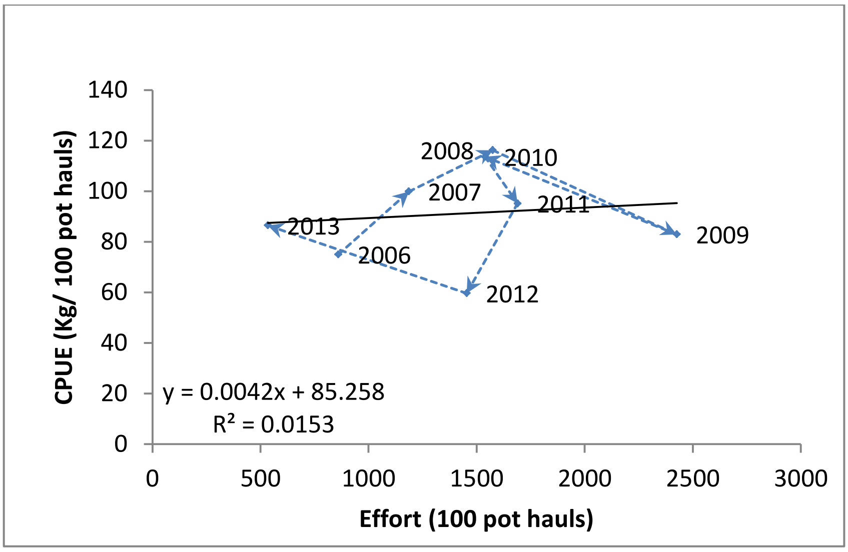


Figure 4.31 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 35F1 2006-2013

4.5.6.3 Surplus Yield Model

The surplus yield model in this example (Figure 4.32) is based on parameters that have not identified any degree of overfishing and so should be considered as indicative only, as it is likely to generate unrealistic estimates of MSY and fOpt. It has been included in this analysis for comparison only.

The model predicts MSY for crab of >400 tonnes with only 17 tonnes for lobster. Why there should be such a vast discrepancy between the two species is unclear however it is likely down to the model being based on parameters that are far from ideal for this type of analysis. This would also explain the extremely high estimates of MSY predicted for crab.

Despite the unreliability of the model it would be safe to conclude that this fishery is still capable of sustaining higher levels of fishing than currently occur there. This could make it ideal for the redistribution of current effort in other areas should the need arise to close areas to fishing or introduce effort limitation.

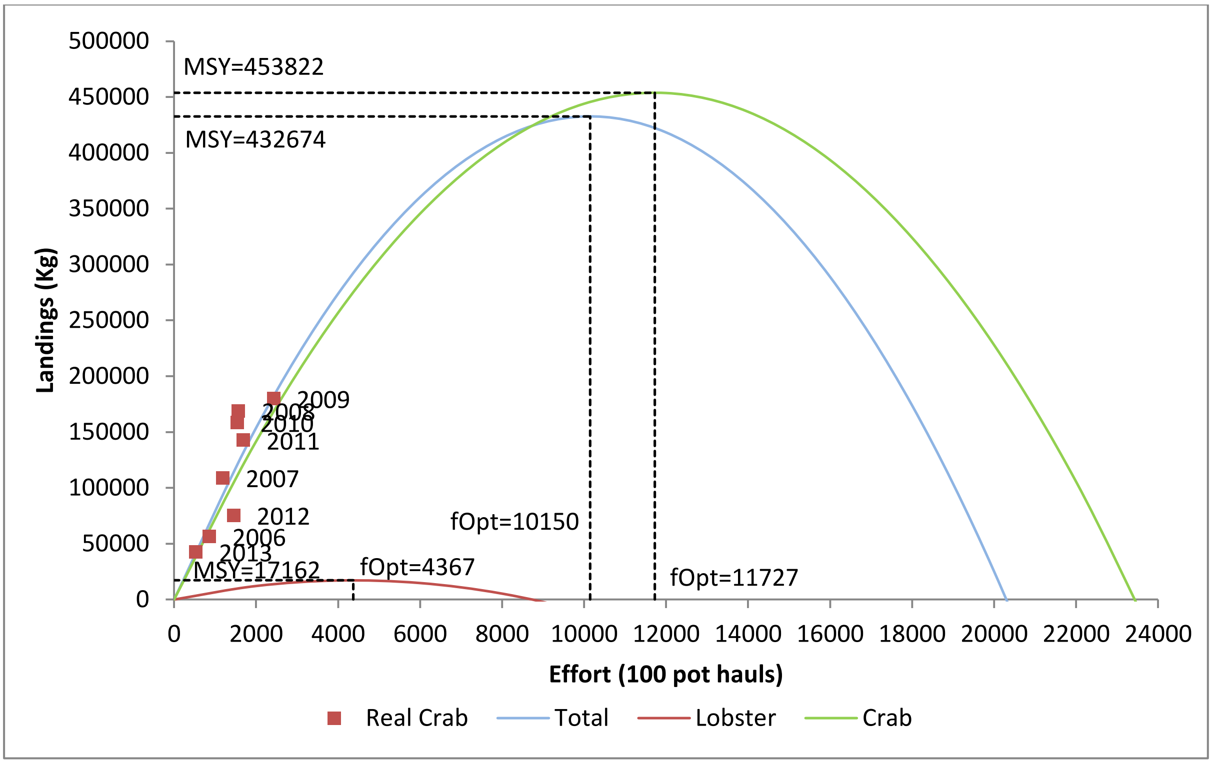


Figure 4.32 Statistical Rectangle 32F1 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2013)

4.6. Discussion

The analysis presented above is the first attempt by EIFCA to utilise MSAR data in the assessment of crustacean fisheries in the district. Previous iterations of this project have attempted to model the fishery based on data obtained from surveys carried out at sea however this data was far from ideal and it is apparent that the estimates of MSY they produced were somewhat unreliable. Substituting this data with records from MSAR submissions has been a long term goal in the hope of producing more reliable estimates however; it has required the accumulation of a number of years' data to allow the analysis to be carried out.

Using the MSAR data in this way has produced mixed results with some areas being modelled more reliably than others. These models have certain data requirements in order to be accurate. One of these requirements is for the data to cover a wide range of fishing efforts that coincide with a negative correlation between effort and CPUEs. Many of the fisheries modelled here do not conform to this requirement as fishing has either been going on for a long period of time allowing effort to reach equilibrium, or the fishery is still not fully exploited meaning the negative relationship between effort and CPUE is not observed. While this may throw the accuracy of the models into question they are still useful tools for indicating the state of the fishery and on the whole things look good. None of the areas examined here seem to be suffering from overexploitation

and all appear to be sustaining healthy stocks that should provide for a viable and sustainable fishery for years to come. While this is true it would be wise to continue the monitoring of crustacean fisheries in the district as a number of the most important and heavily fished areas appear to be reaching the threshold of sustainability. It would be advisable for example to limit fishing effort for the main Wells and Cromer fishing grounds (35F0 and 34F1 respectively) at around current levels as these areas in particular appear to be close to reaching MSY as predicted by this analysis.
One of the areas identified in this report seems to be vastly underexploited (35F1) and would likely benefit from additional effort, whether this is feasible depends on the ability of potting vessels to reach the area as it is located offshore.

4.7. Conclusion and recommendations

Crustacean fisheries in the district appear to be healthy and there is no indication that overexploitation is occurring however; it is apparent that in some cases threshold levels may be being approached. The majority of fishing activity is concentrated around the North Norfolk coast and makes a significant contribution to local and national economies both directly to those actively engaged in the industry and indirectly as a draw to tourists.

Given the economic importance of this fishery, continued monitoring would be advised with the development of more accurate and reliable assessment methods a priority. Revival of biosampling regimes both at point of landing and at sea would be recommended to allow population analysis to be included in future assessments. Such a program of study would allow a more in depth analysis of the health of stocks to be carried out.

With much of the fishing activity concentrated around the North Norfolk coast and the limited resources available to dedicate to the project, it would be sensible to make this area the focus of future study allowing a more thorough analysis to be undertaken.

MSAR data can be used to analyse fishing activity to higher levels of spatial resolution, highlighting hotspots of activity within the most productive areas and spatially mapping areas of high effort and productivity using GIS software. This could also be used to compliment the Authority’s fishing activity mapping project and support the work being carried out on the revised approach to fisheries management within European Marine Sites.

5.0 FINFISH PROJECT

5.1 Introduction

The project has been instigated in order to enhance understanding of finfish in our district, to be better able to meet our objectives of sustainable management of healthy seas supporting viable industry and communities.

A logical sequence of examination was followed, starting with an examination of large scale factors (such as climate) which largely govern the potential distribution of species within our district. This was followed by an overview of the commercial and recreational sectors utilising finfish as a resource. As it is not possible within the scope of this project to look at in detail all species within our district, this examination was restricted to species selected on the basis of their particular economic, leisure, environmental or legislative importance.

The project was initially conceived as requiring and involving a considerable amount of fieldwork; however, it quickly became apparent that there would be far more "bang for buck" by basing the project mostly on already available sources of information, and reworking this data for our own needs as appropriate. Sections using these data sources are included. We have conducted some field sampling ourselves, and this has generated valuable additional data compatible with and supporting the information gleaned from other sources.

The six species (or group of species, in the case of Grey Mullet) selected for more detailed examination, together with the main reasons why and issues affecting those species, are –

Bass

A very important species for some sectors of the commercial fleet, and also a very important – indeed totemic – species for recreational sea angling (RSA). A species which is approaching the northern limit of distribution in our district, and therefore susceptible to fluctuations in climate, leading to variable recruitment.

There is an oft expressed desire among the RSA sector for "more and bigger" bass.

Dover Sole

A very valuable and important fish for the commercial sea angling fleet

Dab

Principally of importance to the RSA sector, where it is often the first fish novice anglers catch – thus leading to both the dab and the angler being hooked.

There has come to prominence recently the issue of "green dab" – unsightly hyperpigmentation of the fish.

Flounder

More important for the RSA sector than commercially in its own right, although there has been concern expressed that flounder are being used as bait in commercial potting, to the detriment of the stocks in, especially, the Stour & Orwell estuaries.

Smelt

(NB with Smelt it is important to distinguish between the European or "cucumber" smelt, *Osmerus eperlanus* discussed here, and the sand smelt *Atherina presbyter*. Confusion between the two is unfortunately all too common – not so much in terms of field identification, but rather when considering habitat requirements and management / legislative actions).

A UK BAP priority species, and therefore subject to special protection and management measures. This is an anadromous species, migrating from sea or estuary to fresh water to spawn. As such, it comes under the remit of the Environment Agency.

Mullet (Grey Mullets – Thick lipped grey mullet, Thin lipped grey mullet, & Golden grey mullet)

Species which are recorded as a component of the commercial catch, but only to a small degree. Have some importance to a relatively specialised sector of the RSA community.

Contents

Points of Note

- Estuaries are very important nursery grounds for many of the species of interest.
- The commercial fishing finfish sector is important to our district from a socio-economic point of view. The finfish sector tends perhaps to be more diffuse and less visible than molluscs or crustaceans.
- Important differences in landings figures between different sources can be identified.
- Recreational sea angling is important from economic, social and cultural points of view.
- Sole and Bass are the two most important commercial finfish species in our district.
- Bass is a very important species for the recreational sea angling community.
- Much of what happens to affect bass recruitment is outwith our direct control (weather, spawning stock being caught, capture of fish migrating to and from spawning grounds), but there is likely to be a local bass stock, thus justifying local management.
- The recreational sea angling community could be a sources of useful data on several aspects of interest, notably quantified catches, and dab hyperpigmentation.
- There are sources of data (Environment Agency Water Framework Directive sampling, Sizewell screens) which assist us in understanding local fish populations, but these are incomplete. It will be useful to continue to update these data, but some targeted work to fill in the gaps will be beneficial. For instance, the EA WFD dataset indicates that Breydon Water is a very important site for several fish species.

5.2 External abiotic factors affecting fish populations in our district

There are factors which affect fish populations over which we as an Authority have no control. Although we can't manage these factors, it is nevertheless important to understand them and be aware of the effects they are having. In doing so, we can assess which changes in fish population are being driven by factors we can influence, and which by factors outside of our control.

Chief among these are the weather and climate, including both long and short term cycles, and day to day variability. There are global and local elements to consider, of which the most significant are listed below.

Only the briefest descriptions of the global / ocean scale phenomena (North Atlantic Oscillation, Arctic Oscillation, Atlantic Multidecadal Oscillation and Latitude of the Gulf Stream and the Gulf Stream North Wall Index) are given here, together with brief summaries of their effects on climate and ecosystems. Much greater detail is available from online resources, with the Wikipedia link for each factor given here as a starting point for further investigation. The eminent fishery scientist Dr. Colin Bannister delivered a seminar to EIFCA in February 2014 in which he considered the effect of these factors on fisheries in some depth. The presentation from that seminar is available within EIFCA data resources.

North Atlantic Oscillation (in particular the Winter NAO)

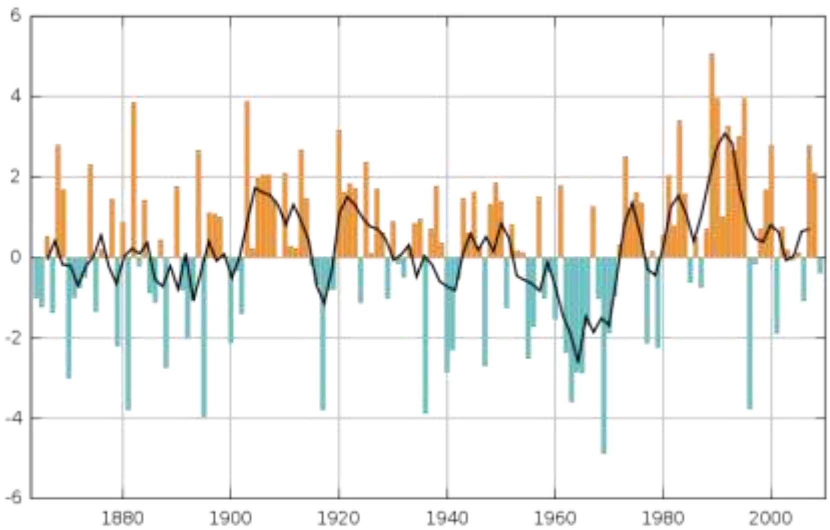


Figure 1 Winter (December through March) index of the North Atlantic oscillation (NAO) since 1864, with a five year moving average (black).
(Source – Wikipedia, http://en.wikipedia.org/wiki/North_Atlantic_oscillation)

The NAO is a measure of the difference in atmospheric pressure between the Azores High and the Icelandic Low. A large positive value indicates a greater difference, leading to more persistent, stronger Westerly winds, bringing milder, wetter weather to the Atlantic seaboard of Europe. This results in milder winters, cooler summers and frequent rain. If the Westerly's are supressed due to a low or negative NAO there are greater extremes of temperature, leading to colder winters and hotter summers.

These atmospheric temperature variations are reflected in the marine environment, with periods of low or negative NAO having lower winter sea temperatures than periods of high NAO. This has appreciable effects of fish populations, especially the survival of larval fish, largely through the effects on the zooplankton which make up the food of this lifecycle stage. It also strongly affects species such as bass which are near to their limits of tolerance to cold within our area. (For more detail see Dr. Colin Bannister's presentation).

This index had been predominantly positive throughout the 1980s / 1990s (Figure 1), but has recently entered a much more variable phase.

The NAO has an influence on the location of the Gulf Stream, with a lag of some two years between changes in the NOA and changes in the Gulf Stream (see "Latitude of the Gulf Stream and the Gulf Stream north wall index" below)

Arctic Oscillation

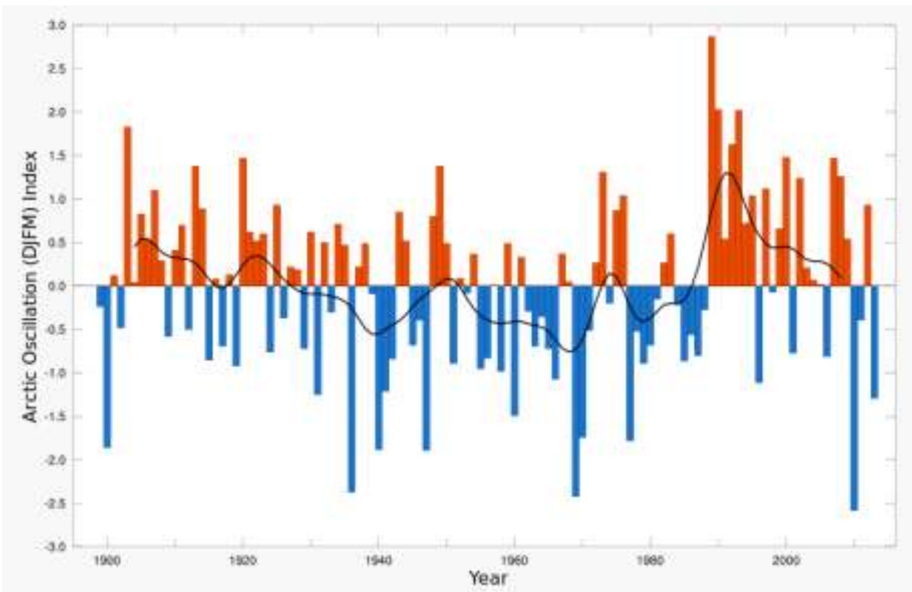


Figure 2 Arctic Oscillation index for the extended winter season(DJFM) 1899-2013.Black line:11-year smooth.
(Source – Wikipedia, http://en.wikipedia.org/wiki/File:Arctic_Oscillation.svg)

The Arctic Oscillation index describes the amount by which the penetration of cold, high pressure polar air into the warmer, low pressure air at lower latitudes varies. As the jetstream follows this boundary, the Arctic Oscillation also describes the variation in latitude of the jetstream around the globe (Figure 3).

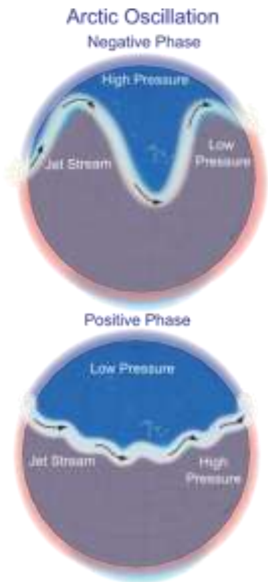


Figure 3 Arctic Oscillation
(Source – Wikipedia, http://en.wikipedia.org/wiki/File:Arctic_Oscillation.svg)

A positive Arctic Oscillation phase is one where cold polar air is “locked” into the far North. A negative phase allows incursions of polar air into lower latitudes at variable points around the Northern Hemisphere. The recent (2013 / 14) very cold weather in North America has been due to this phenomenon, and the associated location of the Jetstream brought the sequence of damaging storms to the UK.

The Atlantic Multidecadal Oscillation (AMO) describes the variation in sea surface temperature over the whole North Atlantic, when the effects of greenhouse gas induced global warming have been removed. The AMO has been linked with changes in weather patterns throughout the entire Northern hemisphere. A positive (warm) phase corresponds to increased rainfall in India, the Sahel, Florida and the North West of North America. Warm phase are also linked with reduced rainfall in central North America, including with the “dustbowl” conditions of the 1920s.

There are also important effects on European weather, climate and sea temperature, these have been less well studied and are not as clear cut.

Atlantic multidecadal oscillation

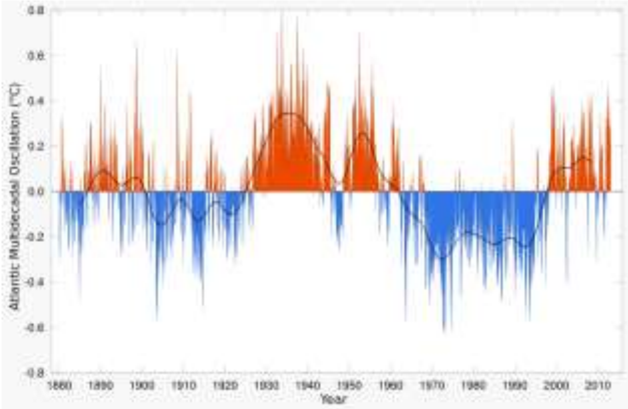


Figure 4 Atlantic Multidecadal Oscillation Timeseries, 1856–2009
(Source – Wikipedia, http://en.wikipedia.org/wiki/Atlantic_ Multidecadal _Oscillation)

Latitude of the Gulf Stream and the Gulf Stream north wall index

(see Wikipedia, http://en.wikipedia.org/wiki/Latitude_of_the_Gulf_Stream _and_the_Gulf_Stream_north_wall_index)

Changes in the location of the Gulf Stream seem to be driven by changes in the NOA, with a lag of some two years before changes are observed in the location of the Gulf Stream.

In turn, changes in the Gulf Stream location drive major changes in many ecological factors, including the abundance and type of plankton at any particular location. As larvae and juvenile marine fish depend on plankton – principally copepods - as a food source, changes in plankton abundance and composition impact on the survival of fish from egg to a size at which they can recruit into a fishery.

See the material presented by Dr. Colin Bannister for a fuller description and explanation of these processes, together with interesting examples.

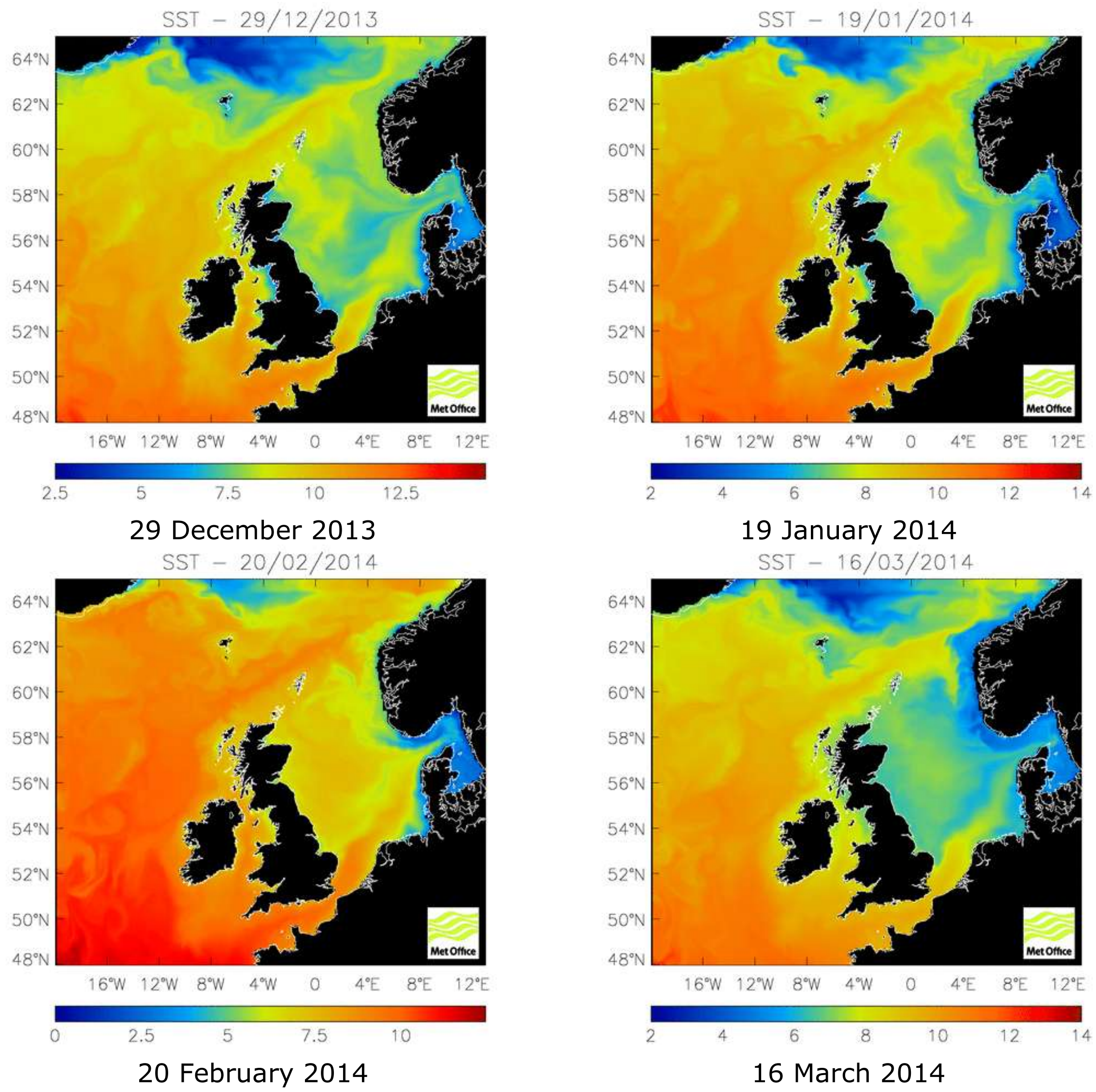
Local effects due to sea currents

In addition to the global / ocean scale effects touched on above, there are more local phenomena which affect the distribution and abundance of fish species within our area. These are driven by the residual sea currents, and express themselves mostly in local effects on sea temperature.

The EIFCA district encompasses that part of the southern North Sea where the southerly current along the Scottish and English East coast meets the North Easterly current flowing in from the English Channel (Figure 5)

Figure 5 Residual Sea Currents within the North Sea.
(Source – European Environment Agency, http://www.eea.europa.eu/legal /copyright).)

In winter, water flowing in from the English Channel is warmer than that in the North Sea, which results in a distinct plume of warmer water along the Suffolk coast. (Figure 6) (Note that this is a prediction, used in weather forecasting. I have checked the temperatures given in this prediction against those actually recorded from several sea surface buoys, and there is very good agreement).



29 December 2013

19 January 2014

20 February 2014

16 March 2014

Figure 6 Sea surface temperature for the North Sea at various dates over winter 2013 / 14 (dates below the images) NB The colours scale relating to sea surface temperature is generated automatically for each day, so there is not consistency of colour for a given temperature between images.
(Source – European Environment Agency, http://www.eea.europa.eu/themes/coast_sea/todays-sea-surface-temperature/sea-surface-temperature-north-sea)

5.3 Eastern IFCA Area – Commercial Fishing Summary

Note that within this section, all data (landings, values etc.) relating to commercial catches refer to figures from the Quarterly Returns from EIFCA Area Officers. These give information relating to landings (weight of catch) and first sale values (value of catch). Summarised raw data can be found as Appendix 1.

Data relating to vessel numbers and sizes, and numbers of crew, are from the EIFCA Fleet List dated November 2012. Summarised data can be found as Appendix 2
As a part of the Fish Project, raw data from both these sources has been used as the basis for a searchable database, such that it is possible to extract information as required.

The makeup of commercial catches varies greatly across our district, as catch returns from each of the historical Area Officer "patches" (Figure 7) show.

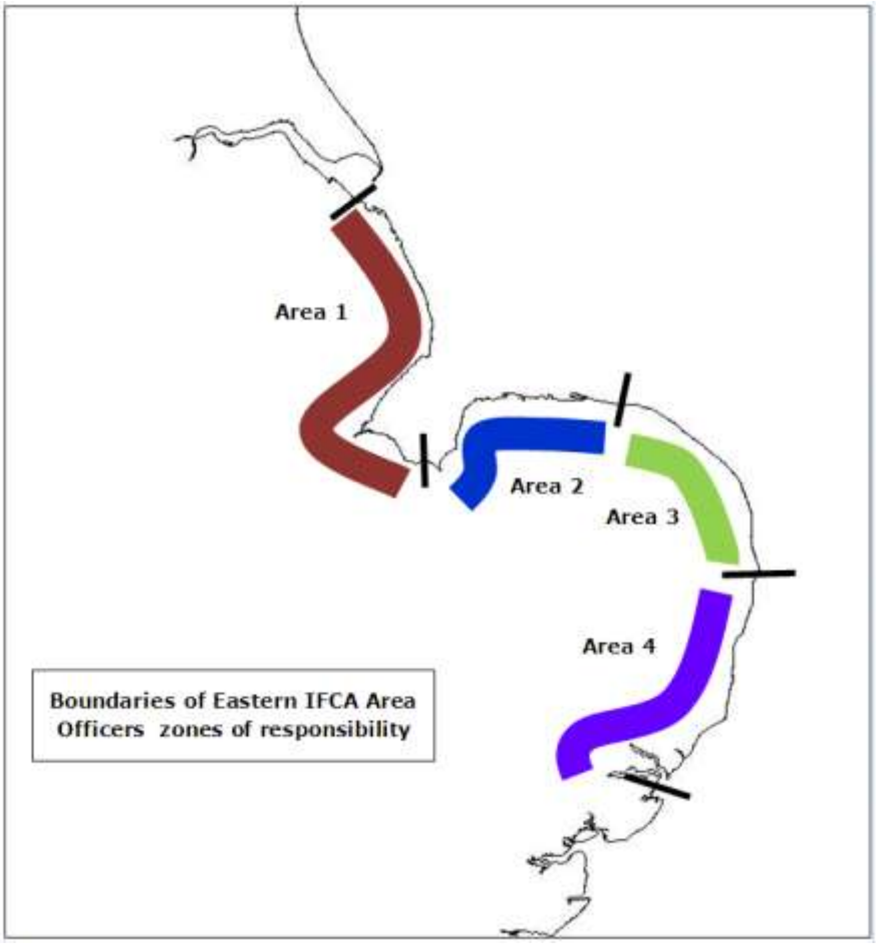


Figure 7 Coastline of the Eastern IFCA area of responsibility showing zones historically allocated to each Area Officer.

These relative weights (Figure 8) and values (Figure 9) demonstrate several trends –

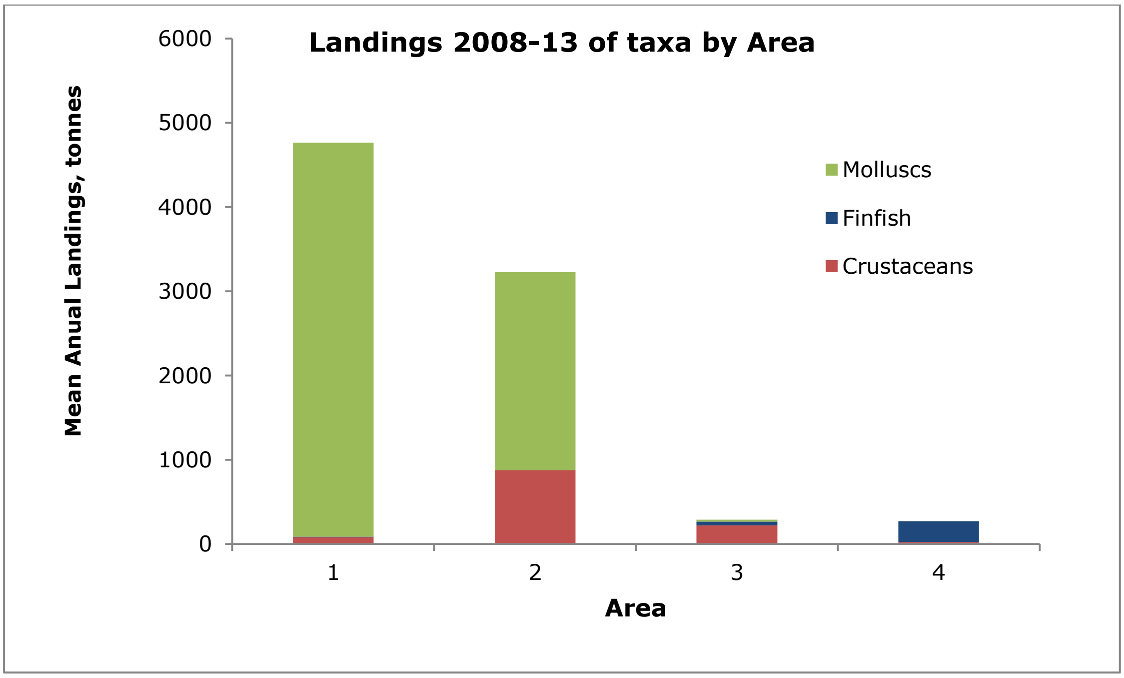


Figure 8 Mean Annual landings (period 2008 – 2013 inc.) by weight of commercial species by Area and Taxa

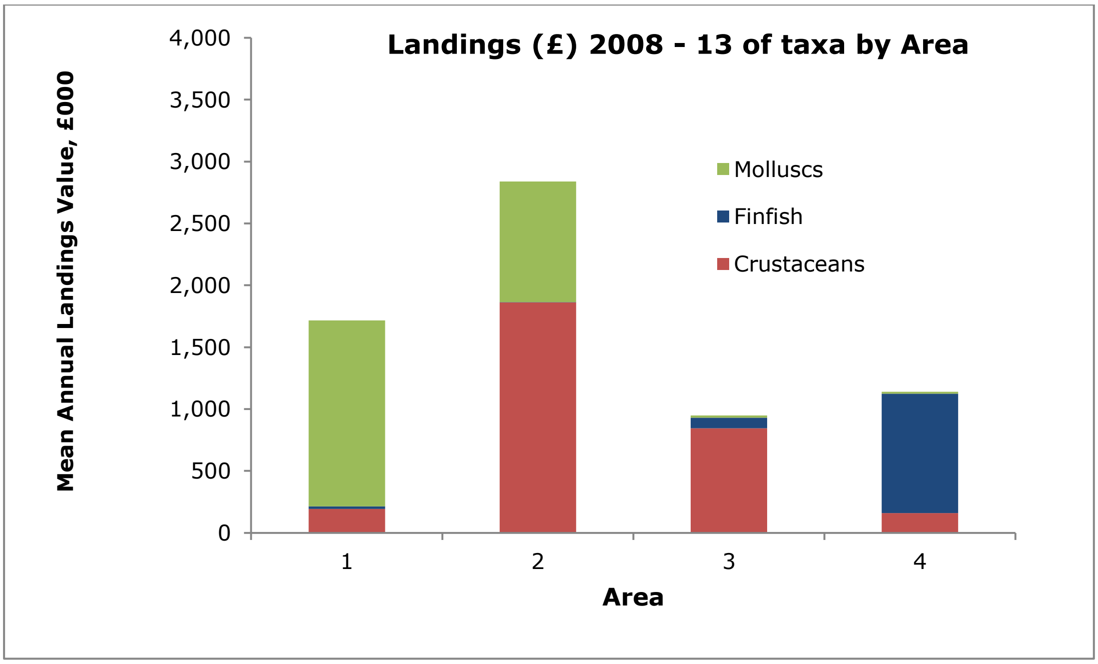


Figure 9 Mean Annual landings (period 2008 – 2013 inc.)by value of commercial species by Area and Taxa

- The proportional contribution of molluscs to the total commercial catch declines from North to South.
- The proportional contribution of finfish to the commercial catch increases from North to South.
- The proportional contribution of crustaceans to the overall catch peaks in the middle of our area of responsibility, with declining importance towards the extremities.
- Whilst the total volume of landings indicates dominance by Area 1, with a major additional contribution from Area 2 only, when looked at from the point of view of value the relative contributions of the areas are much less skewed. It is value of landings which indicates the socio-economic importance of a fishing activity, rather than volume.
- Molluscs contribute proportionally less to the value of the catch than to the volume (weight) of the catch. This is due to the considerably lower value / kg of molluscs compared to crustaceans and finfish (Figure 10).

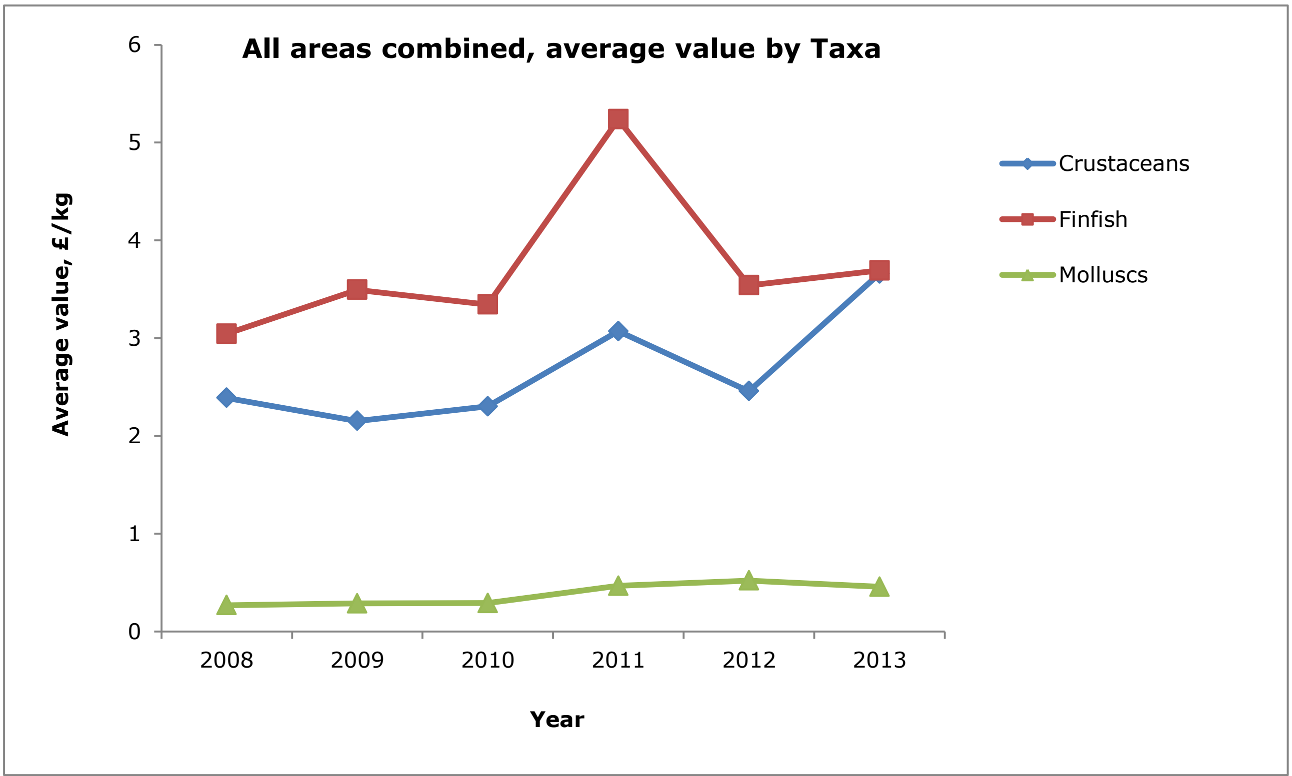


Figure 10 Average value, £/kg, of taxa for all areas combined for each year 2008 – 2013

The relative importance of each of these areas for landings of each taxa has been constant for some years, with the relative contribution to the overall catch of molluscs (Figure 11), finfish (Figure 12) and crustaceans (Figure 13) from each area remaining very similar, although the actual amounts have varied.

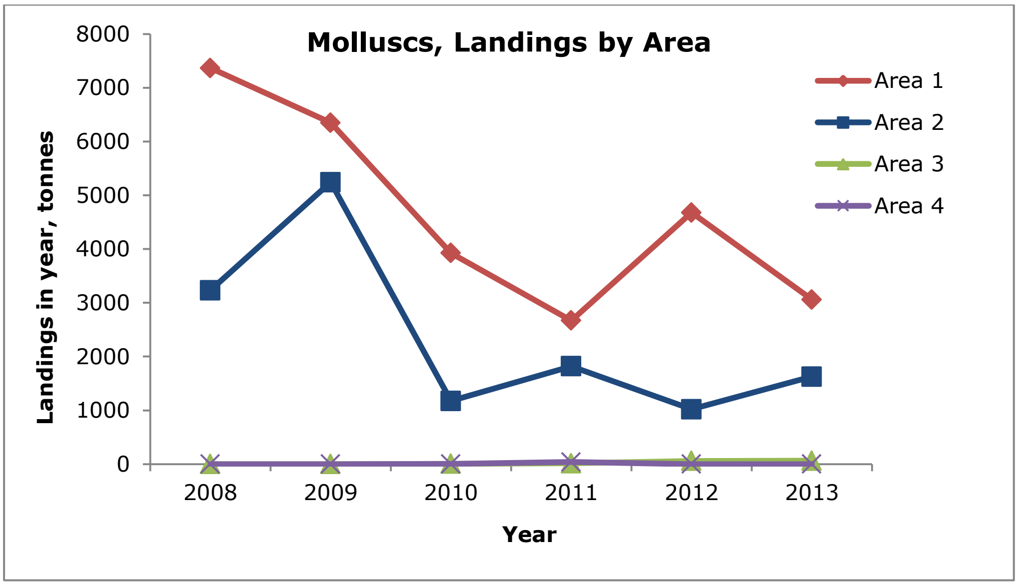


Figure 11 Landings of molluscs (all species combined) by area, 2008 – 2013 inc.

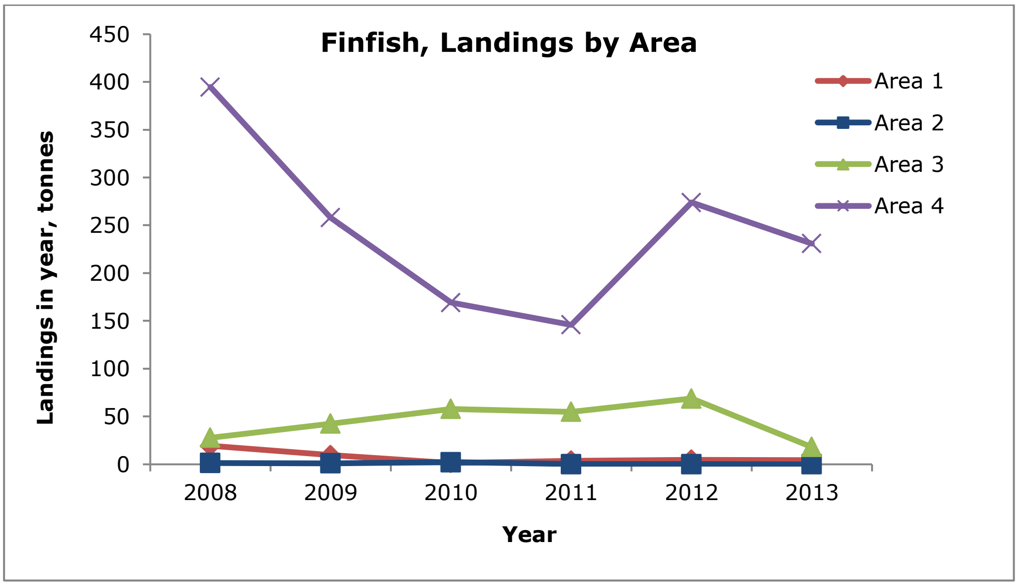


Figure 12 Landings of finfish (all species combined) by area, 2008 – 2013 inc.

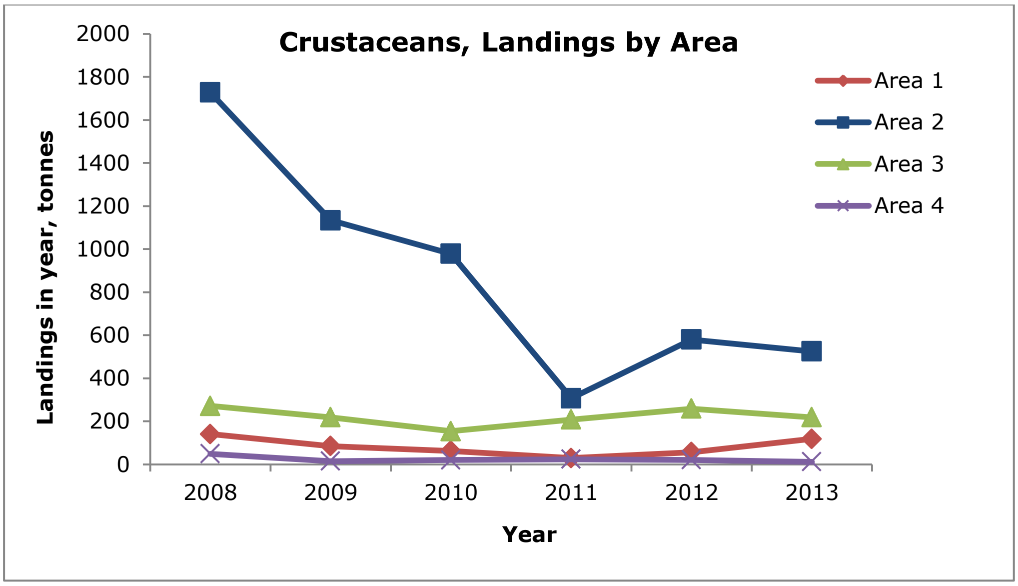


Figure 13 Landings of crustaceans (all species combined) by area, 2008 – 2013 inc.

The different make up of the fishing activity across our district is reflected in the make-up of the fishing fleet (Figure 14). Registered fishing boats in areas 1 & 2 tend to be larger, and with a higher proportion of full time as opposed to part time crew, than those in areas 3 & 4. The vast majority of boats registered in areas 3 & 4 fall below the 10 m. length at which many fishing regulations change. (Note that these figures and subsequent calculations are based on boats REGISTERED within a certain area. The boats may actually be fishing in other areas, or may not be actively fishing much if at all.)

Records indicate that there are in total about 350 crew, both full and part time, on vessels across our district (Figure 15). (This figure is somewhat imprecise, as the dataset is not complete for this measure). The average number of crew members per vessel shows a generally decreasing trend as one goes from north to south within our district (Figure 16), reflecting the change in character of fishing and fishing boats. That notwithstanding, the total number of people deriving income as crew on commercial fishing boats is spread across our district (Figure 15, Figure 16) rather than being concentrated in areas 1 & 2, as a cursory inspection of the landings by weight (Figure 8) might suggest.

The differing character of areas 1 & 2 compared with areas 3 & 4 is emphasised by the difference in earnings per vessel (Figure 17), with the larger vessels of areas 1 & 2 earning appreciably more. Earnings per crew member (Figure 18) show a similar but less marked picture, probably representing both the increasing proportion of part time fishermen in areas 3 & 4 and the lower cost of operating the smaller boats usual in areas 3 & 4.

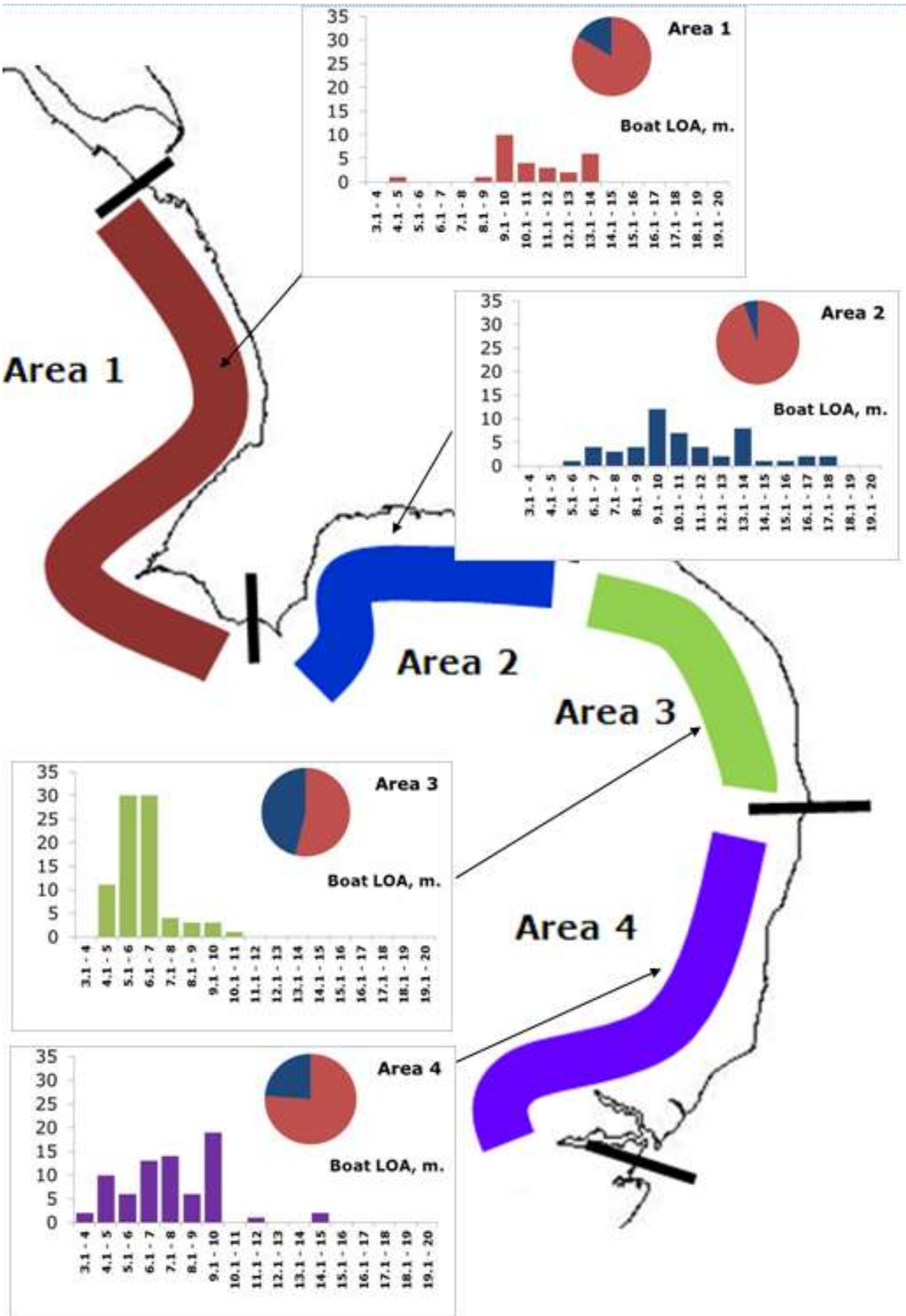


Figure 14 Numbers of registered fishing boats by length class (bar graphs); and proportion (pie charts) of full time (red-brown) and part time (blue) crew, in EIFCA areas.

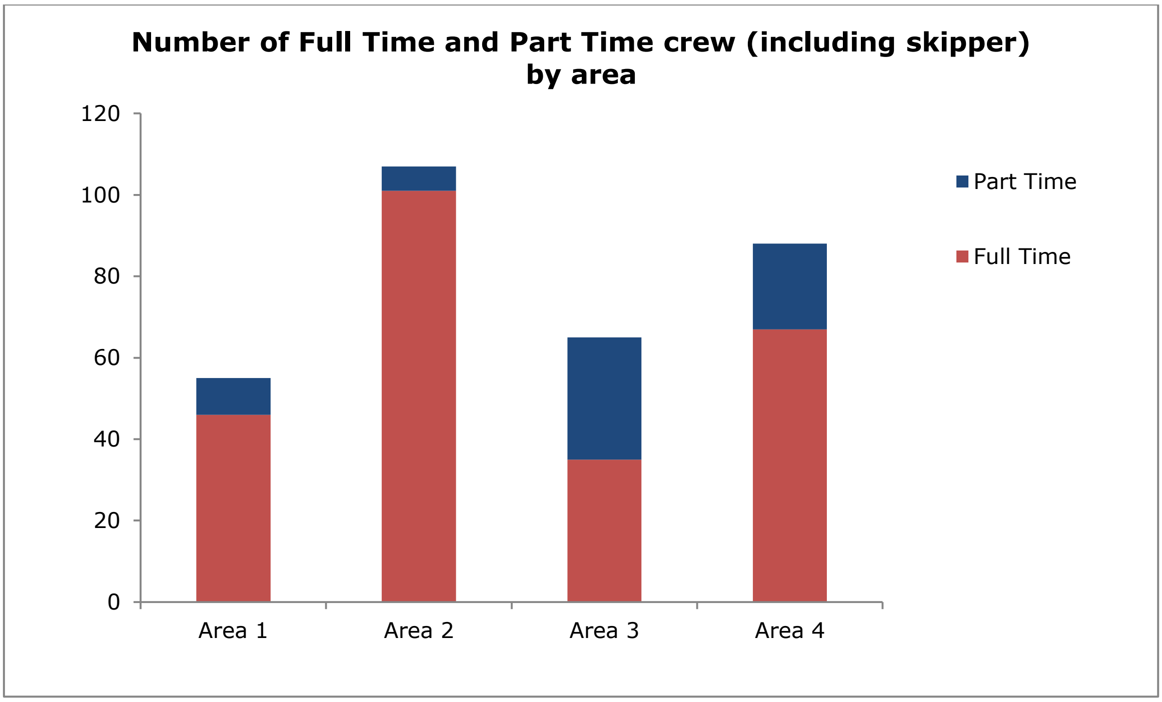


Figure 15 Number of full and part time crew in EIFCA areas

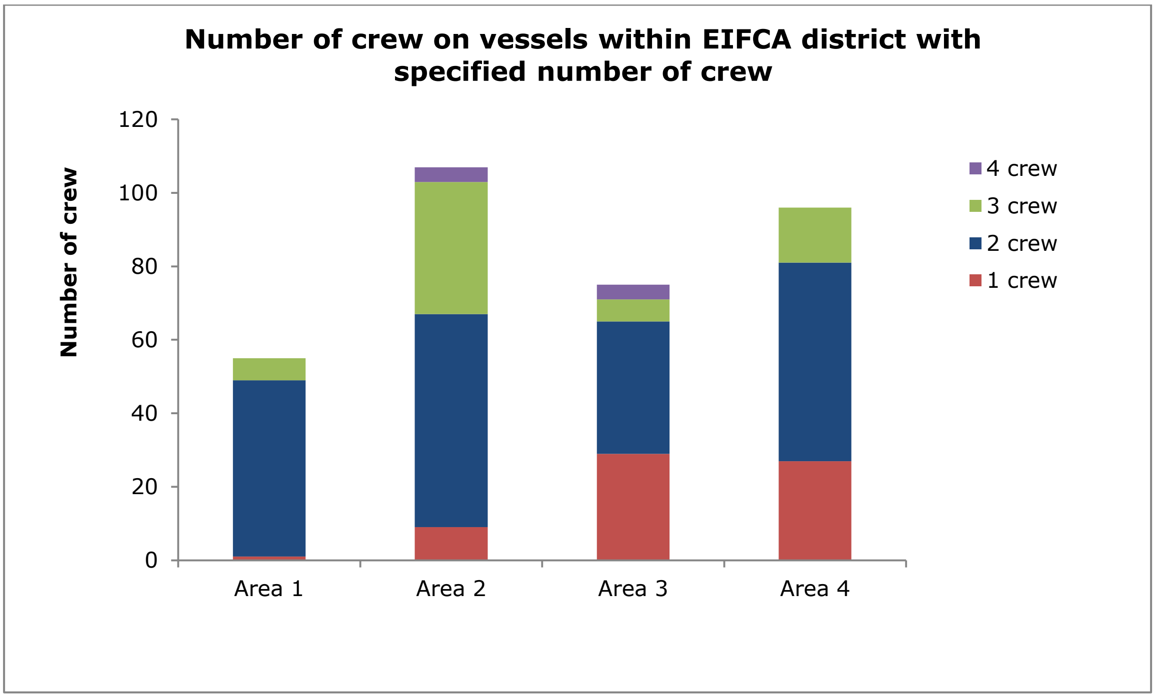


Figure 16 Number of crew on vessels carrying various crew sizes, by area

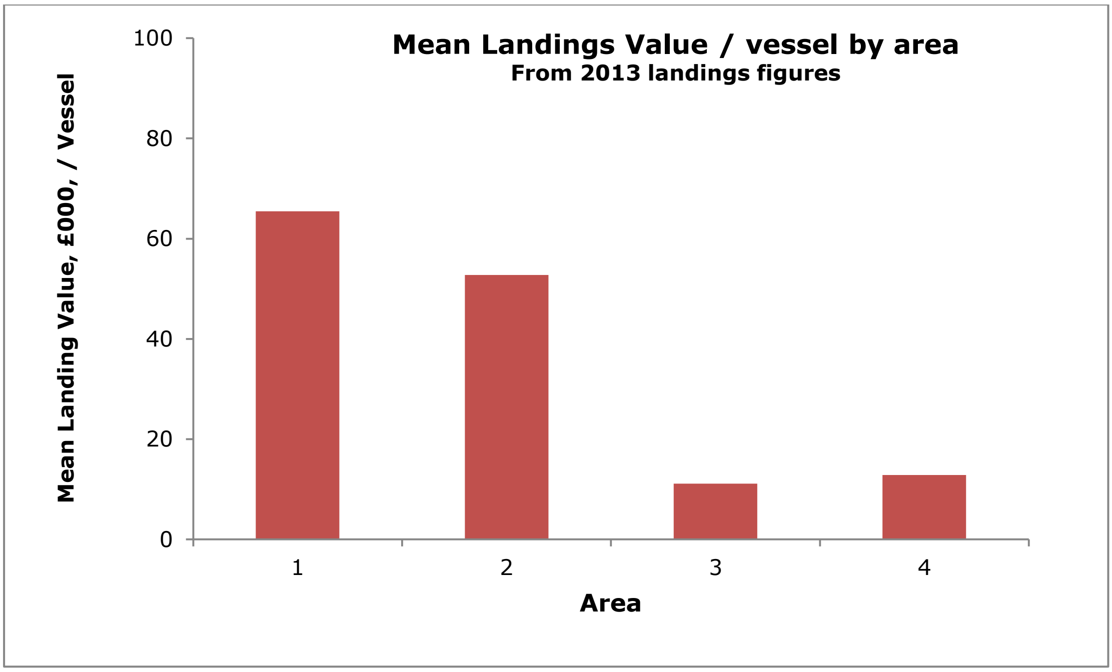


Figure 17 Average value of landings (2013 figures) per vessel registered in each area of EIFCA district

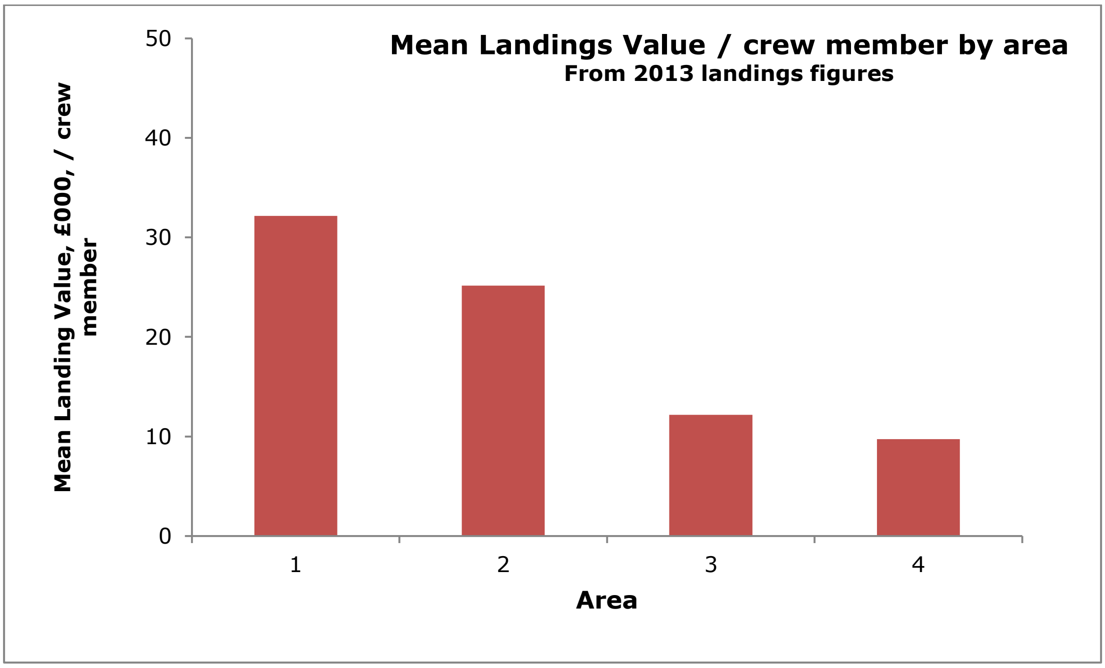


Figure 18 Average value of landings (2013 figures) per crew member in each area of EIFCA district

Appendix 1

Summary of Eastern IFCA Landings Data from area officers' reports

Weight, tonnes			**Year**			
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Area 1						
Crustaceans	140.4	85.1	62.1	28.8	56.7	118.5
Finfish	19.3	9.6	1.3	3.8	4.7	4.2
Molluscs	7365.2	6348.8	3925.6	2670.0	4677.9	3060.6
Total	7524.9	6443.5	3989.1	2702.5	4739.3	3183.3
Area 2						
Crustaceans	1727.8	1133.7	978.6	306.9	580.0	525.1
Finfish	1.3	1.0	2.1	0.2	0.1	
Molluscs	3233.1	5244.1	1173.3	1819.8	1018.8	1627.3
Total	4962.2	6378.8	2154.1	2126.9	1598.9	2152.4
Area 3						
Crustaceans	271.1	218.5	154.1	208.5	259.0	218.6
Finfish	27.8	42.5	57.9	54.9	68.7	18.1
Molluscs	0.0	0.0	6.2	14.0	58.4	62.2
Total	298.9	261.0	218.2	277.4	386.1	298.8
Area 4						
Crustaceans	48.9	15.3	20.4	23.8	20.9	12.0
Finfish	394.6	258.0	169.1	145.8	273.8	230.9
Molluscs	0.0	0.0	3.6	40.0	0.0	
Total	443.5	273.3	193.1	209.6	294.8	242.9
All Areas Combined						
Crustaceans	2188.2	1452.6	1215.2	568.0	916.7	874.2
Finfish	443.0	311.1	230.4	204.6	347.3	253.2
Molluscs	10598.2	11592.9	5108.8	4543.8	5755.0	4750.1
Grand Total	13229.5	13356.6	6554.4	5316.4	7019.0	5877.5

Value, £				Year		
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Area 1						
Crustaceans	374742	133914	116619	58201	123631	347287
Finfish	64534	20600	5177	11451	15323	19812
Molluscs	1419510	1903233	947448	1345484	1987176	1401391
Total	1858786	2057747	1069244	1415135	2126130	1768489
Area 2						
Crustaceans	3430267	2062569	1974108	641207	1096268	1957859
Finfish	10441	2228	319	360	230	
Molluscs	1432794	1438555	526444	750090	972036	734235
Total	4873502	3503352	2500870	1391657	2068534	2692093
Area 3						
Crustaceans	1061906	835653	614930	846861	908502	801988
Finfish	73367	61643	88800	105490	110706	71693
Molluscs	0	0	4127	7106	37740	38560
Total	1135273	897296	707857	959457	1056948	912241
Area 4						
Crustaceans	361945	96092	92060	197810	124312	92164
Finfish	1200403	1002431	675985	954407	1102919	843359
Molluscs	0	0	10284	24000	0	
Total	1562348	1098523	778329	1176217	1227231	935523
All Areas Combined						
Crustaceans	5228859	3128227	2797717	1744078	2252713	3199298
Finfish	1348745	1086902	770281	1071707	1229178	934864
Molluscs	2852304	3341788	1488303	2126680	2996952	2174185
Grand Total	9429908	7556917	5056301	4942465	6478843	6308346

Appendix 2

Composition of the commercial fishing fleet within the EIFCA district

Number of vessels of each size registered within EIFCA areas

Vessel LOA, m.	Area 1	Area 2	Area 3	Area 4
3.1 - 4	0	0	0	2
4.1 - 5	1	0	11	10
5.1 - 6	0	1	30	6
6.1 - 7	0	4	30	13
7.1 - 8	0	3	4	14
8.1 - 9	1	4	3	6
9.1 - 10	10	12	3	19
10.1 - 11	4	7	1	0
11.1 - 12	3	4	0	1
12.1 - 13	2	2	0	0
13.1 - 14	6	8	0	0
14.1 - 15	0	1	0	2
15.1 - 16	0	1	0	0
16.1 - 17	0	2	0	0
17.1 - 18	0	2	0	0
Total number of registered vessels	**27**	**51**	**82**	**73**

Number of crew (full and part time) on vessels within EIFCA district

		Number of crew in total per crew size			
		Area 1	Area 2	Area 3	Area 4
Number of Crew inc skipper	1	1	9	29	27
	2	48	58	36	54
	3	6	36	6	15
	4	0	4	4	0
	Total number of crew in area	**55**	**107**	**75**	**96**

5.4 Eastern IFCA Area – Composition of Commercial Finfish catch

Note that within this section, all data (landings, values etc.) relating to commercial catches refer to figures from the Quarterly Returns from EIFCA Area Officers. These give information relating to landings (weight of catch) and first sale values (value of catch). Summarised raw data can be found as Appendix 1.

As a part of the Fish Project, raw data from both these sources has been used as the basis for a searchable database, such that it is possible to extract information as required.

Area 4 (Southernmost area of our district) has long been and is still pre-eminent in the amount of finfish landings whether assessed by weight (Figure 19) or value (Figure 20).

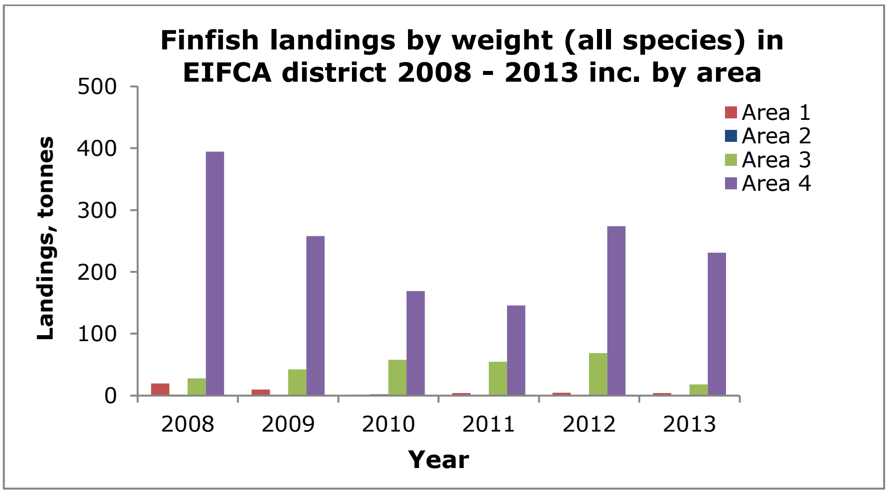


Figure 19 Annual weight of finfish landings by area (all species combined) for the EIFCA district, years 2008 – 2013 inc.

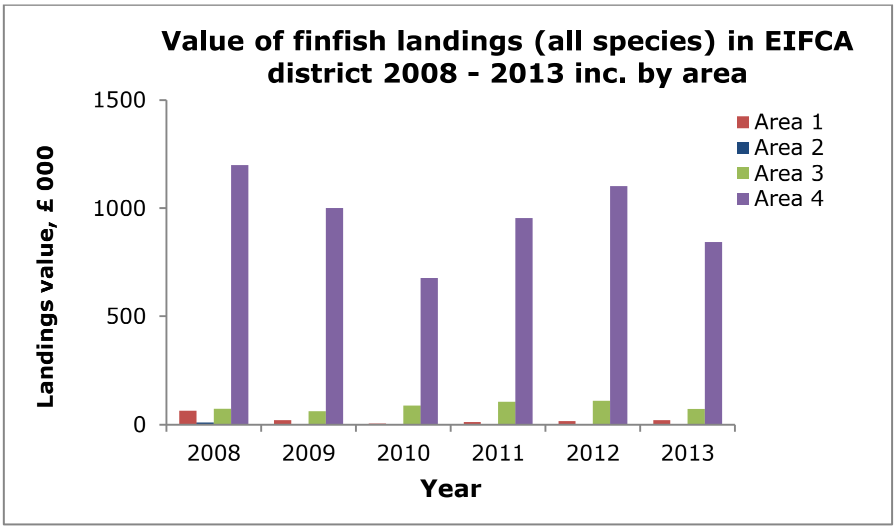
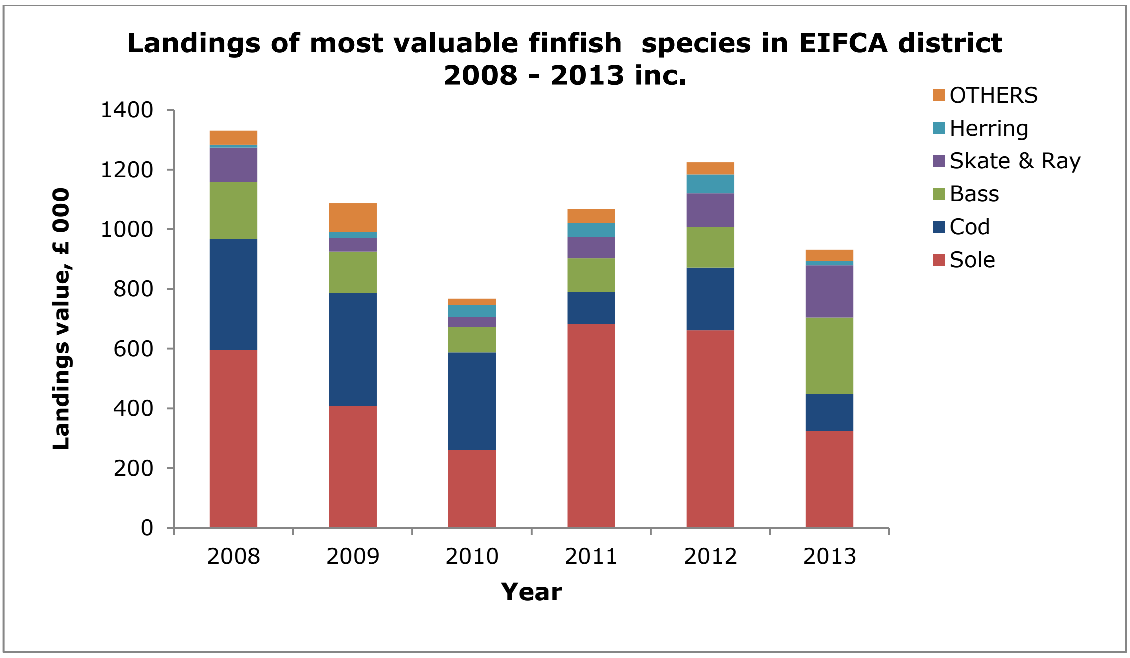


Figure 20 Annual value of finfish landings by area (all species combined) for the EIFCA district, years 2008 – 2013 inc.

Finfish landings with the EIFCA district are dominated by relatively few species, with Sole, Cod, Bass, Skate & Ray (effectively Thornback ray) and Herring between them making up more than 95% by value (more than 90% by weight) of landings throughout the EIFCA district for the years 2008 – 2013 combined (Figure 21).



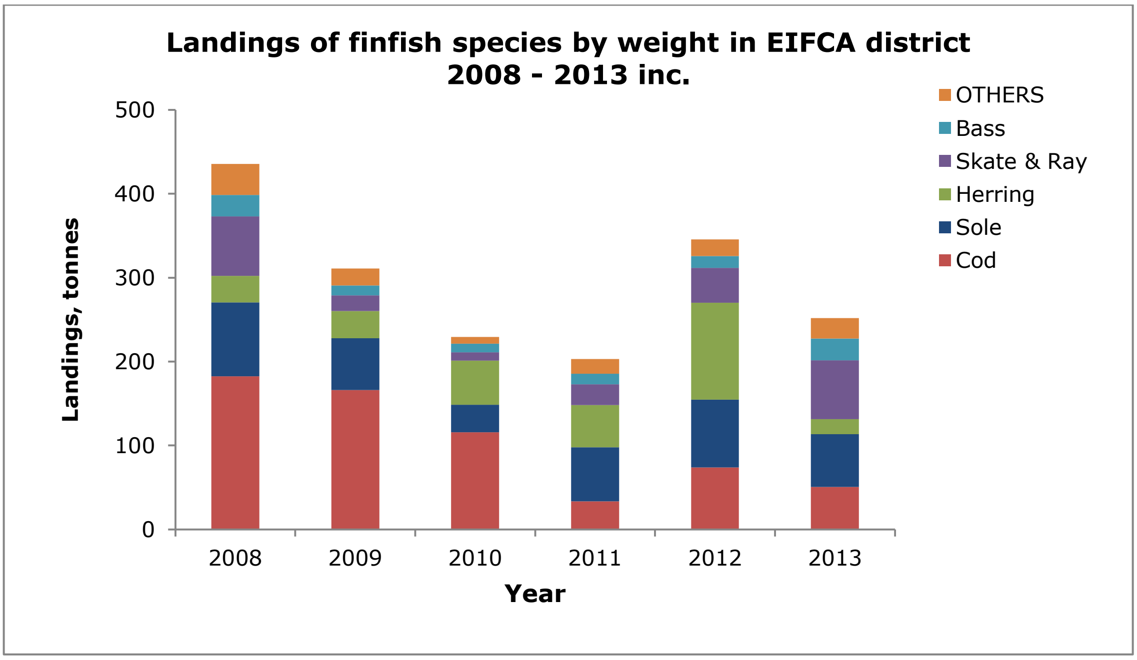


Figure 21 Annual landings of main species of finfish by value (top) and weight (bottom) with the EIFCA district 2008 – 2013 inc.

Of these five top species, there is evidence of a clear split between the "premium" species of Sole and Bass, and other species, which achieve a lower first sale price (Figure 22).

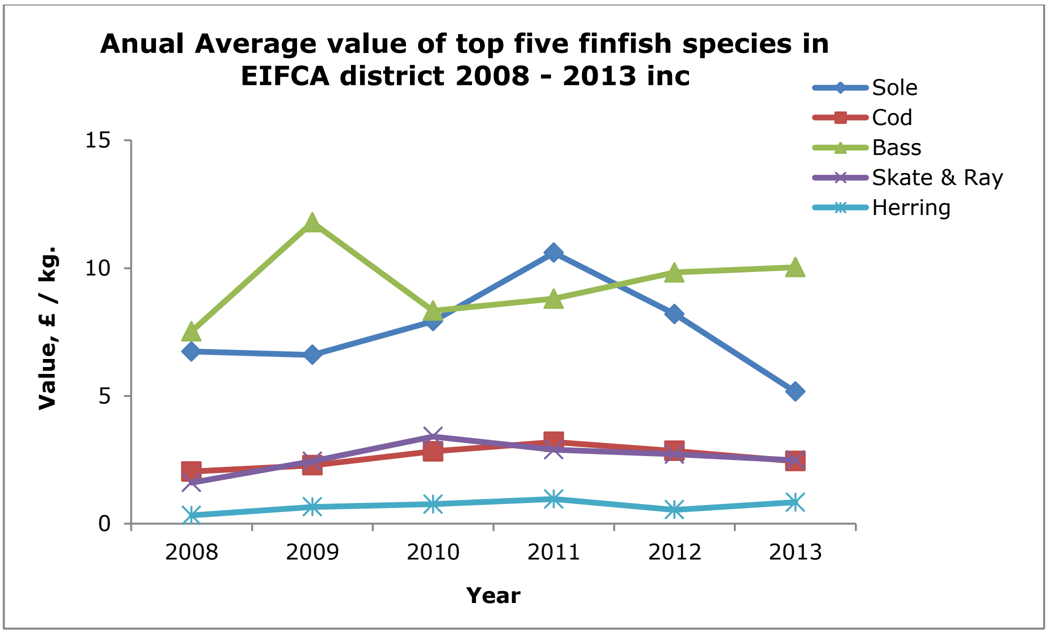
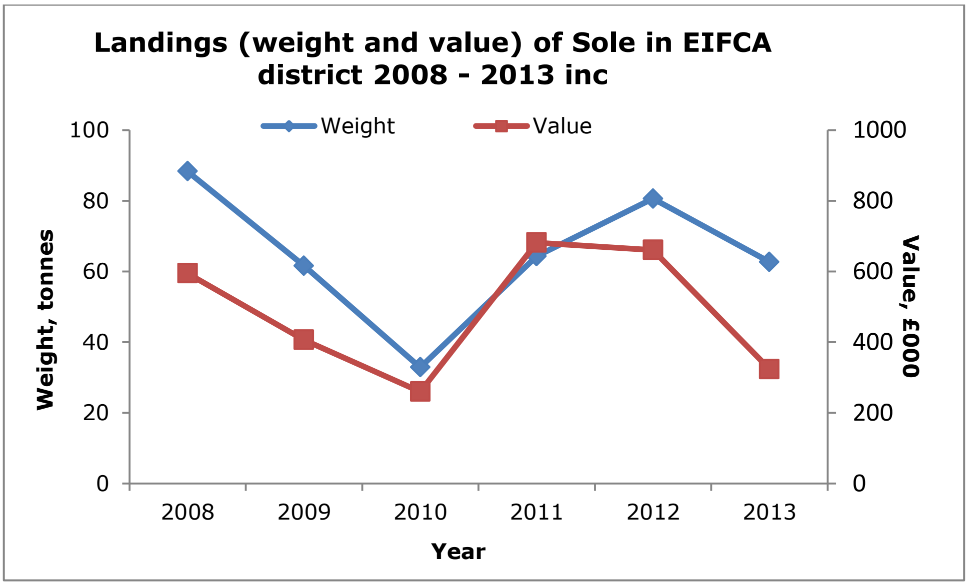


Figure 22 Annual average first sale values of top five finfish species with the EIFCA district 2008 – 2013 inc.

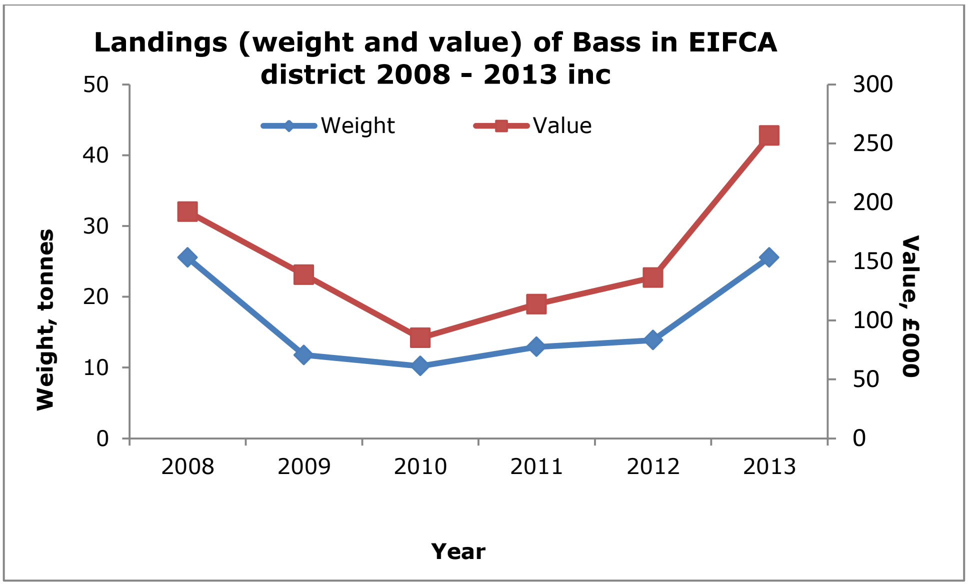
Of all these species, it is only Bass which is showing evidence of a sustained upward trend in first sale price / kg.

Landings of these species show differing patterns over the six year period here examined (Figure 23).

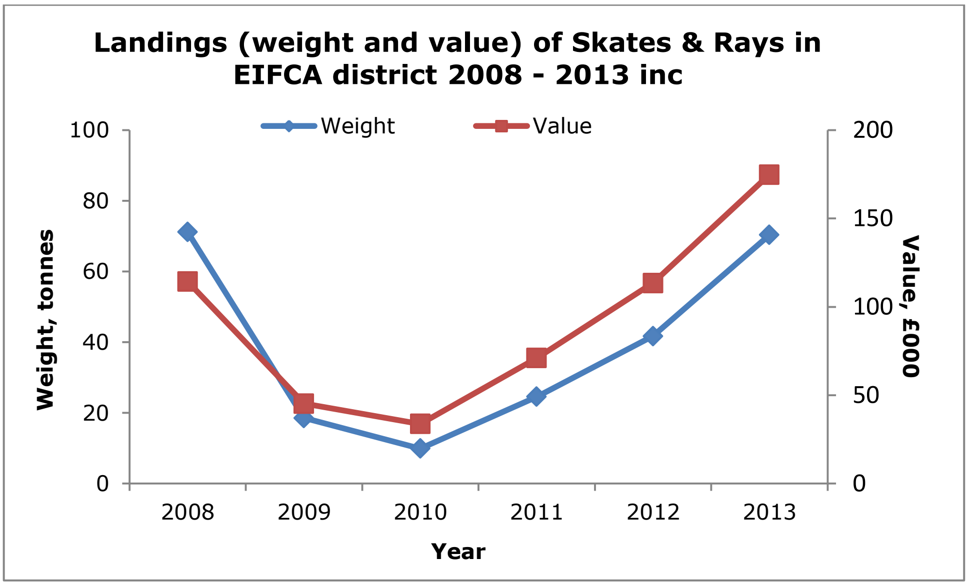
5A



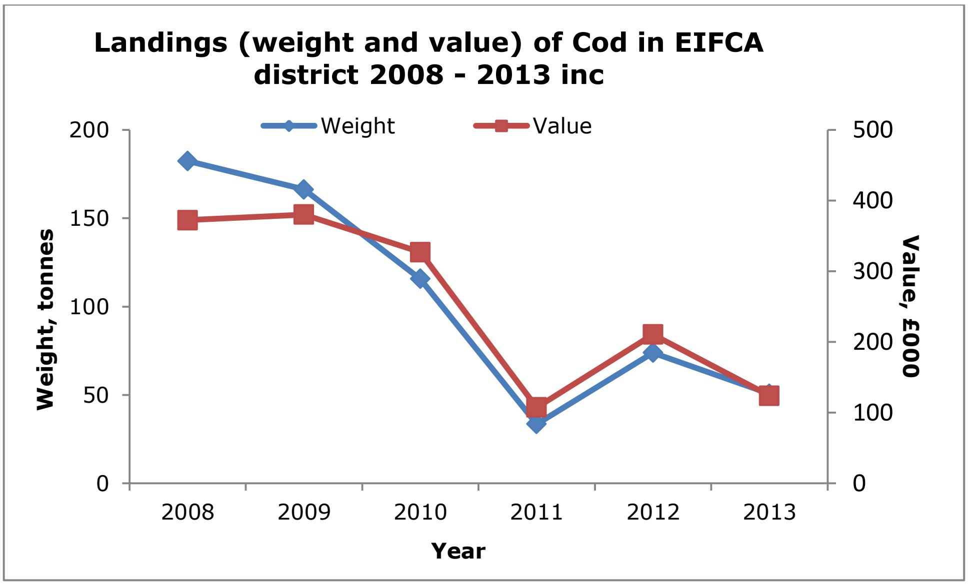
5B


Landings (weight and value) of Bass in EIFCA district 2008 - 2013 inc
Weight
Value
Weight, tonnes
Value, £000
Year
0
10
20
30
40
50
0
50
100
150
200
250
300
2008
2009
2010
2011
2012
2013

5C


Landings (weight and value) of Skates & Rays in EIFCA district 2008 - 2013 inc
Weight
Value
Weight, tonnes
Value, £000
Year
0
20
40
60
80
100
0
50
100
150
200
2008
2009
2010
2011
2012
2013

5D


Landings (weight and value) of Cod in EIFCA district 2008 - 2013 inc
Weight
Value
Weight, tonnes
Value, £000
Year
0
50
100
150
200
0
100
200
300
400
500
2008
2009
2010
2011
2012
2013

5E

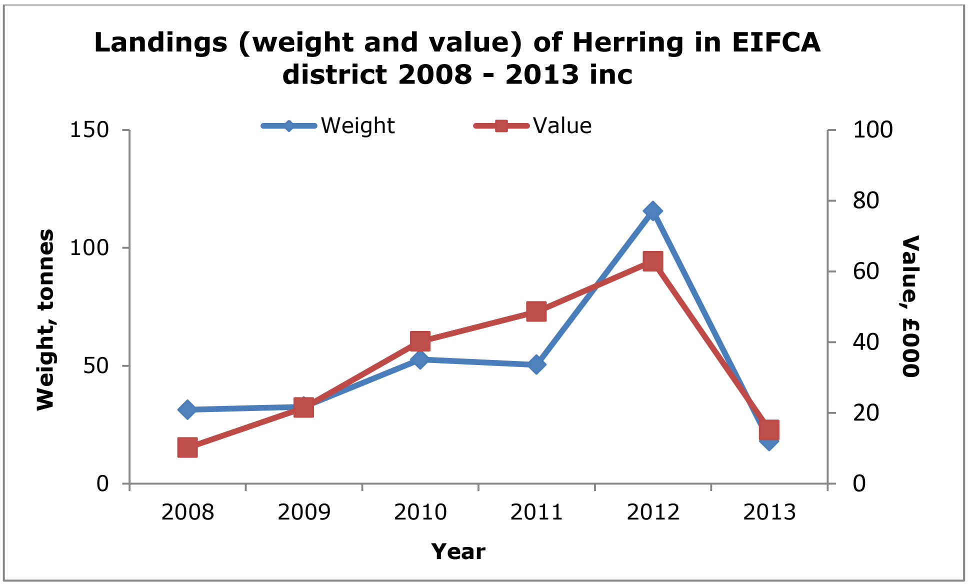


Figure 23 Annual landings by weight and first sale value of Sole (A), Bass (B), Skates and Rays (C), Cod (D) and Herring (E) within the EIFCA district 2008 – 2013 inc.

Bass, and Skates and Rays show a general upward trend (albeit with a dip from high levels in 2008). Landings of Sole and Herring show no clear trends, but rather vary year to year. Landings of Cod show a clear downward trend, with no concomitant increase in per kg value to offset this trend. This has resulted in the total value of the Cod landings falling so that it has now fallen below those of both Bass, and Skates and Rays (figure 24)

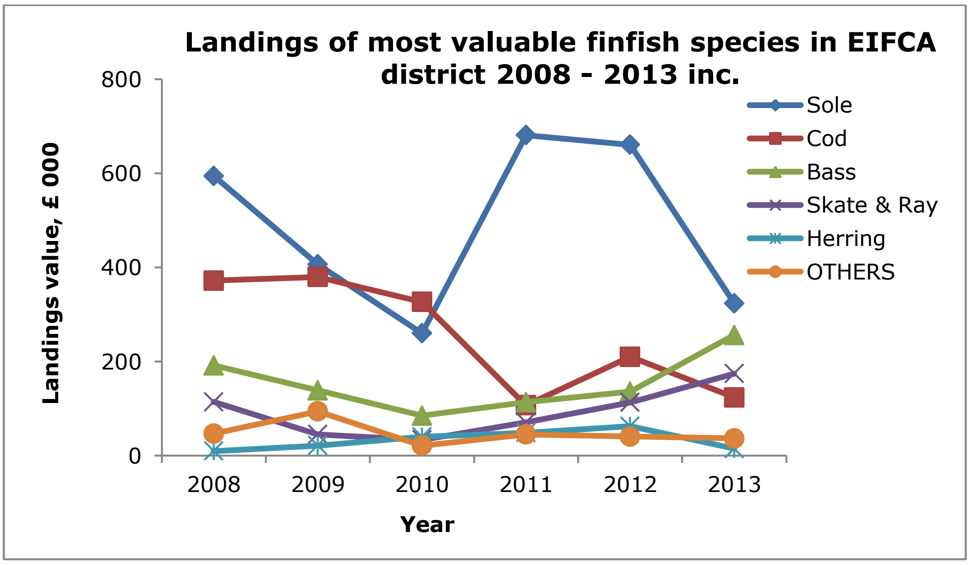


Figure 24 Annual landings by value of finfish species within the EIFCA district 2008 – 2013 inc.

Initial comparison of some MMO & EIFCA landings data

Information given above has been derived from EIFCA Area Officers reports. This is obtained by the Area Officer contacting fishers in their area, asking for information on recent catches, and then using experience to judge the validity of that data. Area Officers submit monthly returns of catches within their areas, and these reports have been used as the basis for the EIFCA landings data. Note that landings at Lowestoft – a major fishing port – are specifically excluded from the EIFCA Area Officers consideration and reporting.

A further source of information on landings is the MMO (Marine Management Organisation) Landings data. This is derived from information gathered under the "buyers and sellers" regulations, wherein fishers and first purchasers of fish report their sales / purchases.

Initial comparisons between the two datasets have been carried out for Bass (Figure 25), Flounder (Figure 26) and Sole (Figure 27). Only samples of species and ports have been presented, in order to illustrate the general principle. For each species, the "Grand Total" for all ports in our area has been presented, together with the Grand Total for all ports EXCEPT Lowestoft (which is only represented in the MMO data).

It is evident that there are important differences between the two sources of information. It is not possible to say that one source or the other is definitively correct. Possible sources of inconsistencies identified are –

EIFCA Data

- Depends on the Area Officer being able to "sample" in some way the information about landings – either by personally checking, telephone conversations, or being in touch with the grapevine. Therefore, if for any reason the officer is unable to be in touch with what is happening, the quality of data suffers. This is particularly challenging for much of the finfish activity which happens from small boats from small harbours, or even the open beach. It is extremely difficult to keep tabs on these activities.

MMO Data

- Depends on "buyers and sellers" regulations, which don't require declaration of individual transactions of less than 25 kg. of fish. This is the case no matter how many of these individual transactions there are – so for instance a boat selling 20 kg of bass to each of ten restaurants would not show up on this dataset. When considering a sector made up predominantly of small boats who do sell in precisely that way, much of the landings will not show up in these figures.

- As the MMO data depends on fishers and purchasers completing returns, there is always the concern that reporting may not be as comprehensive as desirable to obtain a full picture.

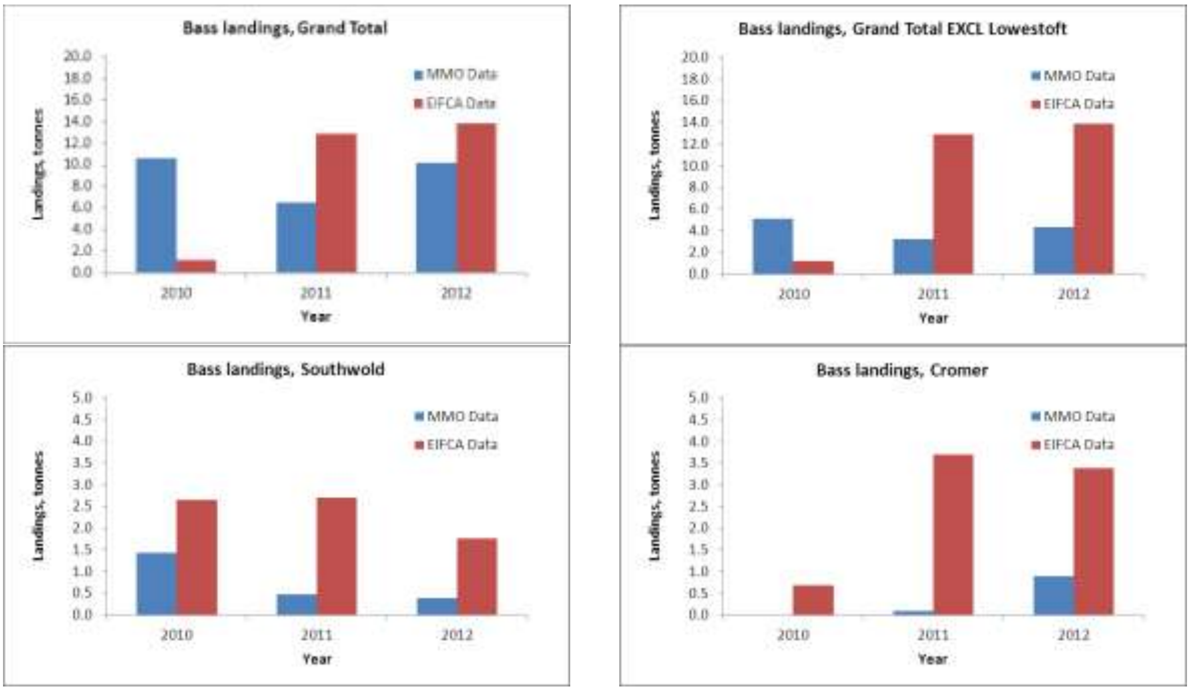


Figure 25 Comparison of landings (tonnes) of Bass from MMO data and from EIFCA data for some selected locations

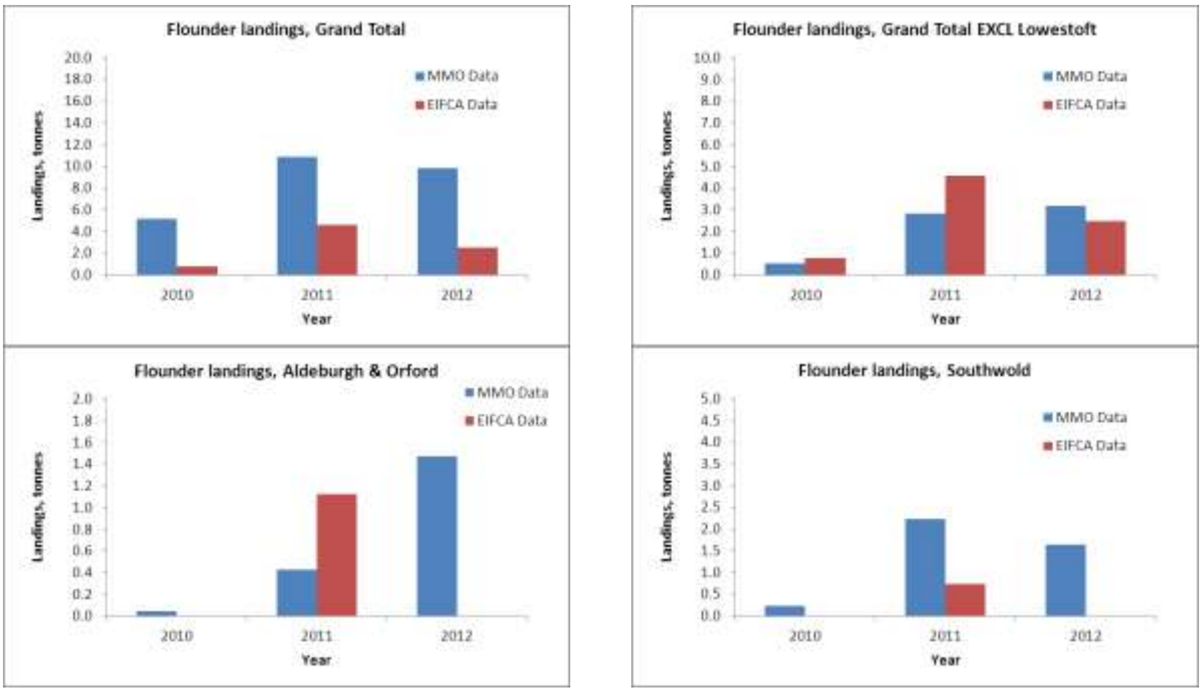


Figure 26 Comparison of landings (tonnes) of Flounder from MMO data and from EIFCA data for some selected locations

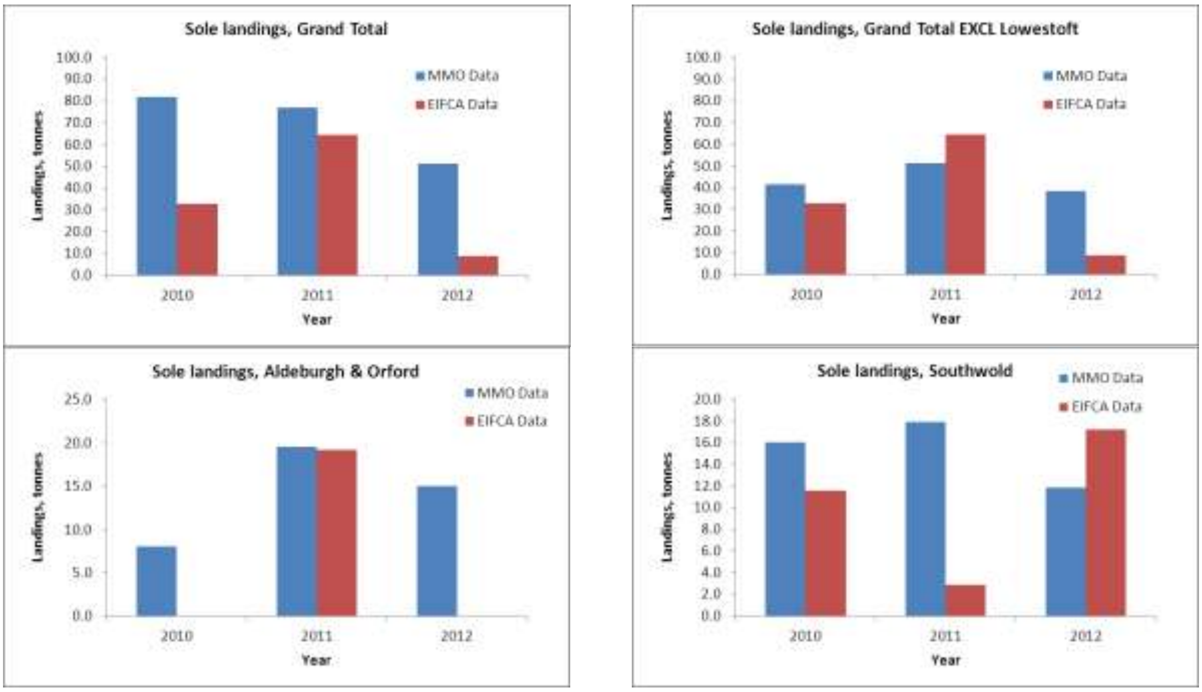


Figure 27 Comparison of landings (tonnes) of Sole from MMO data and from EIFCA data for some selected locations

<u>Recreational Sea Angling Sector</u>

A very major study on the Recreational Sea Angling (RSA) sector has recently been completed (Sea Angling 2012), to examine "*how many people go sea angling in England, how much they catch, how much is released, and the economic and social value of sea angling*".

The report and summaries from that study – readily available online – contain far more information and detail than can be reasonably reproduced here. There are some highlights which it is worth bearing in mind (all figures for sea anglers below refer to England only) –

- There are estimated to be 884 000 sea anglers– 2% of all adults going sea angling. (An interesting comparison here is that the RSPB – a leading wildlife charity – has approximately 1 million members worldwide, including all members of a family on family membership schemes. From this it is evident that sea angling has a huge following, which is probably under-represented on the political stage)
- More than four million "anglers days" were spent sea angling in 2012, three million of these from the shore.
- In 2012 sea anglers spent £ 1.23 billion, which supported 10400 full-time equivalent jobs.

- Taking into account the multiplier effect of this spend on expenditure and employment, sea angling supported total spending of some £ 2.1 billion, and over 23 000 jobs.
- There is a widespread belief that fish numbers have declined over a five year period – even more so over a twenty year period.

Numbers quoted above are for England as a whole (as the report is currently structured it is difficult to pull out regional data), but it is reasonable to assume that the Eastern IFCA region enjoys a significant proportion of those benefits and feels an equally significant pressure. EIFCA is in the process of developing a more structured RSA strategy than has previously been the case.

In addition to the economic and social aspects of RSA, and the implications on management of resources due to proper recognition of the value of the sector, it is possible to consider the RSA community as a source of information. Specifically, information on the catch rates of leisure anglers, and the species composition and size distribution of their catches, can be used as an indication of the status of fish stocks in that vicinity. Particularly useful are data from which it is possible to calculate a "catch per unit effort" – i.e. numbers of fish caught per angler per hour. Results from sea angling matches would supply exactly such data, and attempts have been made to obtain these. So far, such attempts have been fruitless, but it will be beneficial to continue these efforts.

5.5 Summary of Environment Agency WFD Survey Effort

Within this section data relating to number, type and other details of surveys are taken largely from the information kindly supplied to us by The Environment Agency (EA) Additional data originates from the survey undertaken in Autumn 2013 by EIFCA in the River Deben. As a part of the Fish Project, raw data supplied by the EA has been used as the basis for a searchable database, such that it is possible to extract information as required.
Acknowledgements The EA data represents the results of numerous surveys carried out by various organisations over a period of years. We would like to thank all organisations who have participated in these surveys, and the Environment Agency for their efforts in extracting this data from their files, thus allowing us access to information which would be impossible to obtain by other means.

The Environment Agency (EA) have undertaken repeated surveys of fish in Transitional waters (estuaries and near shore coastal waters) in connection with the Water Framework Directive (WFD). The WFD protocol requires that at least two sampling methods are used at a location, in order to reduce the species selectivity which could otherwise occur (Note that the EIFCA survey of the River Deben was one method only – seine net. This was due to time and equipment limitations). In addition, the EA have sourced information from other, broadly comparable, surveys in the same areas, and combined this with their own data. There has been variation in effort over time, with some areas being surveyed more intensively at some times than at others. There has also been variation in the methods used, with some organisations using methods other than those specified by the EA for WFD work. Note that in this context a "survey" is one deployment of the net in question – so it is possible to do multiple surveys in one day.

For this examination, individual sample stations have been grouped together in areas representing coherent habitats.

Surveys are recorded as either being Spring surveys (collected between January and July, normally in May or June) or Autumn surveys (collected between August and December, normally in September or October).

These factors have resulted in a dataset which contains appreciable variations in the mix of survey methods used, and with the number of surveys carried out varying by both time (see Figure 28) and location (see Figure 29).

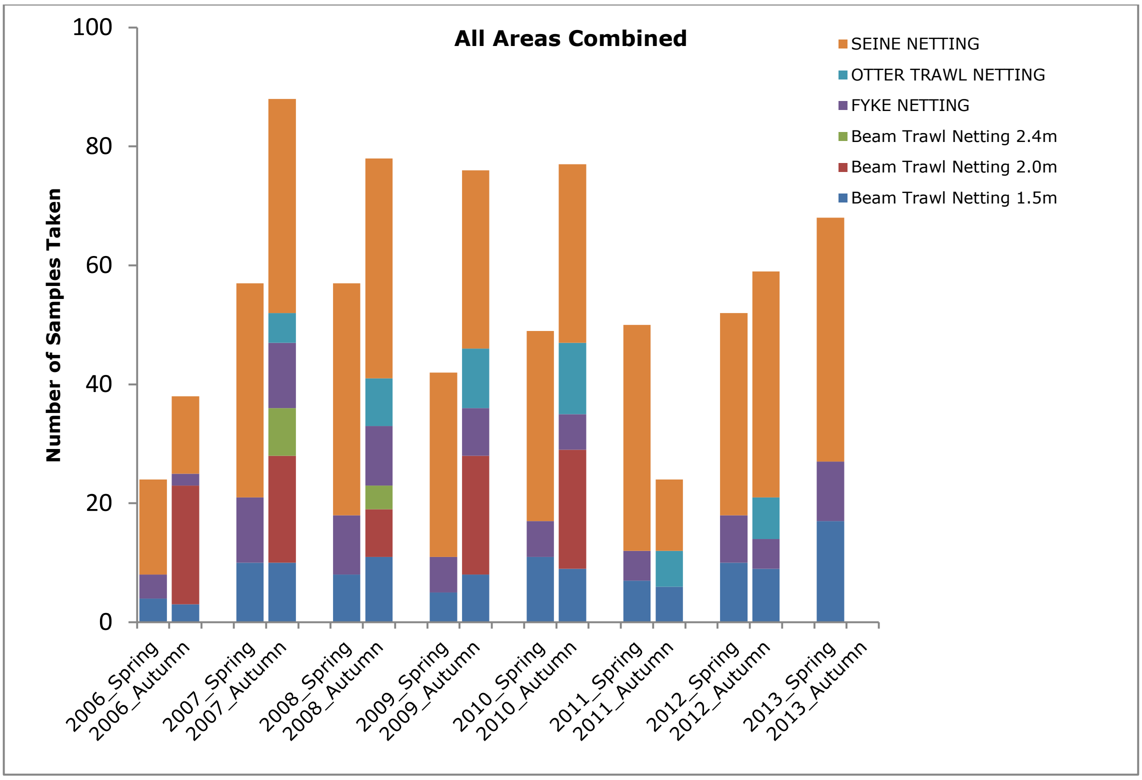


Figure 28 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013.

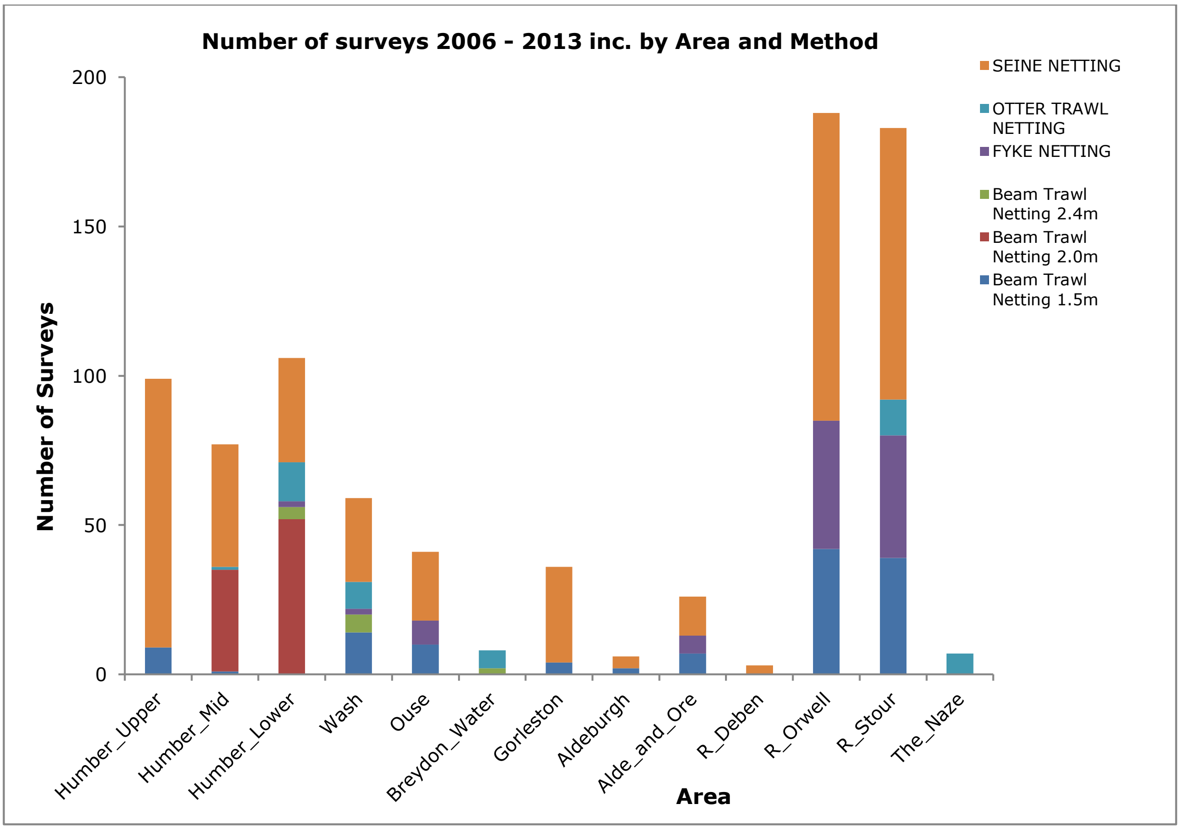


Figure 29 Number of surveys by area and sampling method for all years 2006 – 2013 combined.

Figures below show the detailed breakdown of numbers of surveys of each type carried out in each area over time, plus the locations of the individual sample stations within the areas. Figure 30 shows the overall picture for the Eastern IFCA district, with subsequent figures showing a breakdown for each area, working from North to South. The upper graphs show a breakdown of the number of surveys carried out by each method over the years investigated (note that the Y axis of these graphs varies), the lower shows the individual sample stations marked with a pin symbol, with the EA station name. These aerial view images are taken from Google Earth.

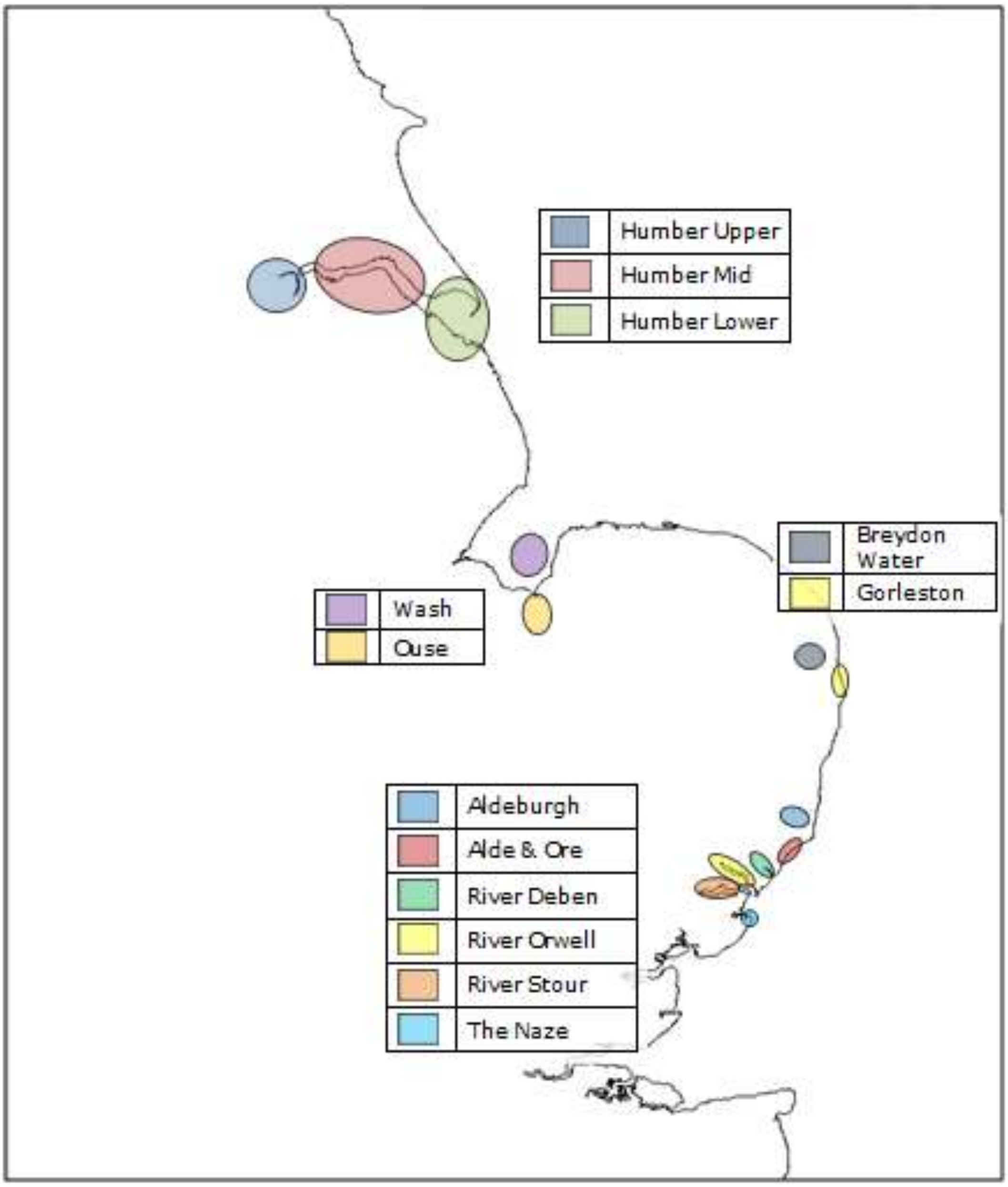


Figure 30 Coastline with Eastern IFCA district, showing Areas by which EA WFD fish survey data has been grouped

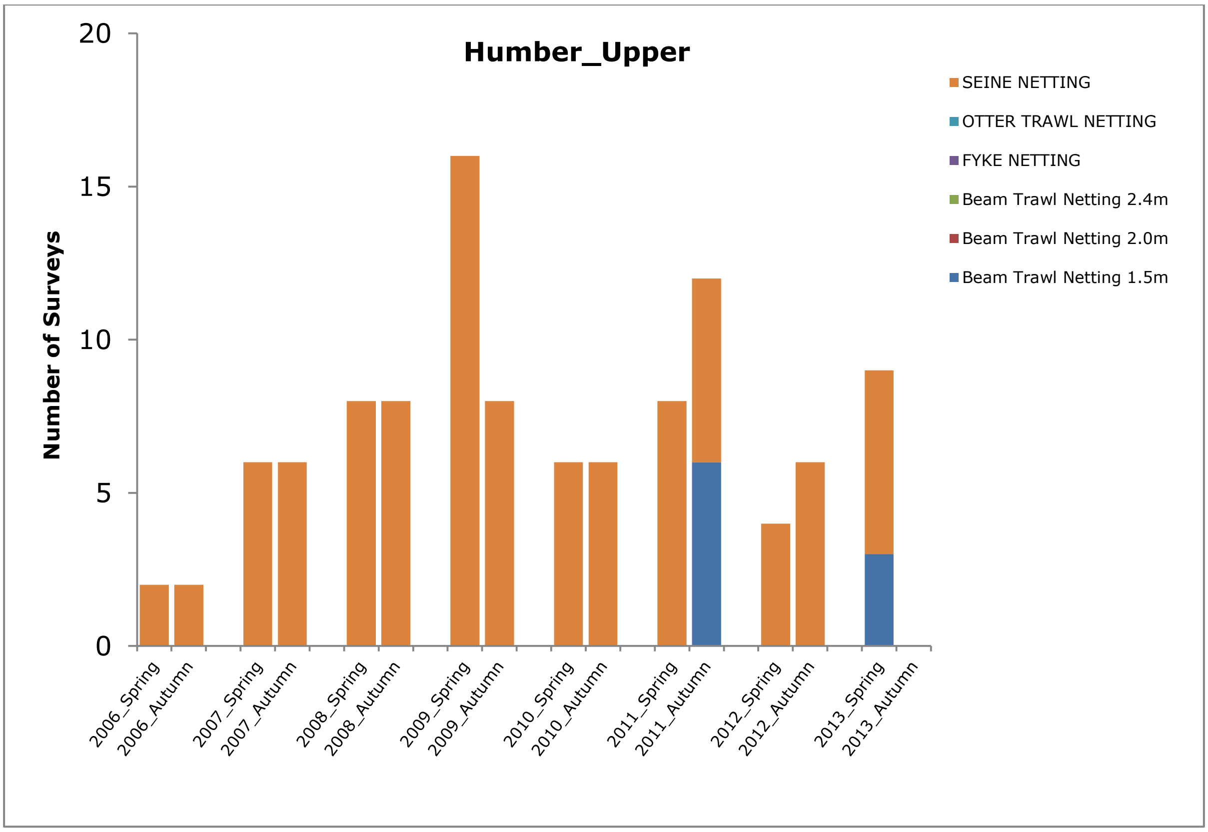


Figure 31 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Humber Upper.

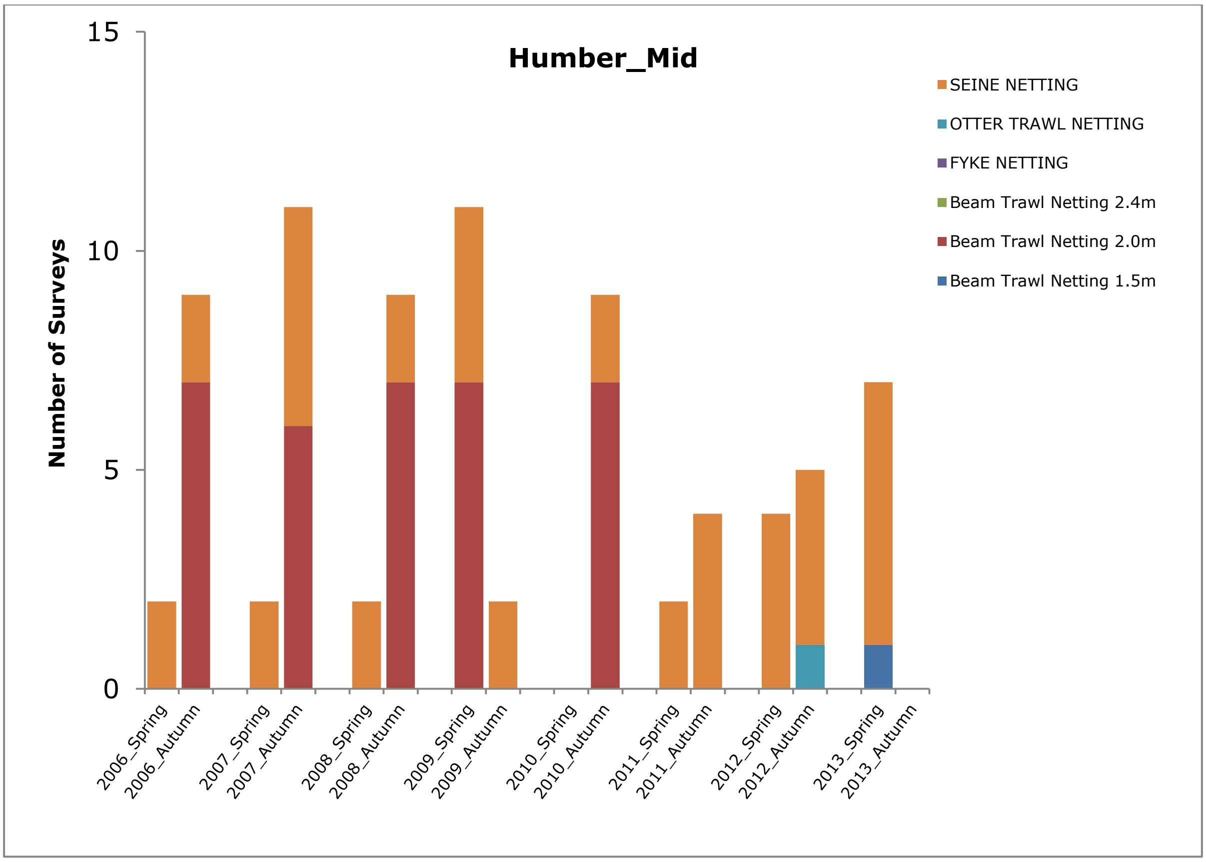


Figure 32 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Humber Mid.

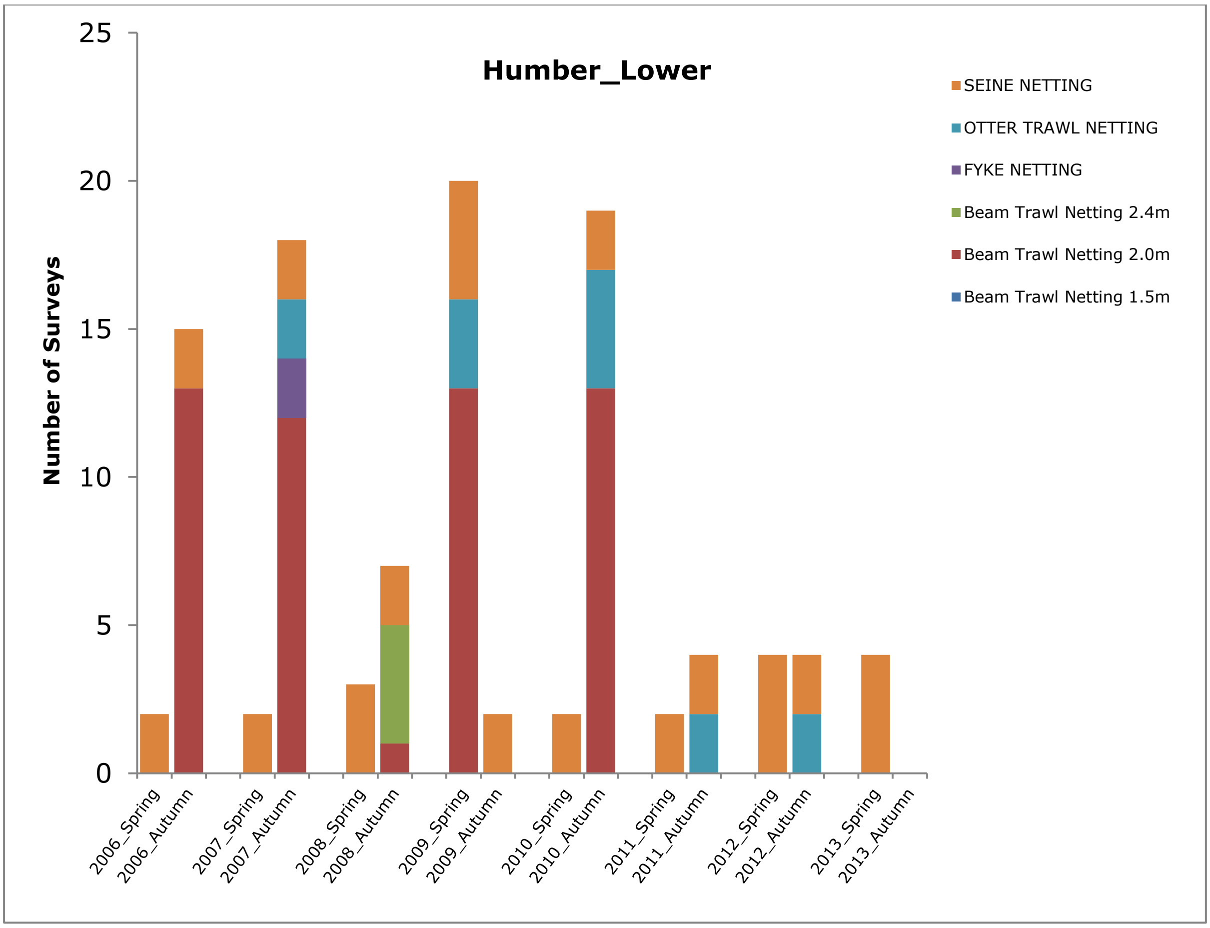
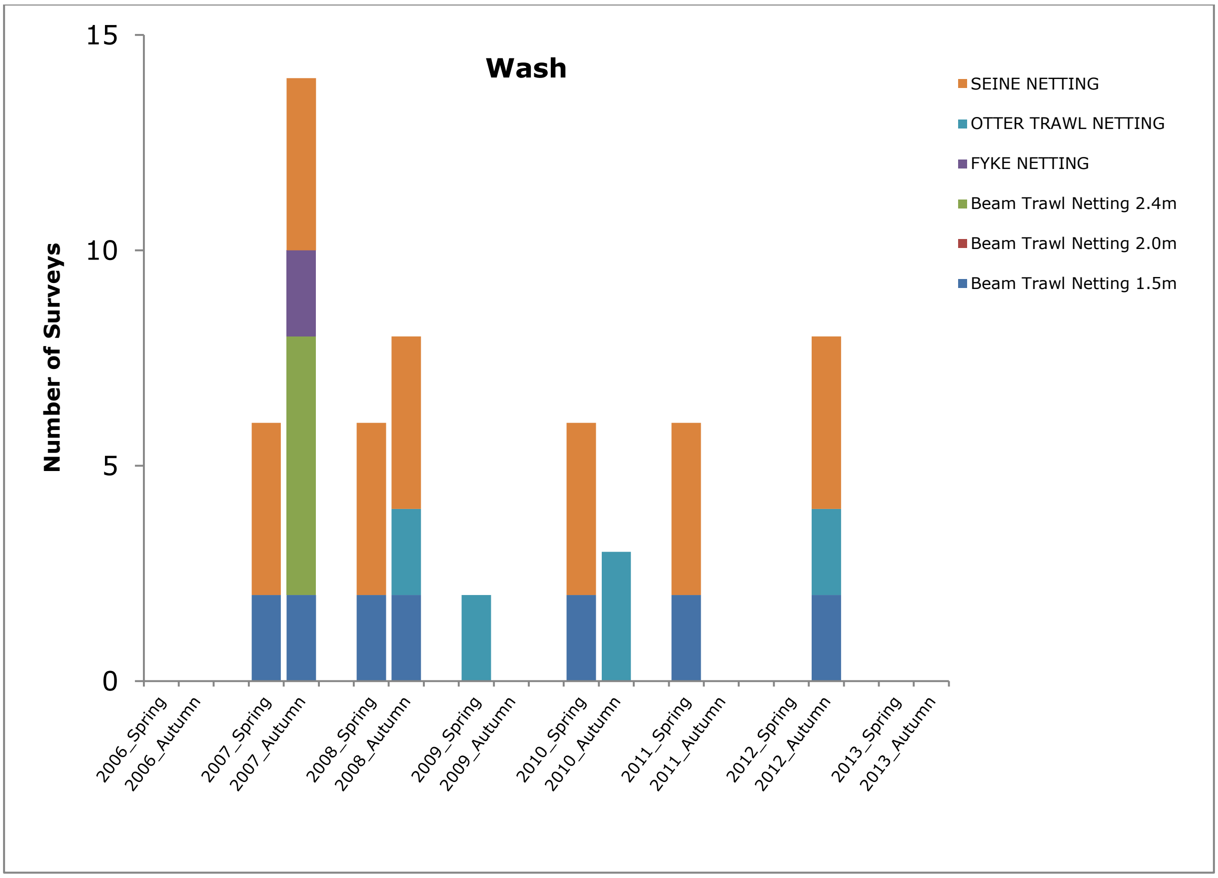


Figure 33 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Humber Lower.



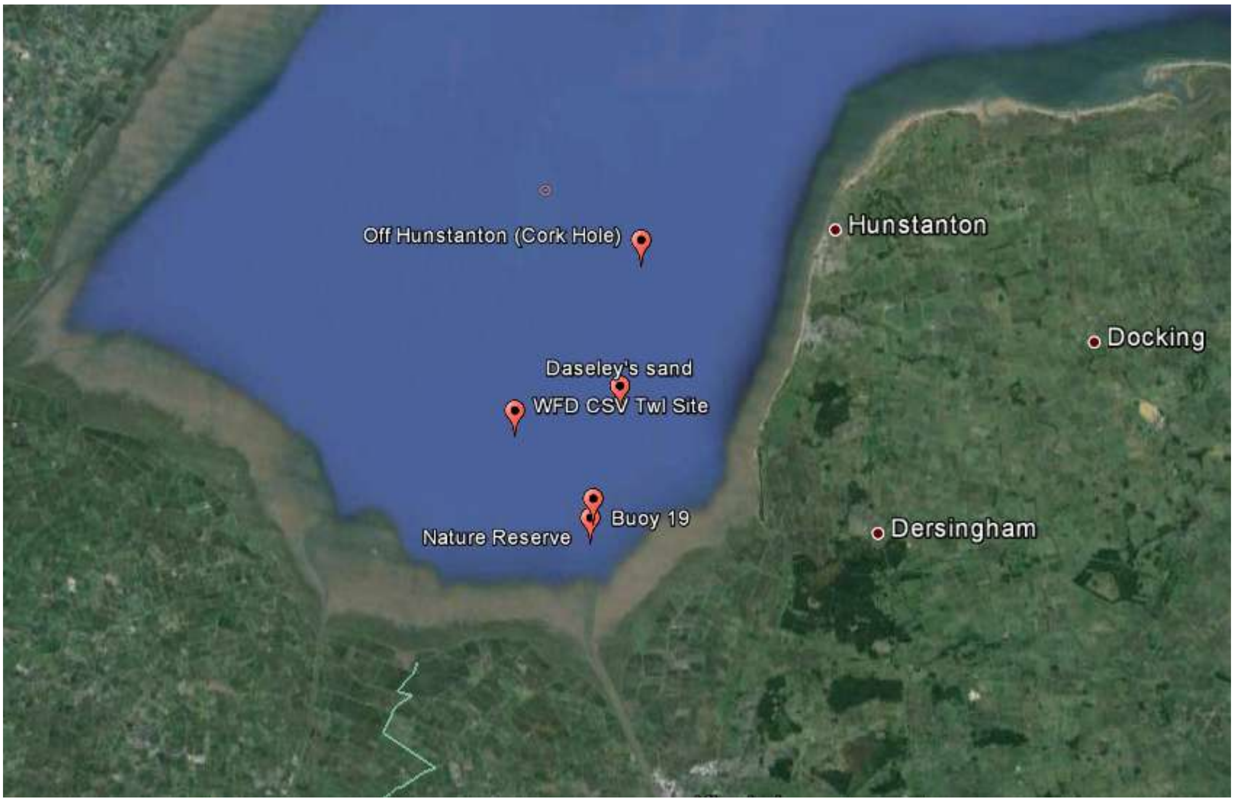


Figure 34 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Wash.

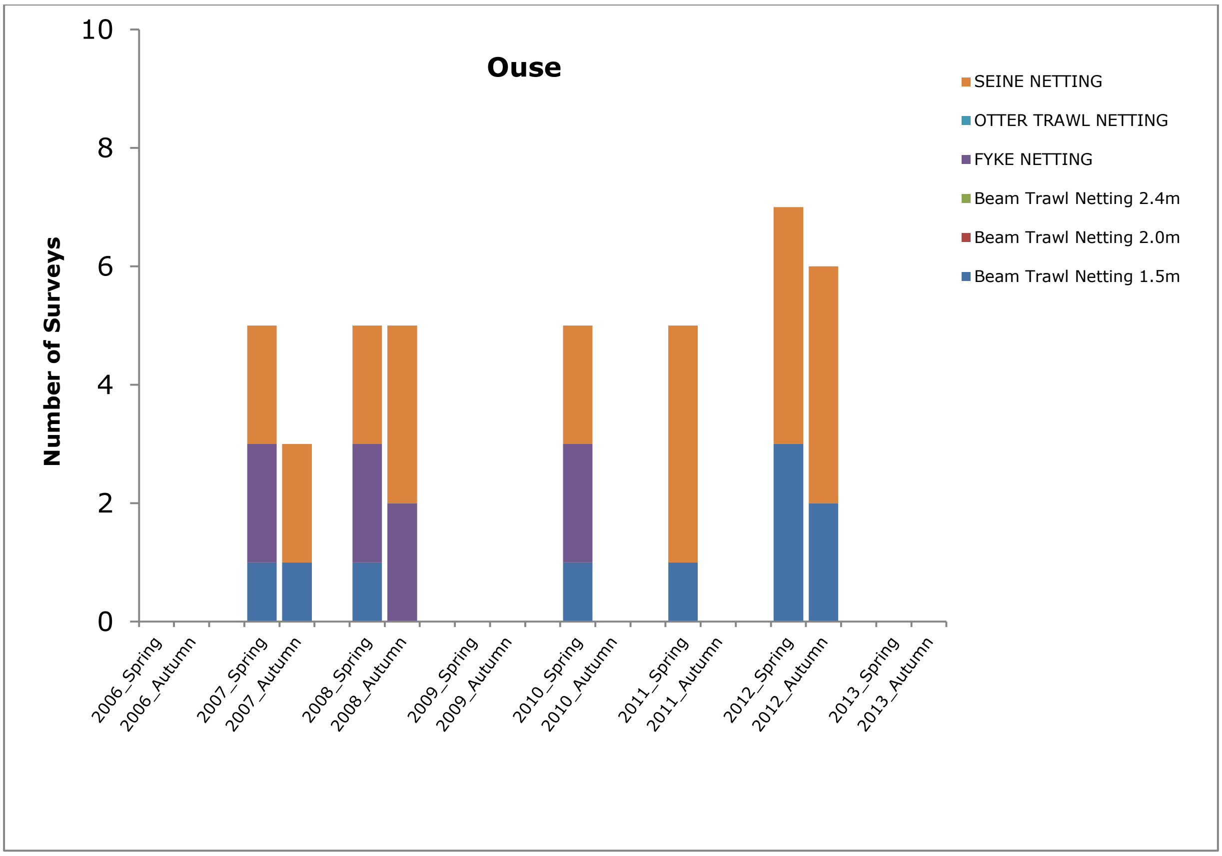
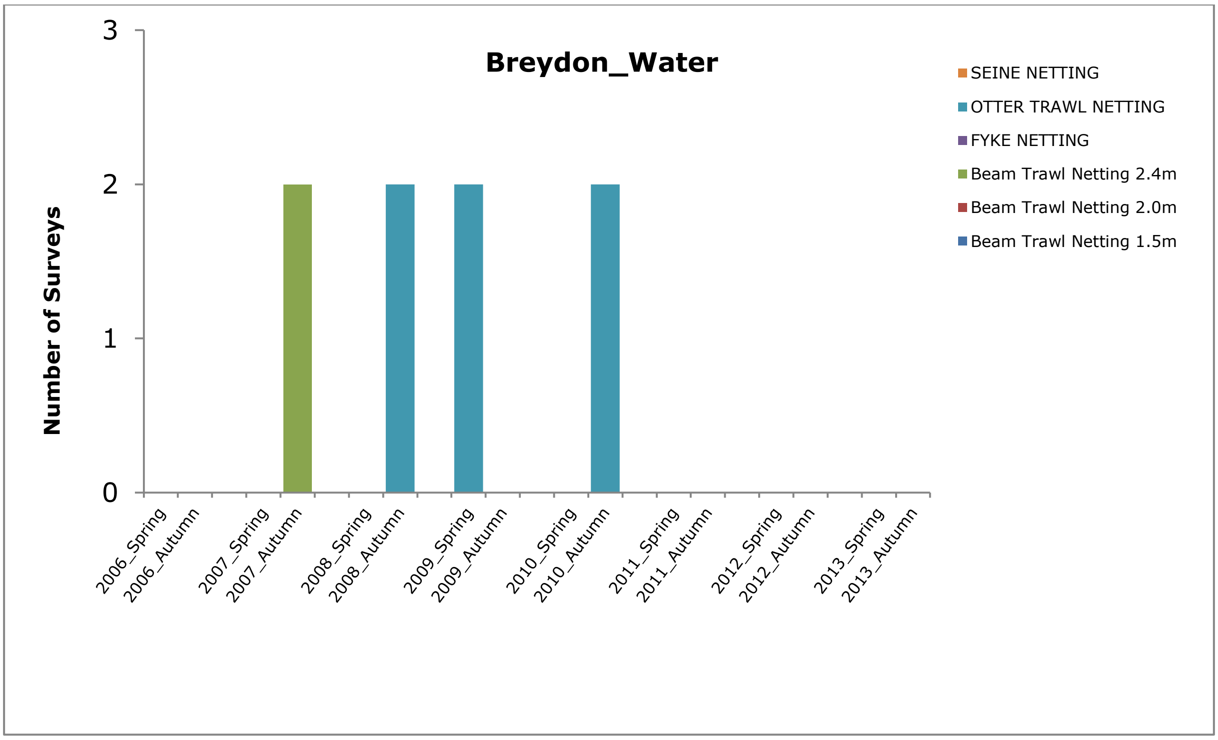


Figure 35 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Ouse.



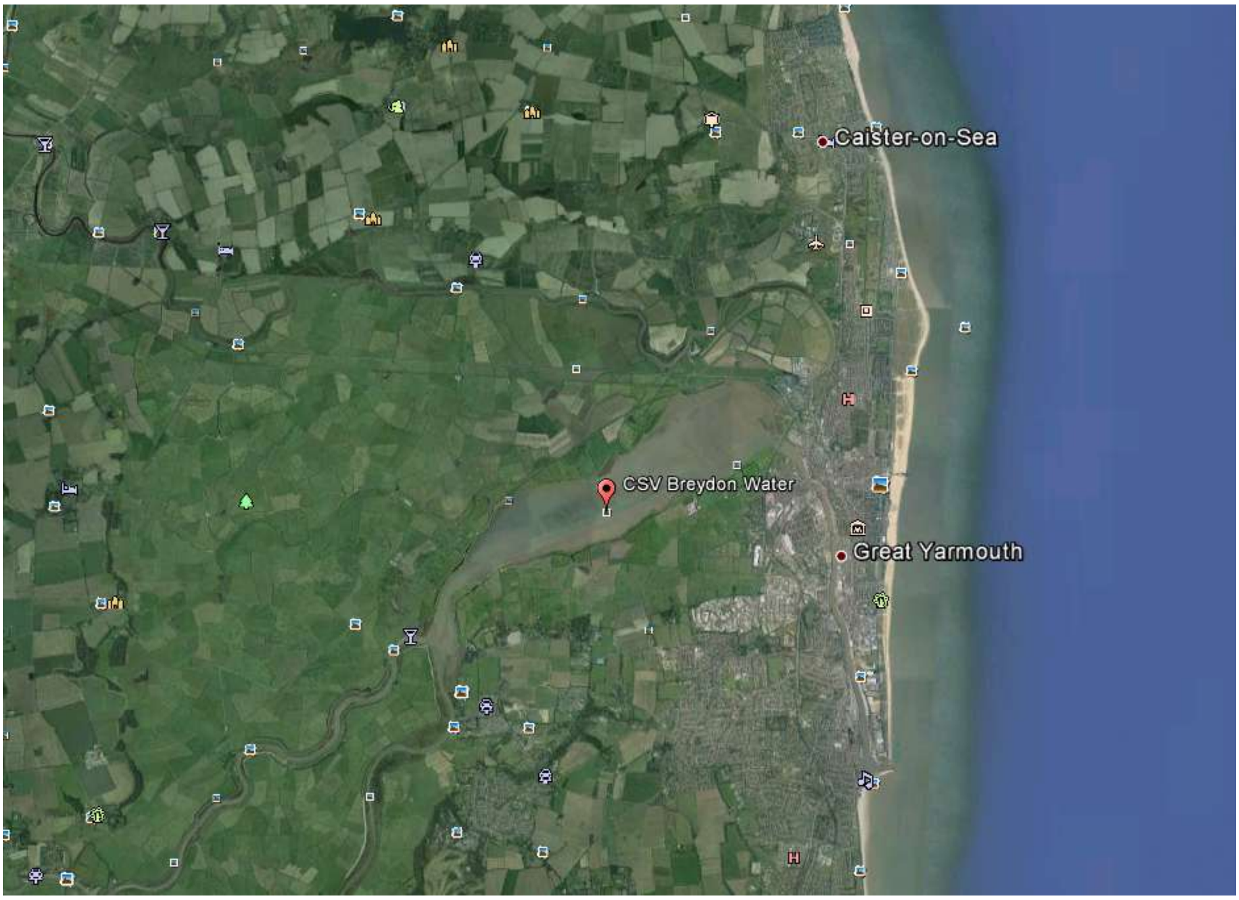
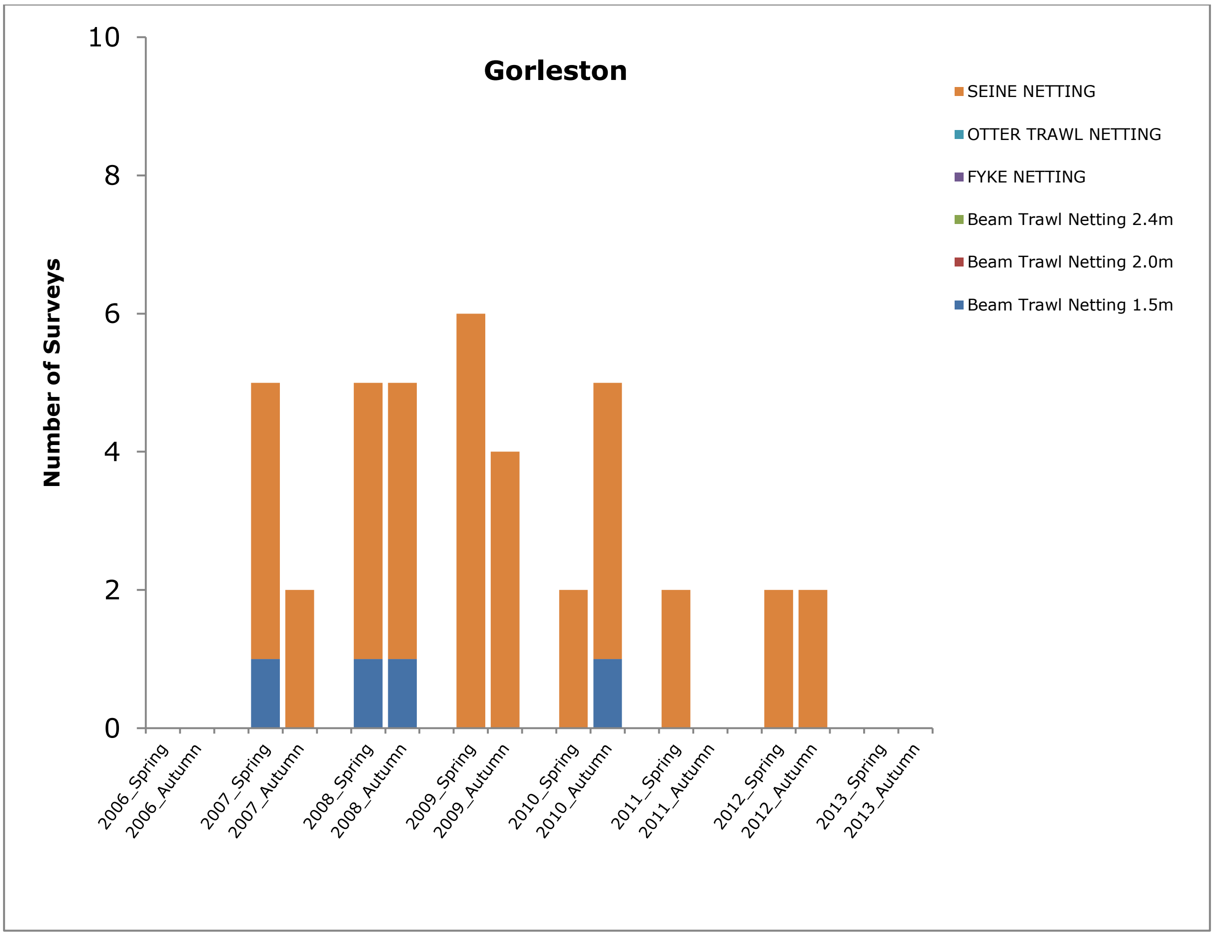


Figure 36 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Breydon Water.



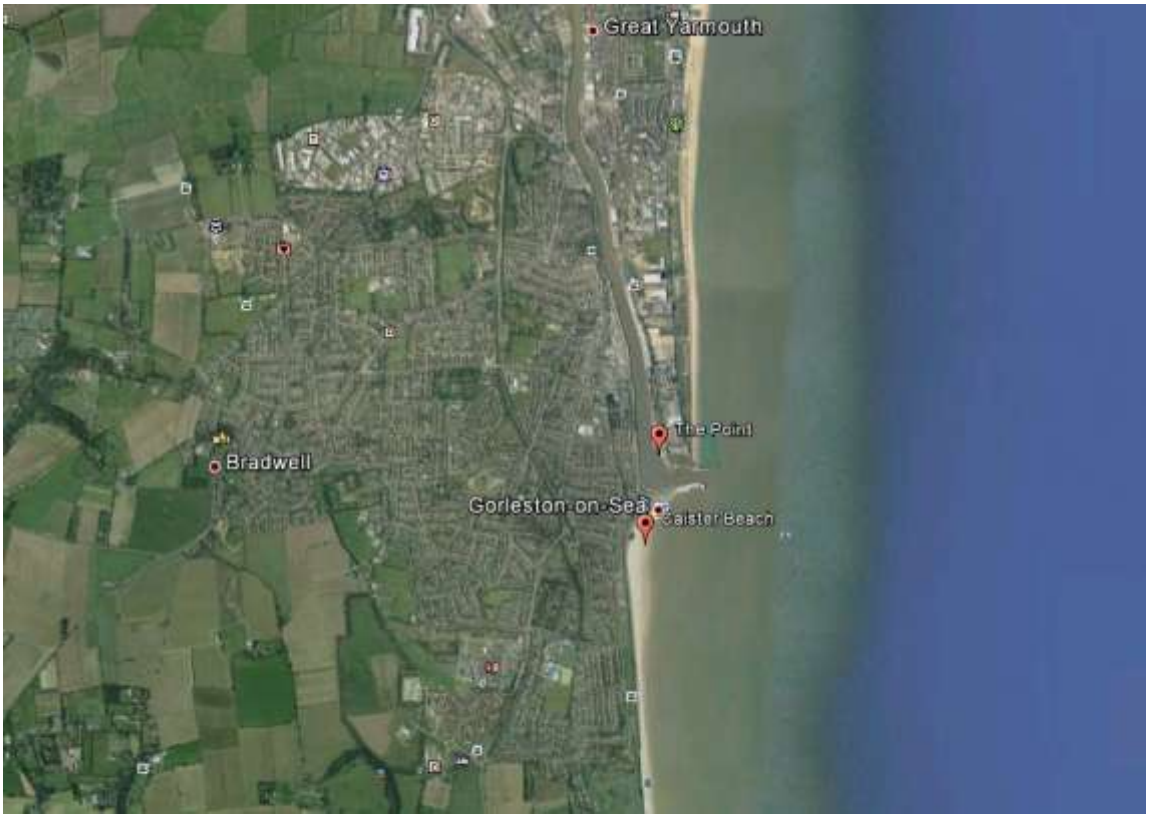


Figure 37 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Gorleston.

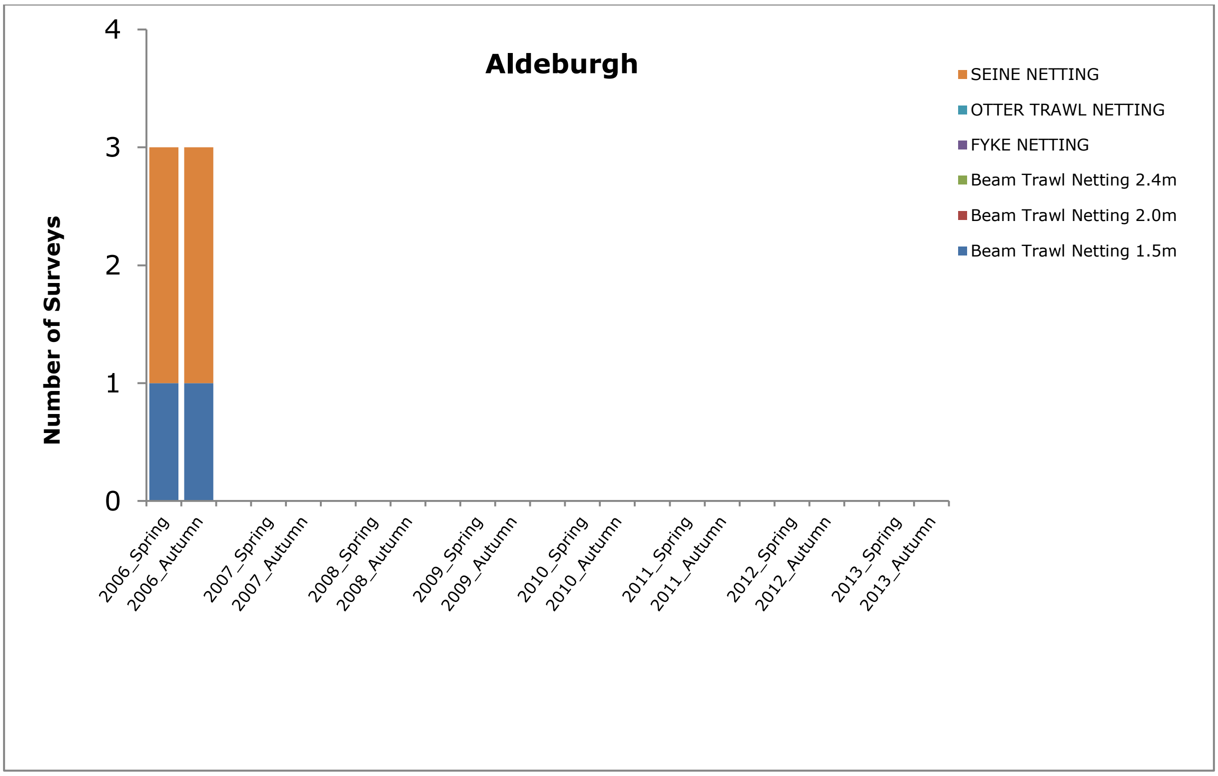
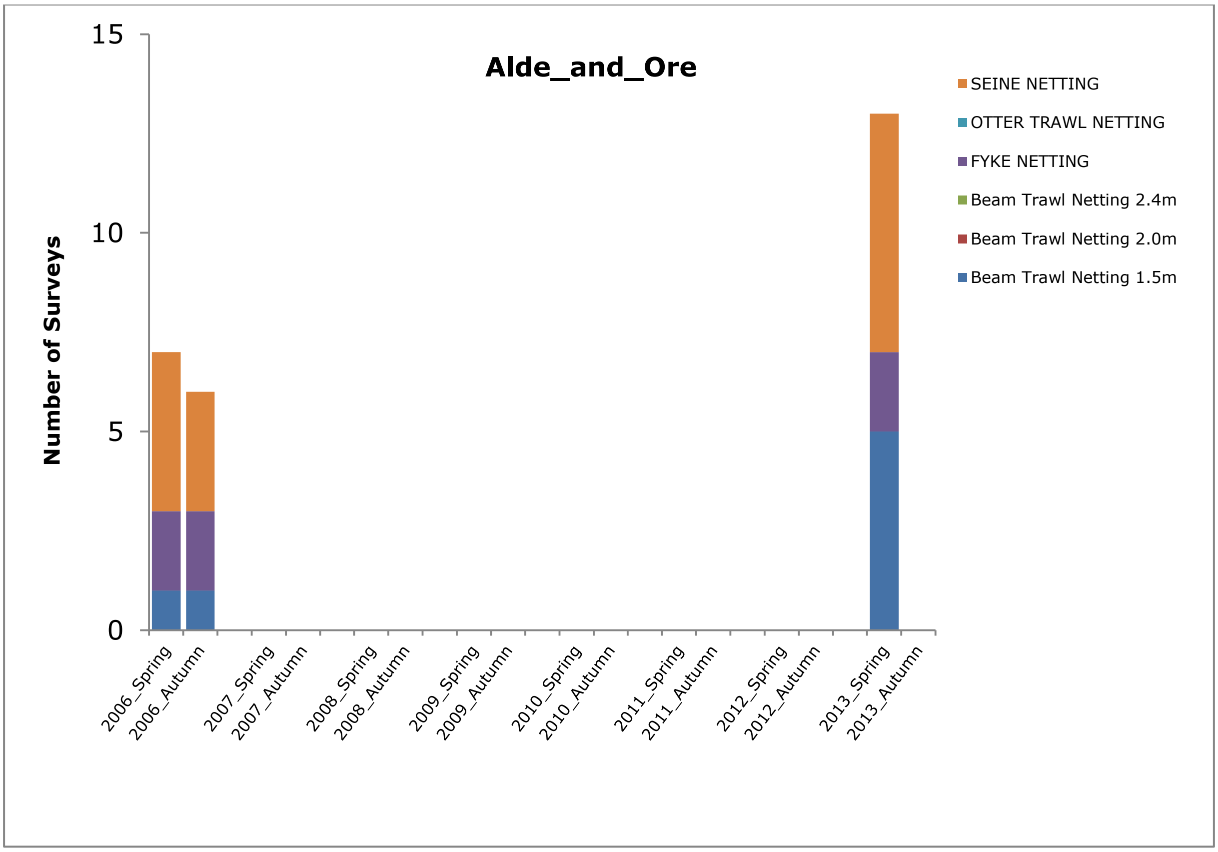


Figure 38 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Aldeburgh.



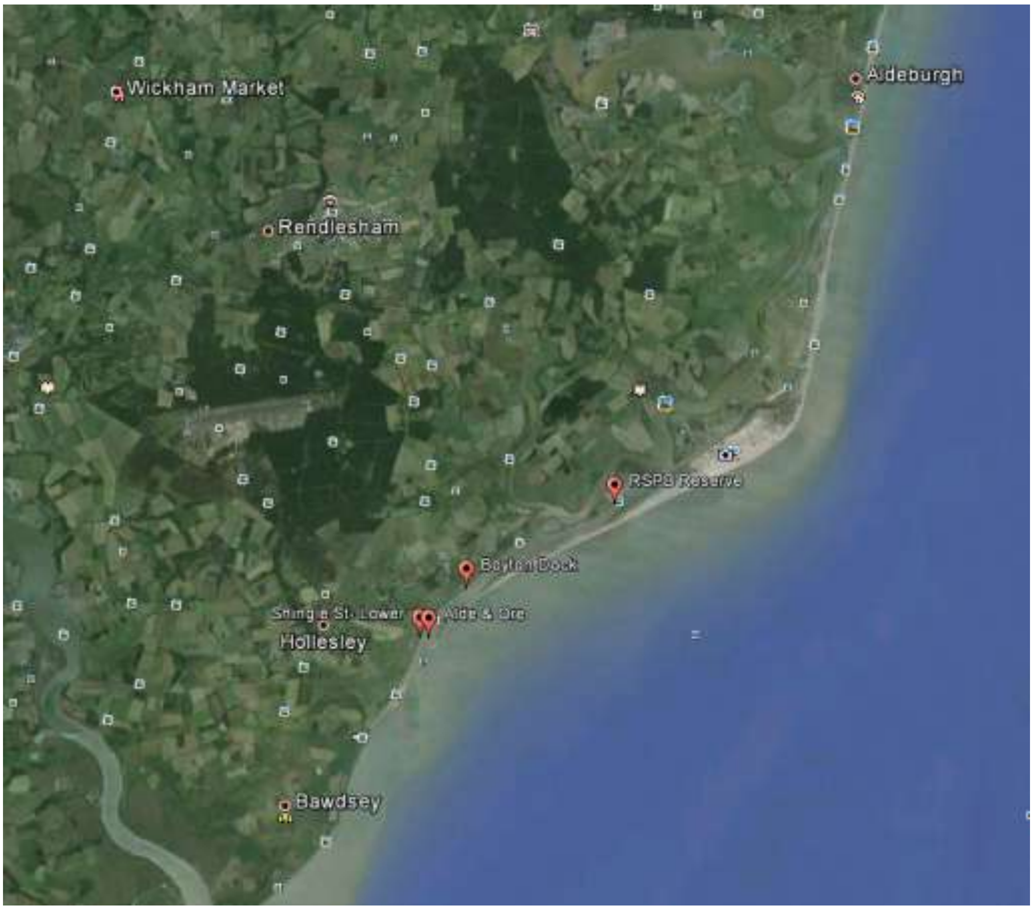
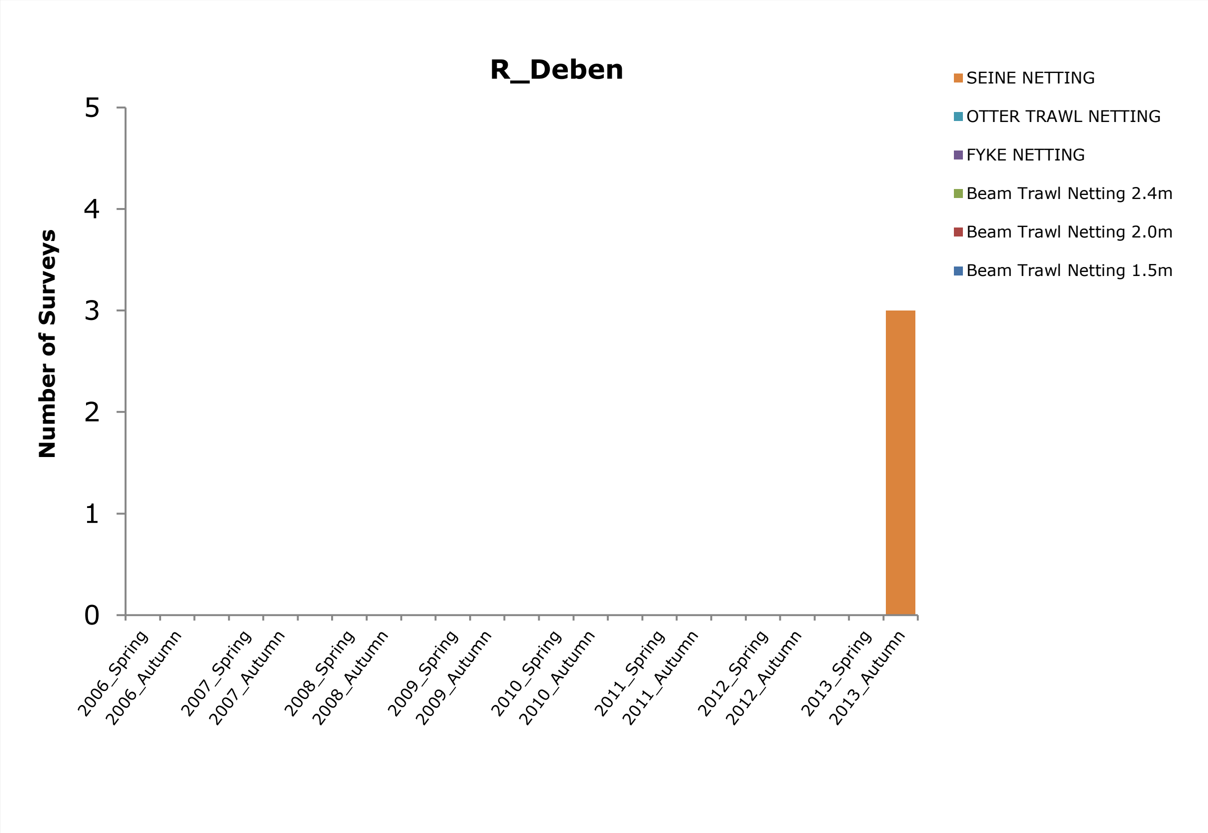


Figure 39 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area Alde & Ore.



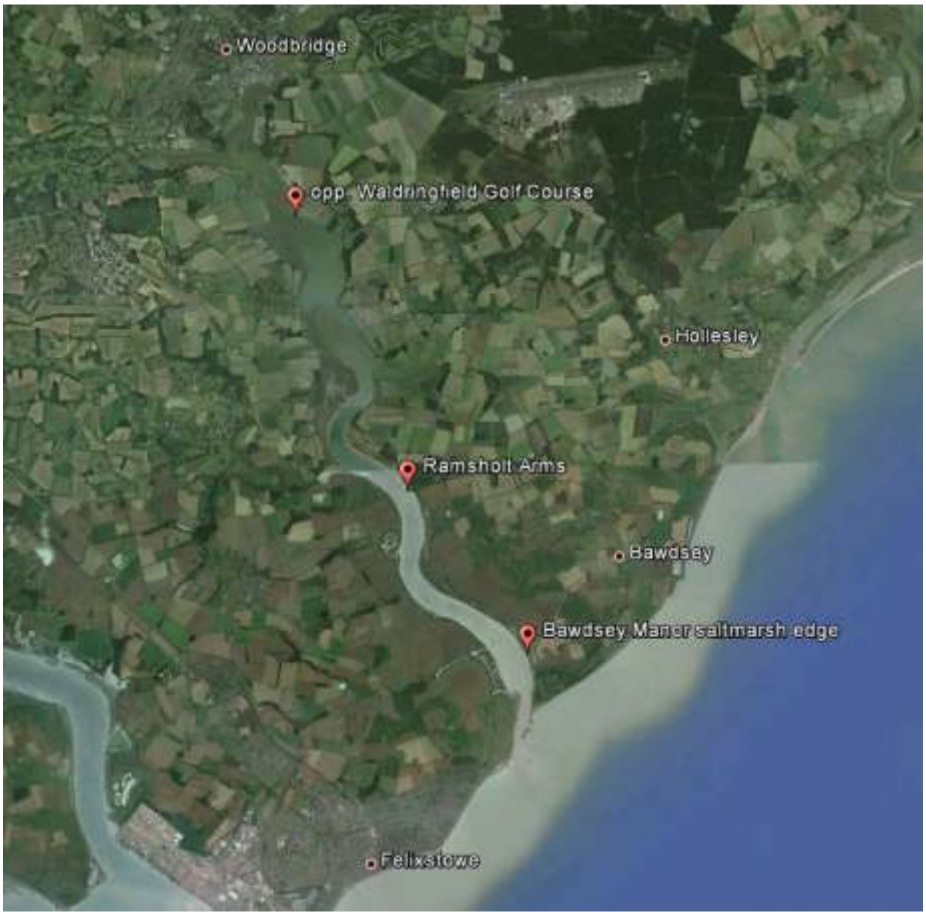
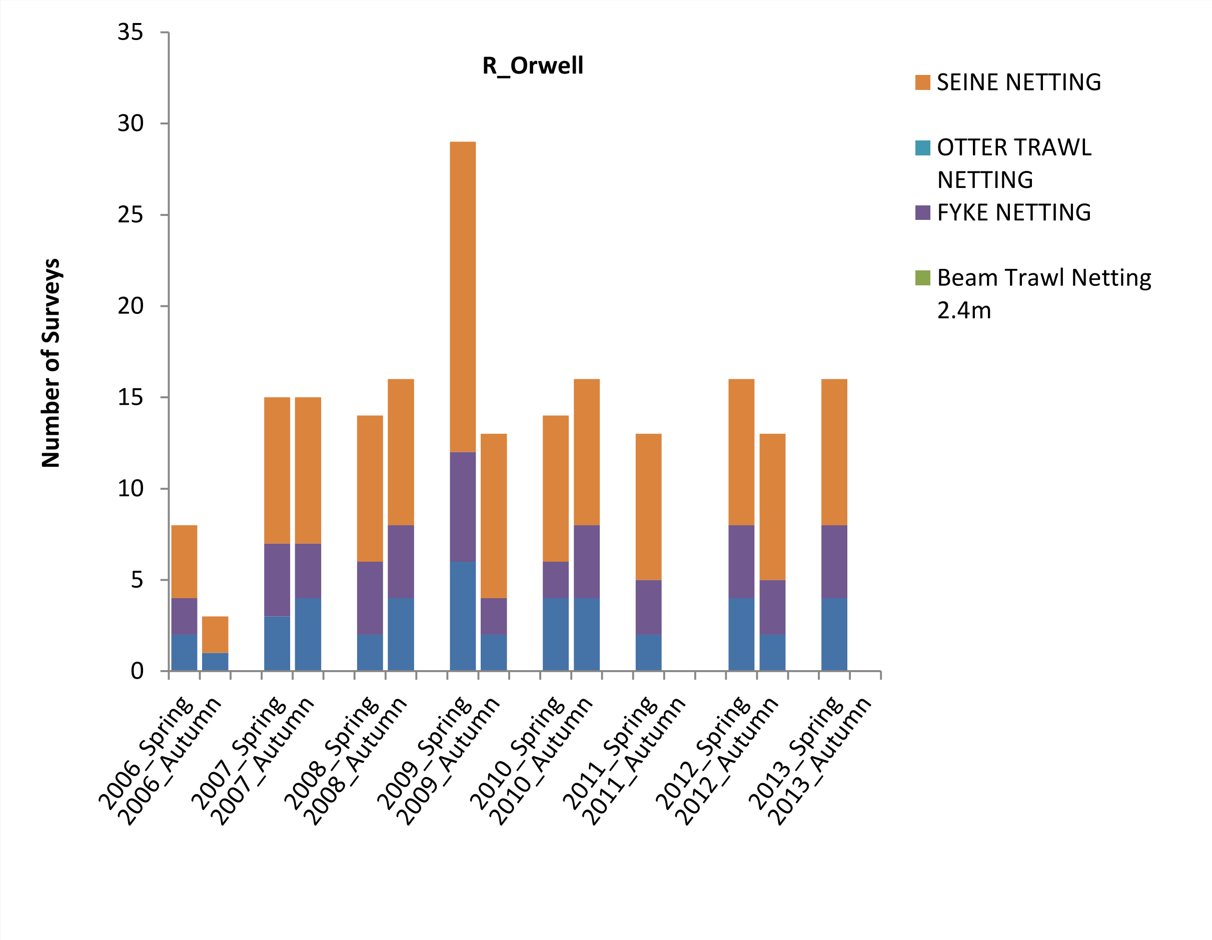


Figure 40 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area River Deben.



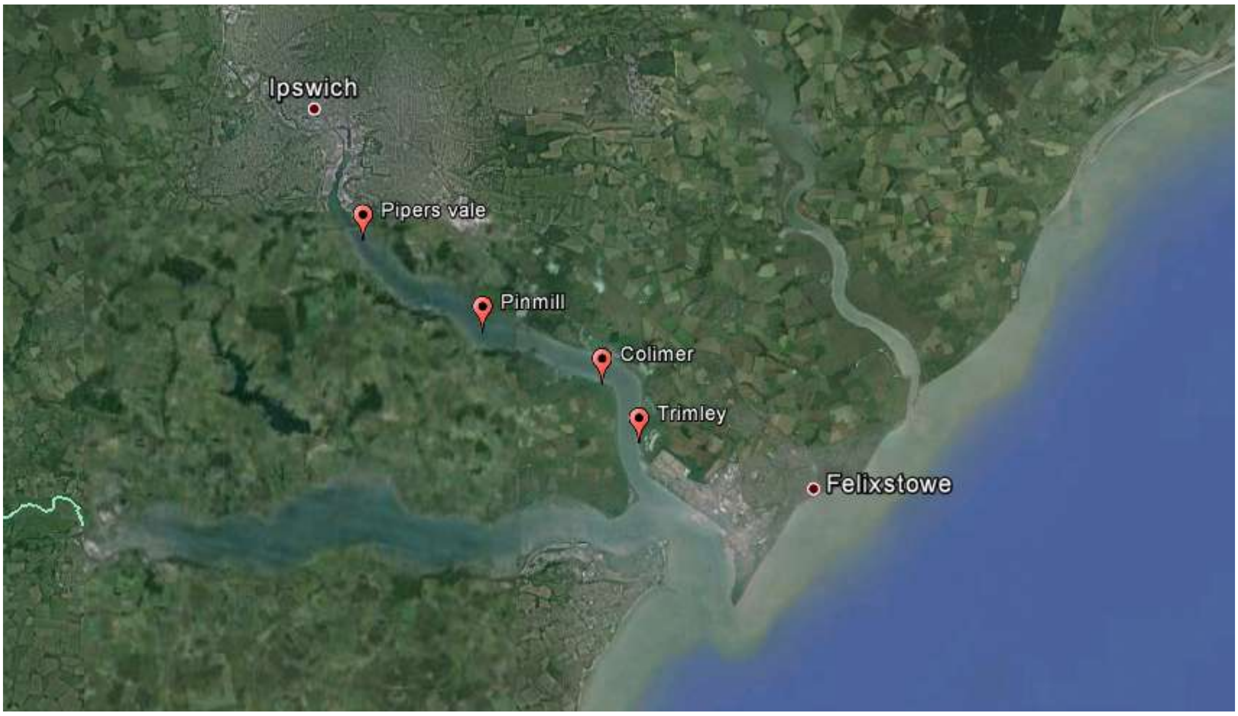
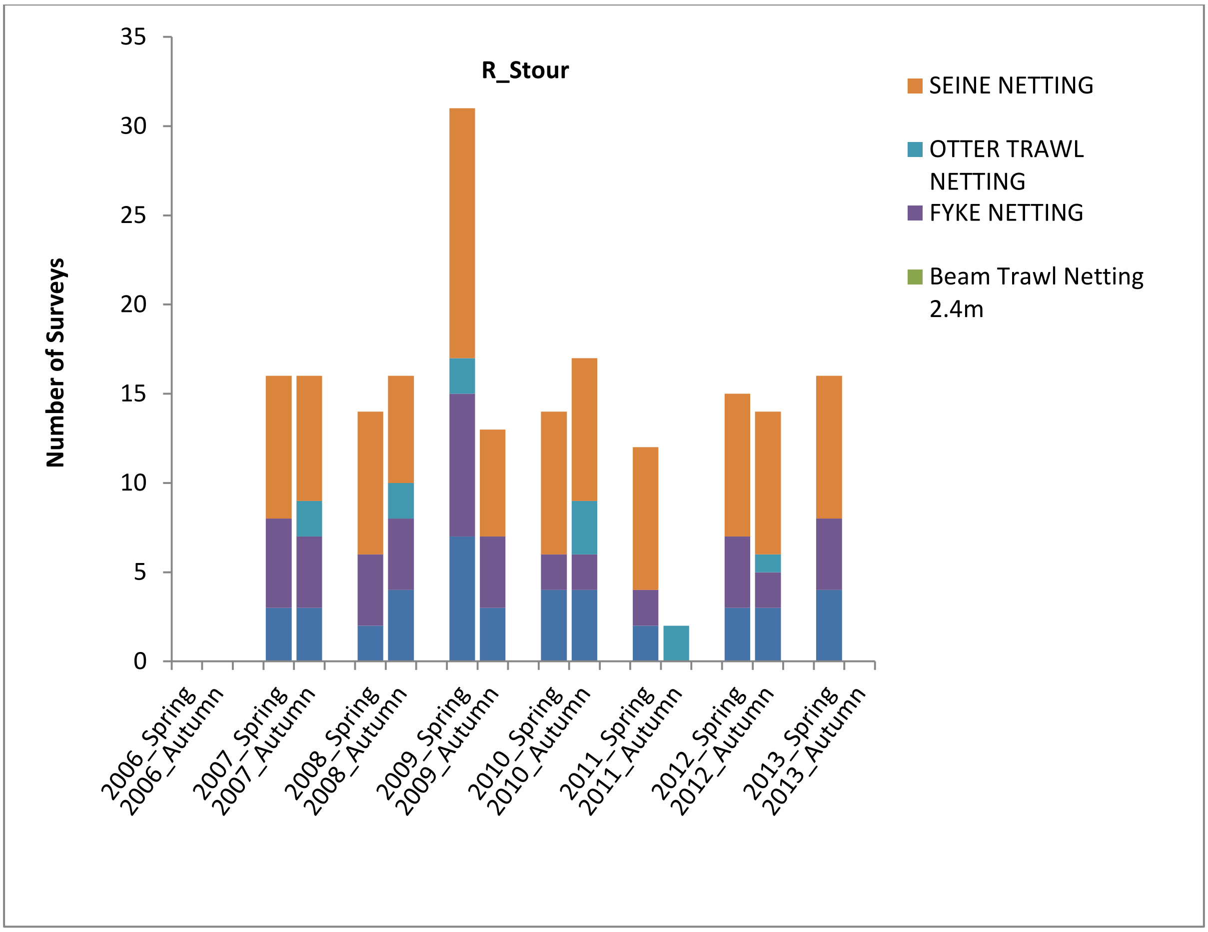


Figure 41 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area River Orwell.



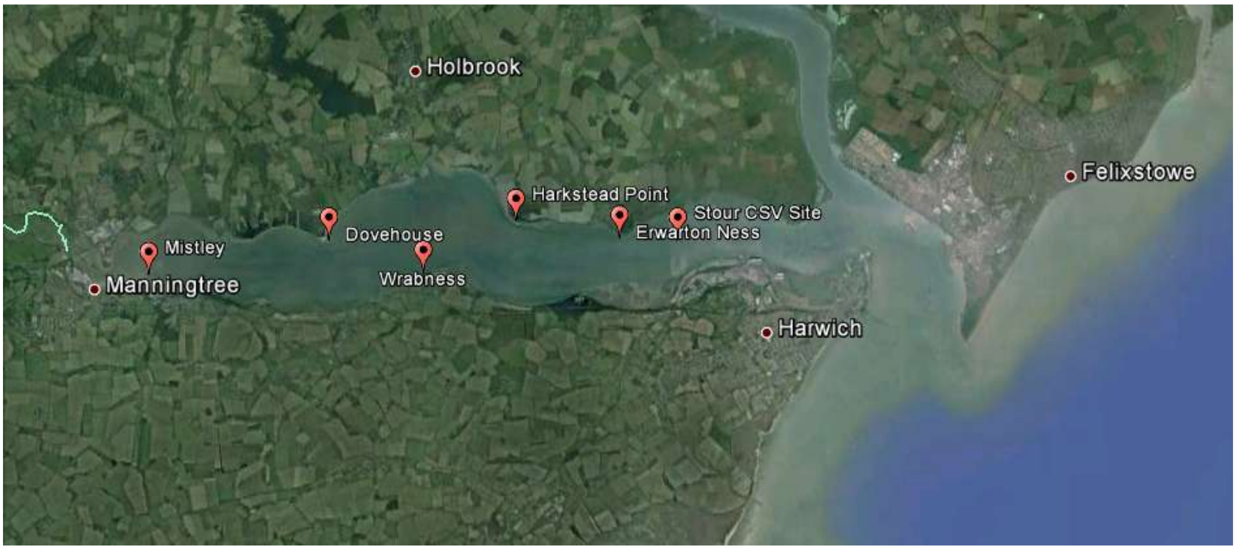
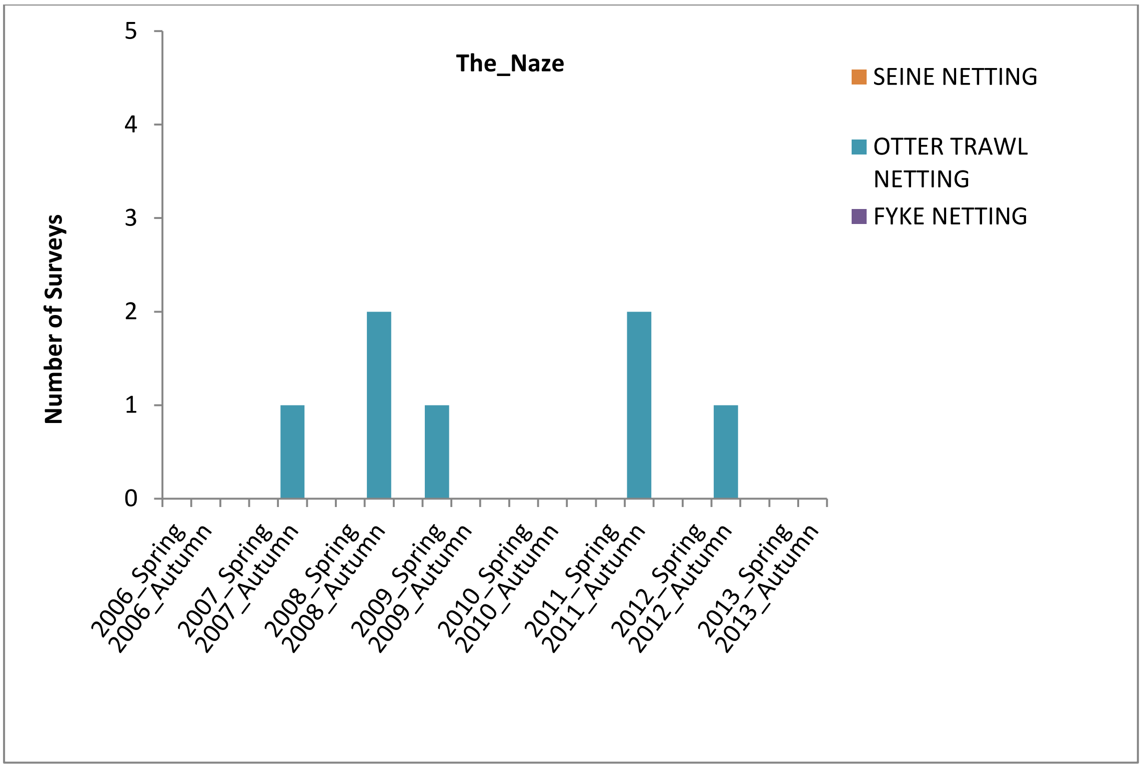


Figure 42 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area River Stour.



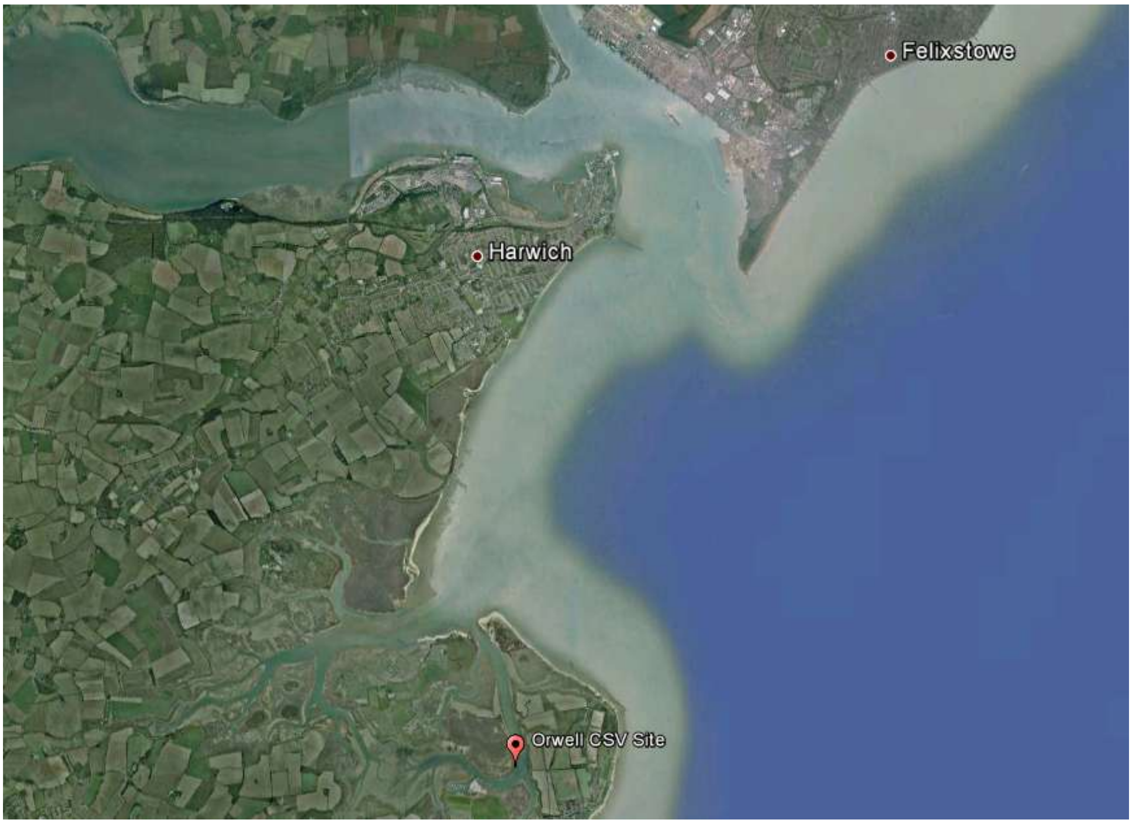
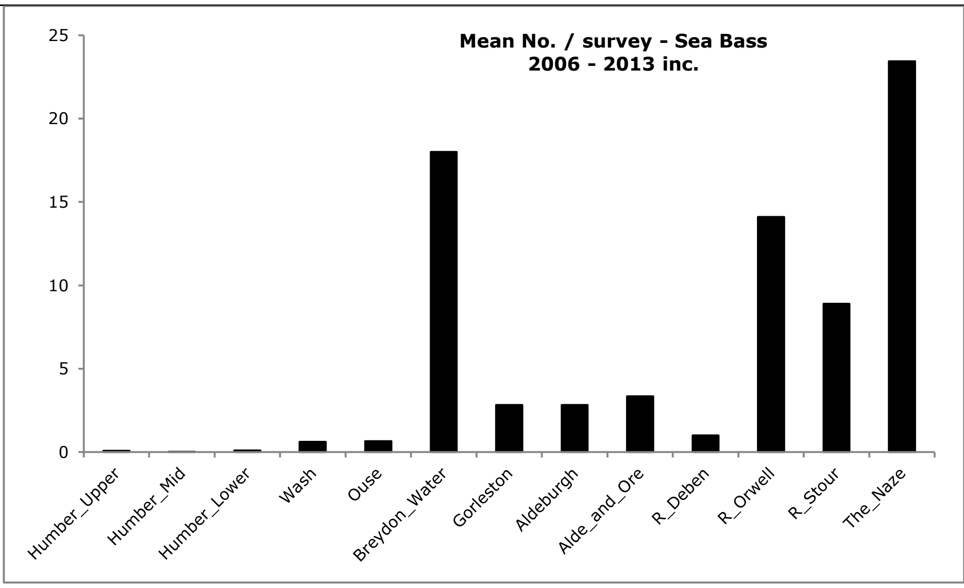
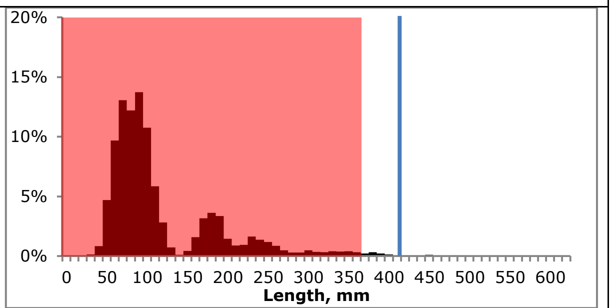
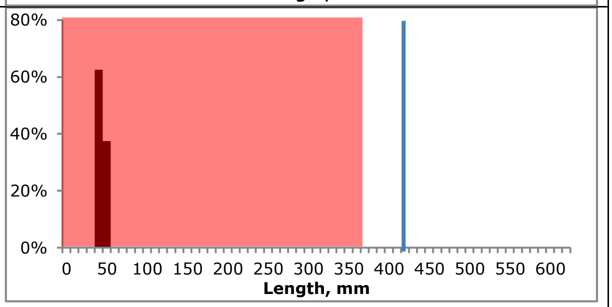


Figure 43 Number of surveys by sampling method in Spring and Autumn by year 2006 – 2013 (top) and location of individual sample stations (bottom) for area The Naze.

Size frequency histograms from EA WFD data - Bass

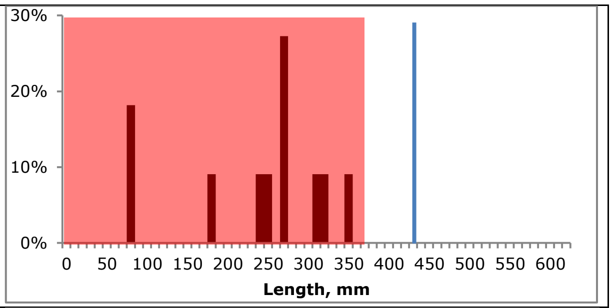
On the size frequency histograms below, the shaded pink area is intended to portray graphically the minimum landing size for Bass within the Eastern IFCA district (360 mm), the blue line is intended to portray the size at sexual maturity for bass (420 mm). (1996 "*The Annual Pattern of Condition and Maturity in Bass, Dicentrarchus labrax, in Waters Around England and Wales*" M.G. Pawson, G.D. Pickett, JMBA Vol 76)



Overall all areas combined 2006 – 2013 inc, Bass N = 3169	
Humber Upper 2006 – 2013 inc, Bass N = 8	
Humber Mid 2006 – 2013 inc, Bass N = 1	One only recorded, 50 mm length

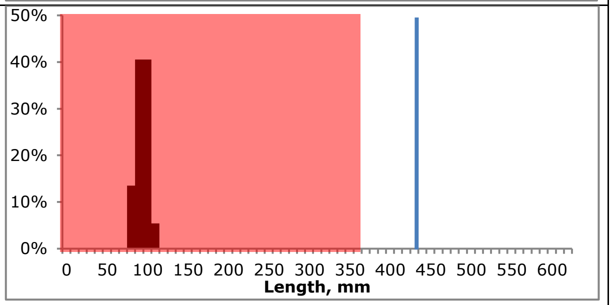
Humber Lower 2006 – 2013 inc, Bass

N = 11



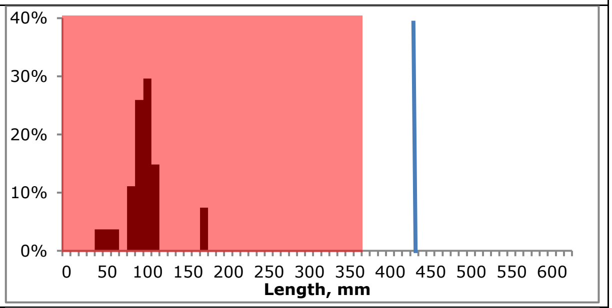
Wash 2006 – 2013 inc, Bass

N = 37



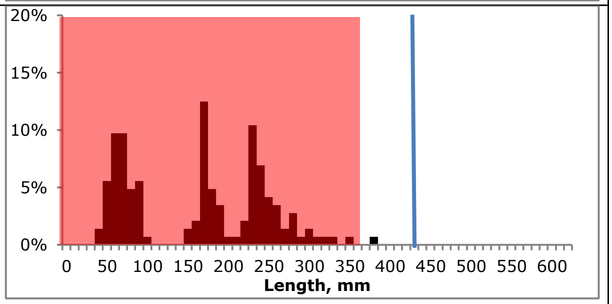
Ouse 2006 – 2013 inc, Bass

N = 27



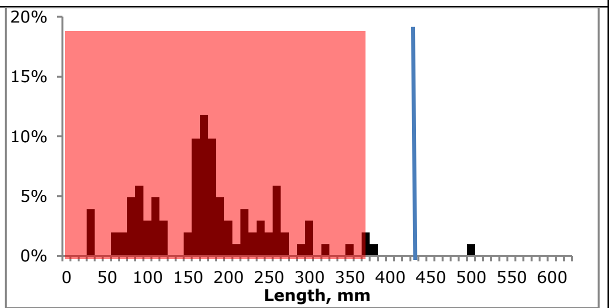
Breydon Water 2006 – 2013 inc, Bass

N = 144



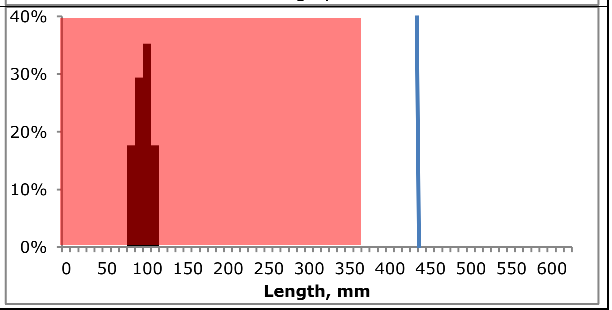
Gorleston 2006 – 2013 inc, Bass

N = 102



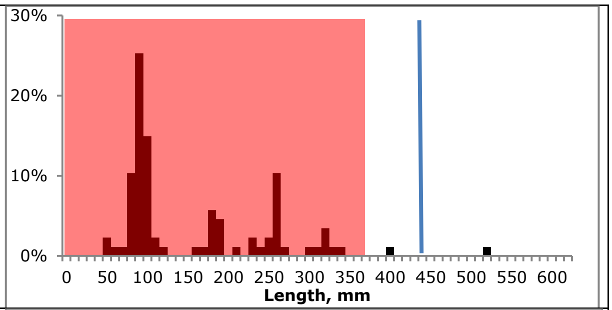
Aldeburgh 2006 – 2013 inc, Bass

N = 17



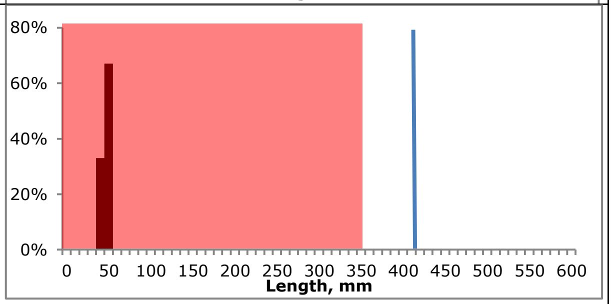
Alde & Ore 2006 – 2013 inc, Bass

N = 87



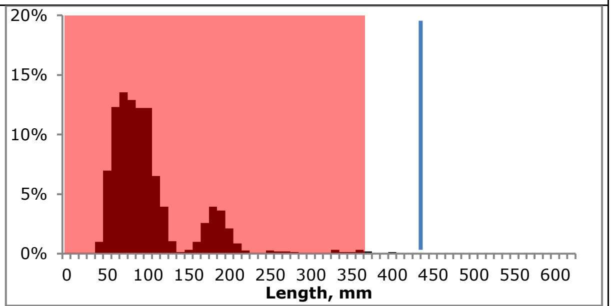
River Deben 2006 – 2013 inc, Bass

N = 3



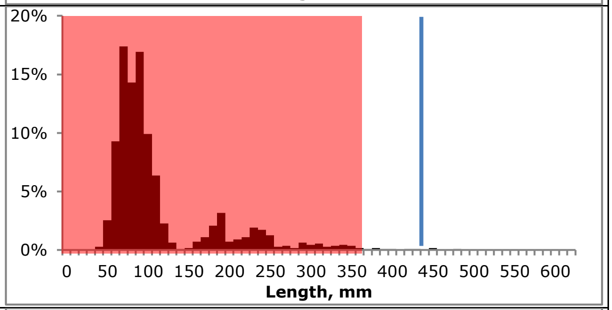
River Orwell 2006 – 2013 inc, Bass

N = 1520



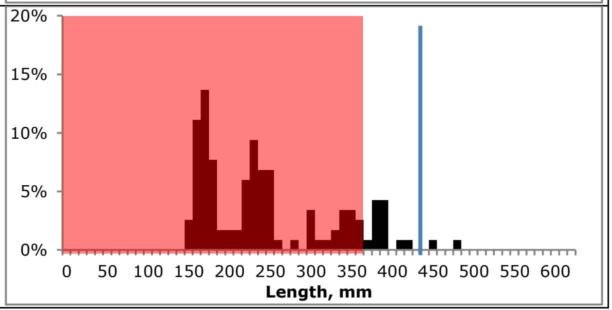
River Stour 2006 – 2013 inc, Bass

N = 1098



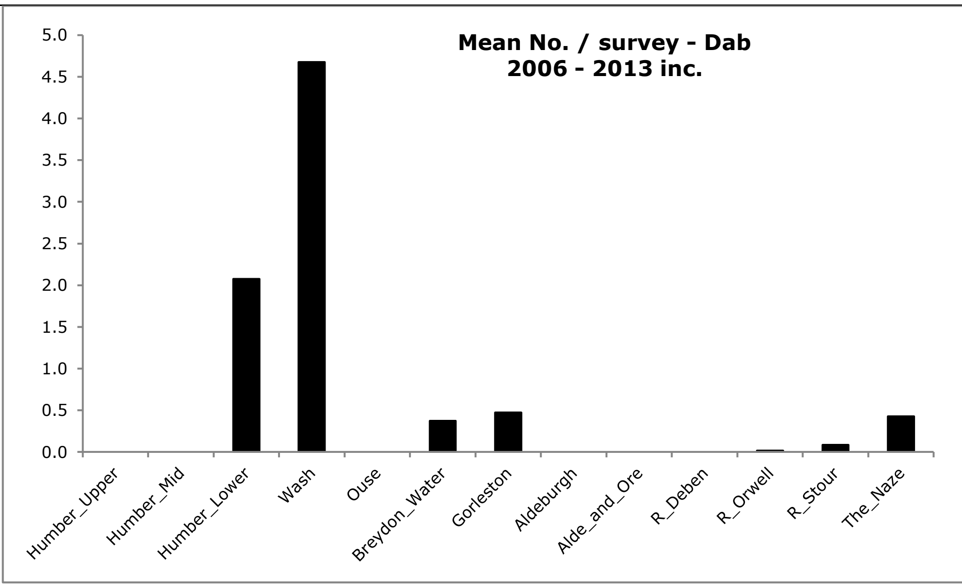
The Naze 2006 – 2013 inc, Bass

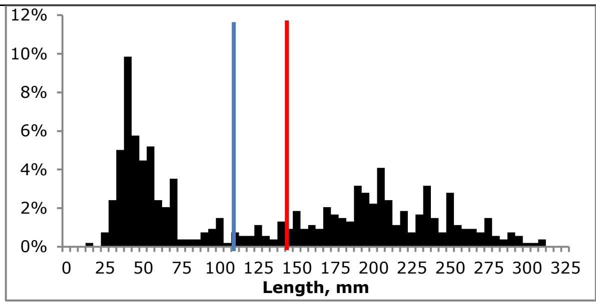
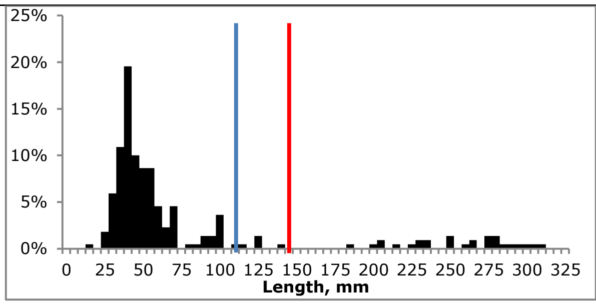
N = 117

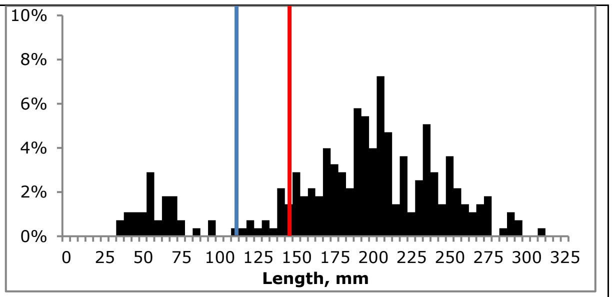
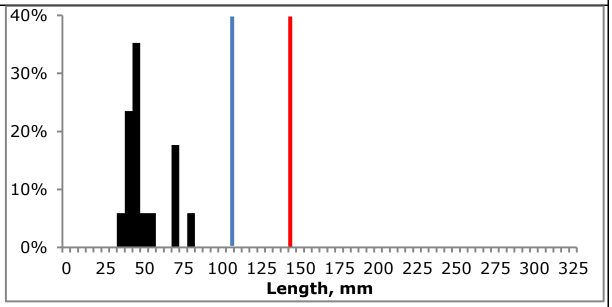
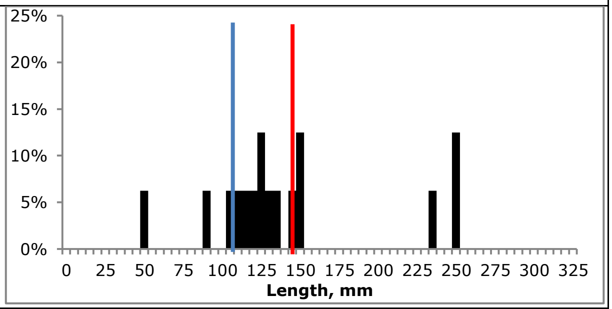


Size frequency histograms from EA WFD data - Dab

On the size frequency histograms below, the blue line is intended to graphically portray the size at sexual maturity for male dab (110 mm) and the red line, that for female dab (140 mm). (1992 "*Population biology of Dab in south eastern North Sea*" Rijnsdorp et al, Marine Ecology Progress series Vol. 91)

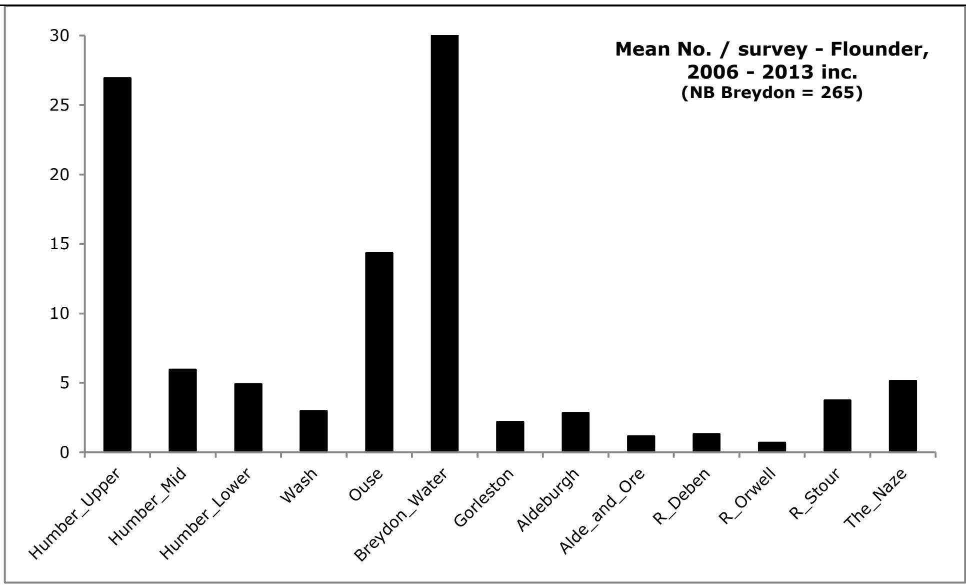


Overall all areas combined 2006 – 2013 inc, Dab N = 538	
Humber Upper	None measured
Humber Mid	None measured
Humber Lower 2006 – 2013 inc, Dab N = 220	

<table>
<tr><td>Wash 2006 – 2013 inc, Dab
N = 276</td><td>
</td></tr>
<tr><td>Ouse</td><td>None measured</td></tr>
<tr><td>Breydon Water 2006 – 2013 inc, Dab
N = 3</td><td>3 measured, all 40 mm.</td></tr>
<tr><td>Gorleston 2006 – 2013 inc, Dab
N = 17</td><td>
</td></tr>
<tr><td>Aldeburgh</td><td>None measured</td></tr>
<tr><td>Alde & Ore</td><td>None measured</td></tr>
<tr><td>River Deben</td><td>None measured</td></tr>
<tr><td>River Orwell 2006 – 2013 inc, Dab
N = 3</td><td>3 measured – 60, 65 & 70 mm.</td></tr>
<tr><td>River Stour 2006 – 2013 inc, Dab
N = 16</td><td>
</td></tr>
<tr><td>The Naze 2006 – 2013 inc, Dab
N = 3</td><td>3 measured – 110, 190 & 215 mm.</td></tr>
</table>

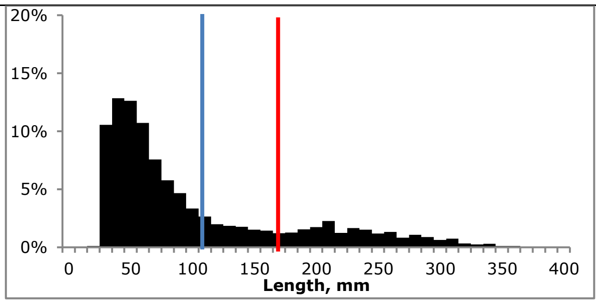
Size frequency histograms from EA WFD data - Flounder

On the size frequency histograms below, the blue line is intended to graphically portray the size at sexual maturity for male flounder (110 mm) and the red line, that for female flounder (170 mm). (2010 Literature review produced for Eastern JSFC "*A review of the European flounder* *<u>Platichthys flesus</u>* *- Biology, Life History and Trends in Population*" Skerrit, quoting several sources (Summers 1979; Bos 1999; Drevs *et al.* 1999))



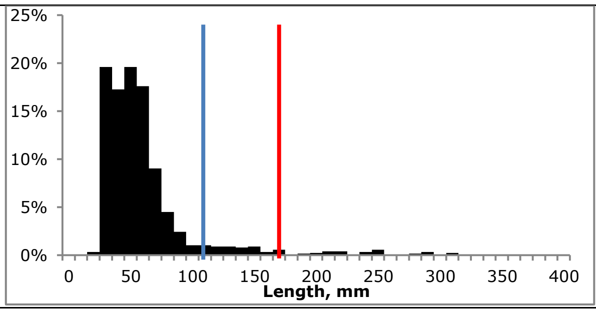
Overall all areas combined 2006 – 2013 inc, Flounder

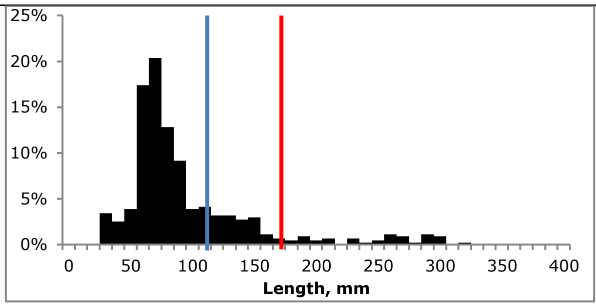
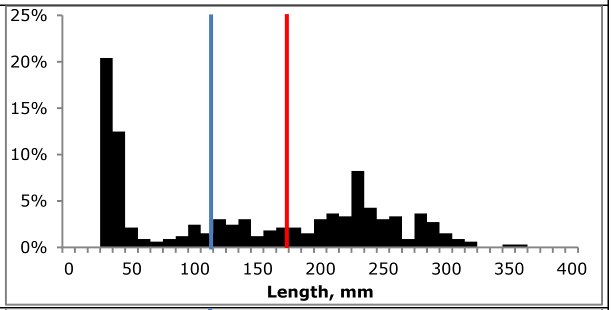
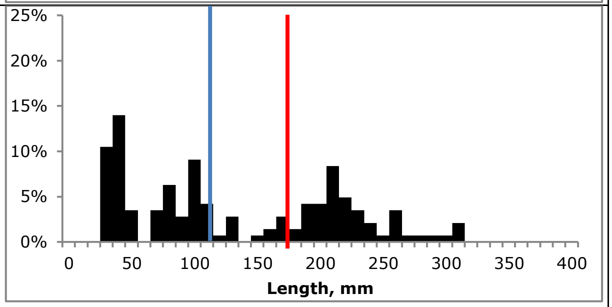
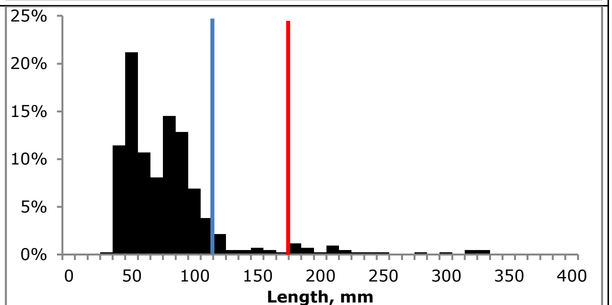
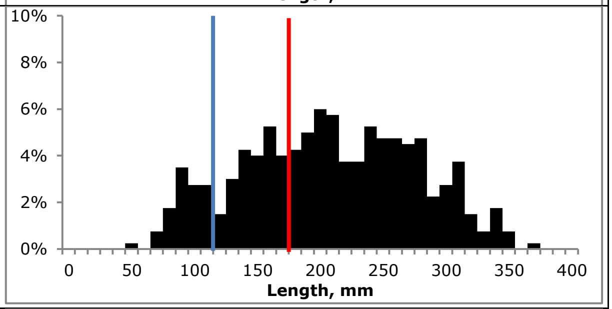
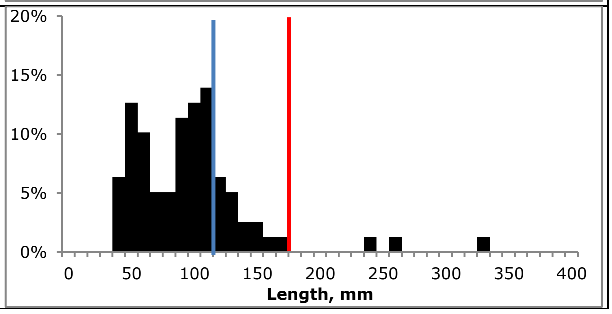
N = 3498

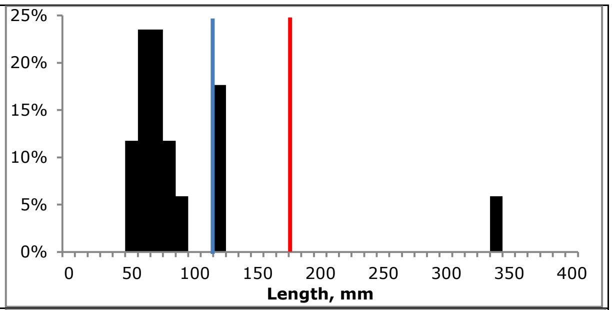
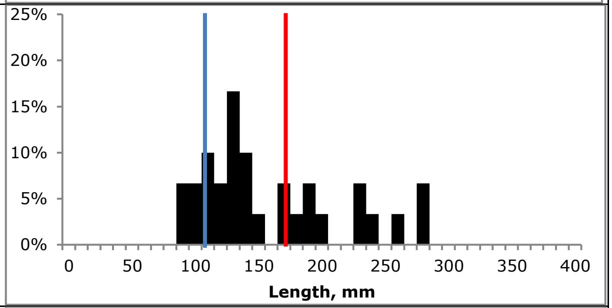
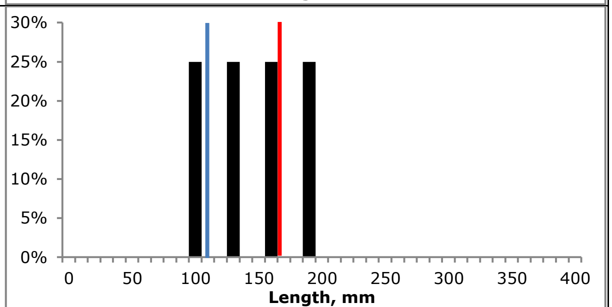
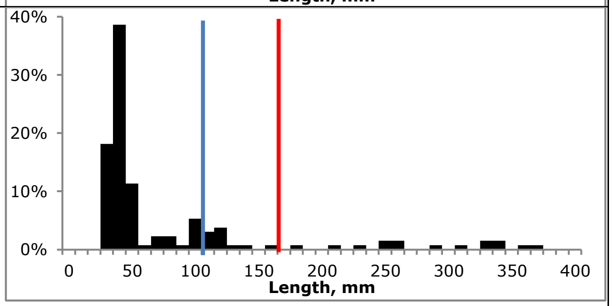
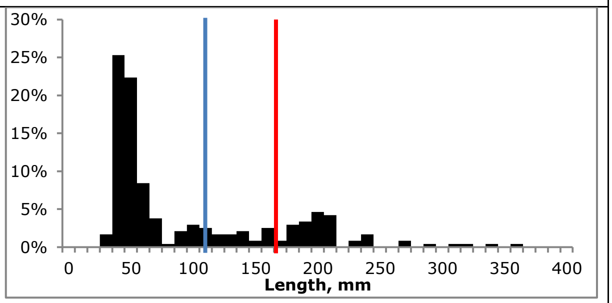
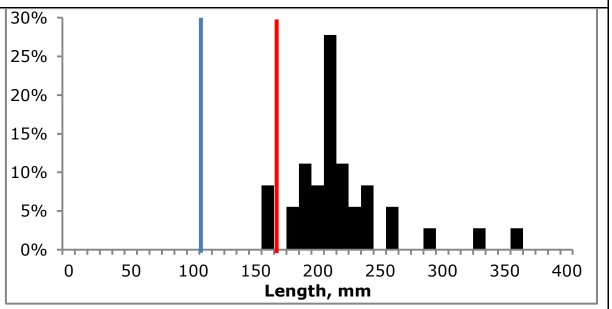


Humber Upper 2006 – 2013 inc, Flounder

N = 1239



Humber Mid 2006 – 2013 inc, Flounder N = 437	
Humber Lower 2006 – 2013 inc, Flounder N = 328	
Wash 2006 – 2013 inc, Flounder N = 143	
Ouse 2006 – 2013 inc, Flounder N = 420	
Breydon Water 2006 – 2013 inc, Flounder N = 400	
Gorleston 2006 – 2013 inc, Flounder N = 79	

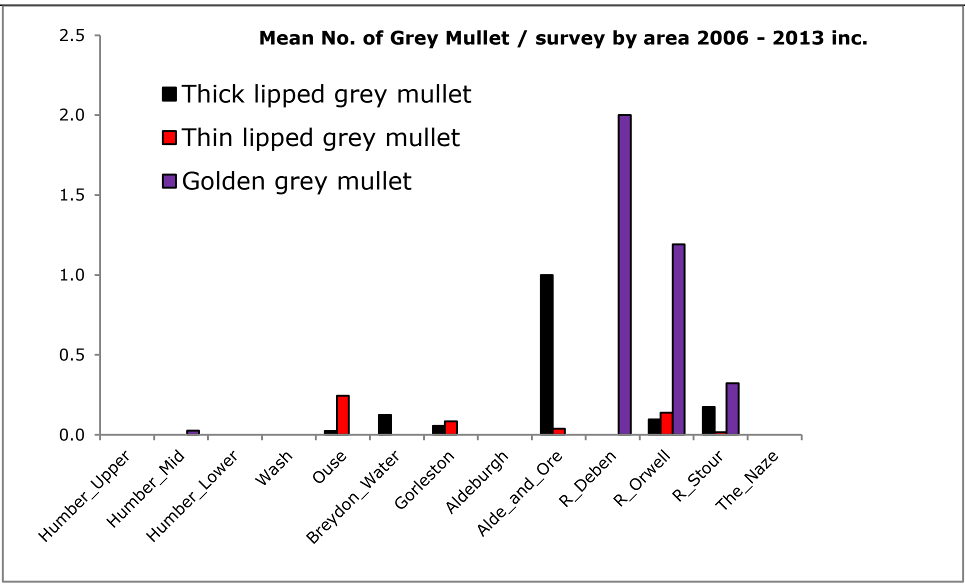
Aldeburgh 2006 – 2013 inc, Flounder N = 17	
Alde & Ore 2006 – 2013 inc, Flounder N = 30	
River Deben 2006 – 2013 inc, Flounder N = 4	
River Orwell 2006 – 2013 inc, Flounder N = 132	
River Stour 2006 – 2013 inc, Flounder N = 237	
The Naze 2006 – 2013 inc, Flounder N = 36	

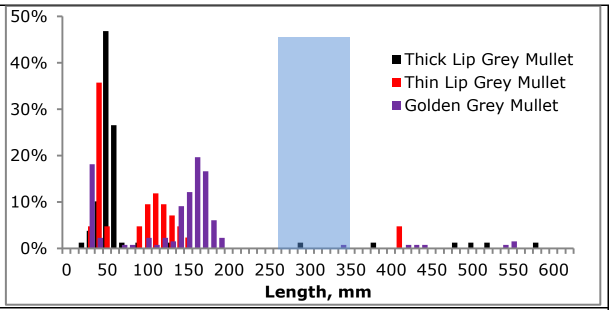
Size frequency histograms from EA WFD data – Grey Mullet

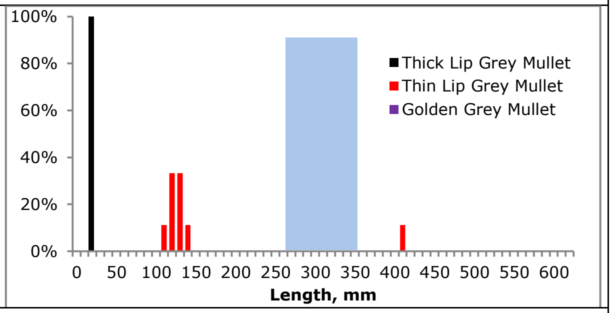
Note that there are three species of grey mullet which have been recorded in the EA WFD surveys – Thick Lipped Grey Mullet (*Chelon labrosus*), Thin Lipped Grey Mullet (*Liza ramada*) and Golden Grey Mullet (*Liza aurata*). The species are considered together for the following reasons –

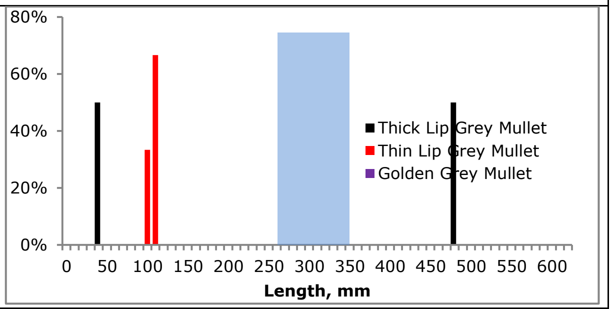
- There is not discrimination between the species within commercial catch records.
- The recreational sea angling community in general does not usually distinguish between the species.
- The general public often do not discriminate between the species.
- The species share many traits of ecology, habitat and life cycle.
- The individual species are found in low abundance, so consideration individually would not show a coherent picture.

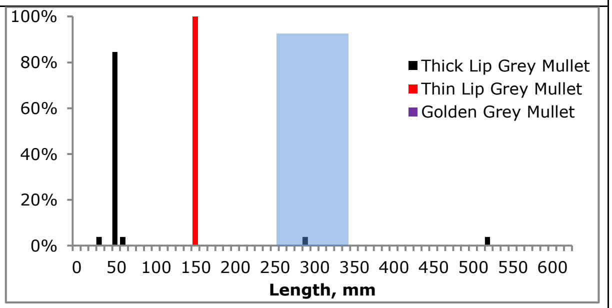
On the size frequency histograms below, the shaded blue area is intended to graphically portray the range of sizes within which sexual maturity would be expected to occur for these species (275 – 350 mm, with males at the lower end of the range and females at the upper end. It should be noted that the size at which grey mullet reach sexual maturity varies with the water temperature where this very widely distributed species lives – in warmer waters sexual maturity is reached at lower sizes, within our area approaching the northern limit for the species fish are larger before becoming mature. (2011 "*The Aquaculture of Grey Mullets*", edited by Oren E.H., quoting several sources, Cambridge Press International Biological Programme Synthesis Series).

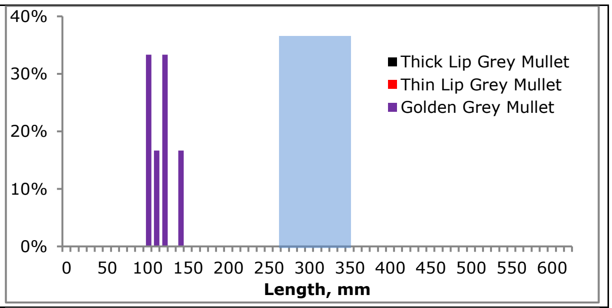
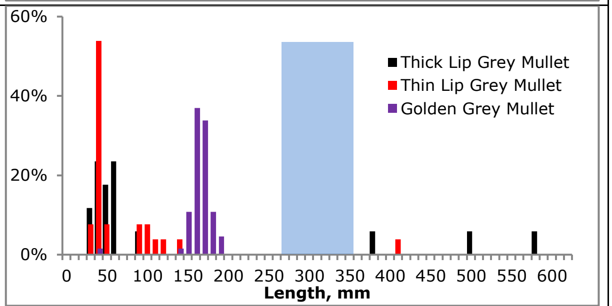
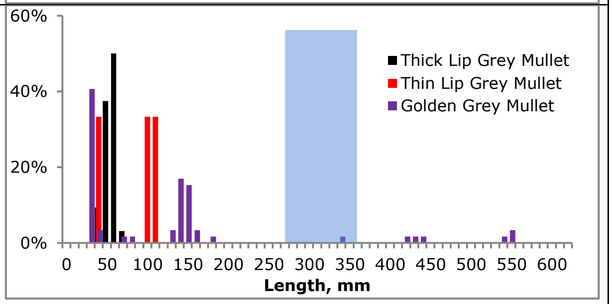


<table>
<tr><td>Overall all areas combined 2006 – 2013 inc
N = Thick Lip 80; Thin Lip 43; Golden Grey 291, total grey mullet = 414</td><td>
</td></tr>
<tr><td>Humber Upper</td><td>None measured</td></tr>
<tr><td>Humber Mid 2006 – 2013 inc
N = Thick Lip 0; Thin Lip 0; Golden Grey 2, total grey mullet = 2</td><td>Two Golden Grey Mullet measured, lengths 100 mm & 120 mm.</td></tr>
<tr><td>Humber Lower</td><td>None measured</td></tr>
<tr><td>Wash</td><td>None measured</td></tr>
<tr><td>Ouse 2006 – 2013 inc

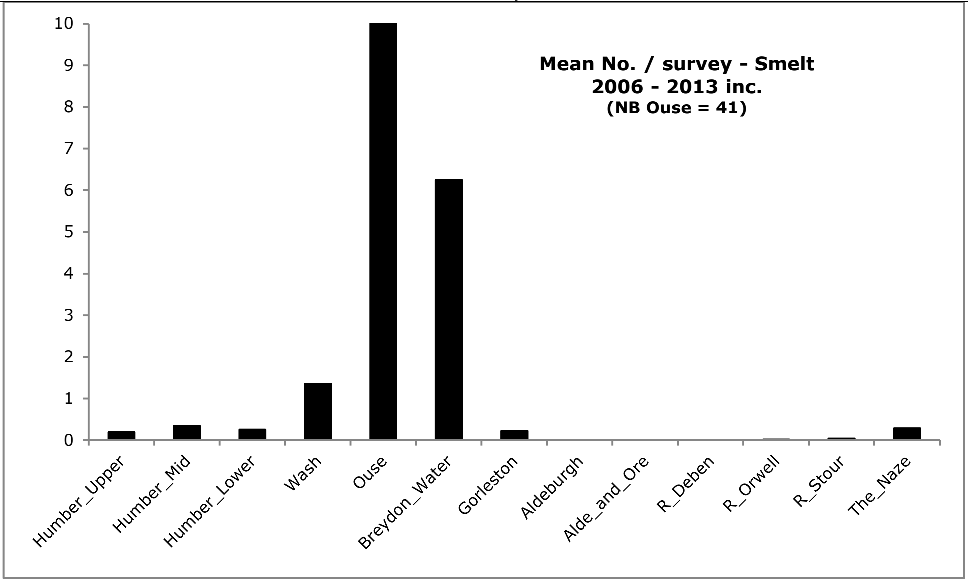
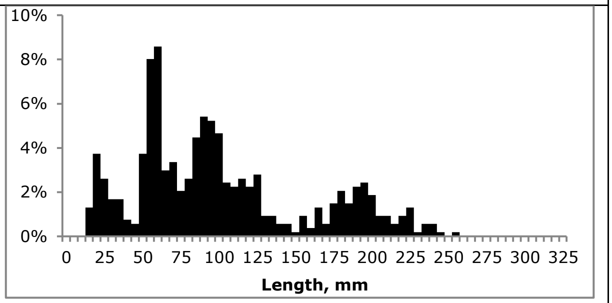
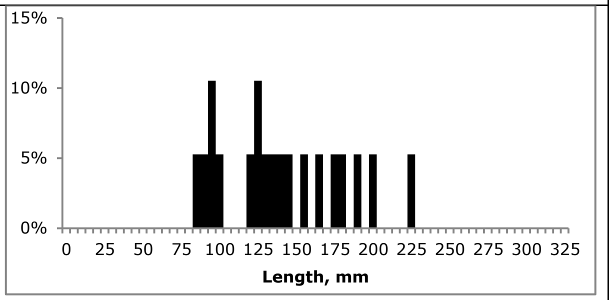
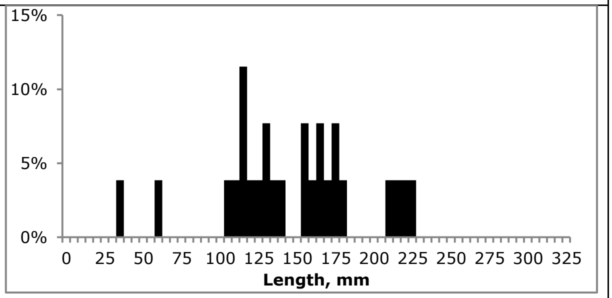
N = Thick Lip 1; Thin Lip 10; Golden Grey 0, total grey mullet = 11</td><td>
</td></tr>
<tr><td>Breydon Water 2006 – 2013 inc
N = Thick Lip 1; Thin Lip 0; Golden Grey 0, total grey mullet = 1</td><td>One Thick Lip Grey Mullet measured, length 130 mm.</td></tr>
<tr><td>Gorleston 2006 – 2013 inc

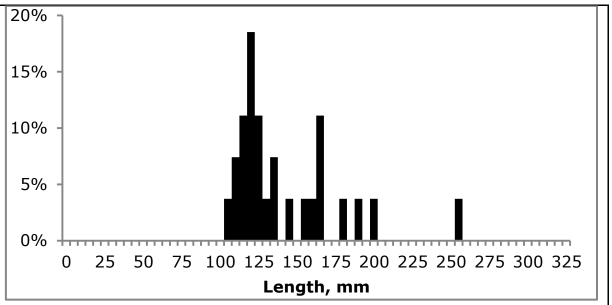
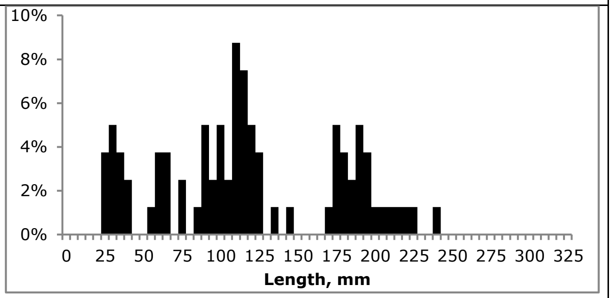
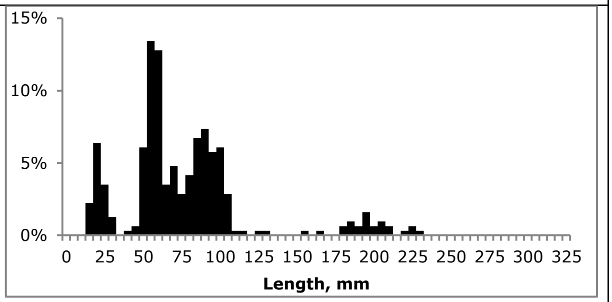
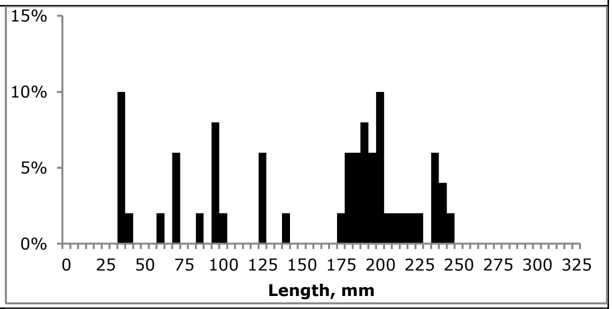
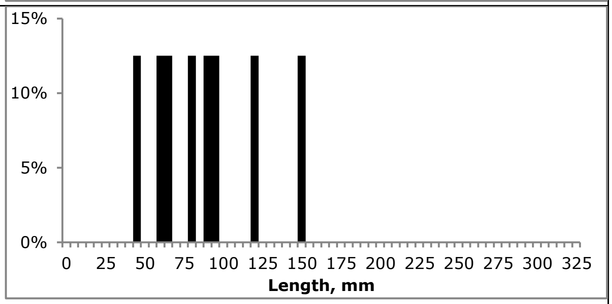
N = Thick Lip 2; Thin Lip 3; Golden Grey 0, total grey mullet = 5</td><td>
</td></tr>
<tr><td>Aldeburgh</td><td>None measured</td></tr>
<tr><td>Alde & Ore 2006 – 2013 inc

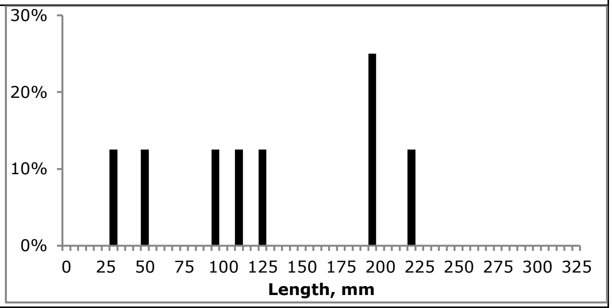
N = Thick Lip 26; Thin Lip 1; Golden Grey 0, total grey mullet = 27</td><td>
</td></tr>
</table>

River Deben 2006 – 2013 inc N = Thick Lip 0; Thin Lip 0; Golden Grey 6, total grey mullet = 6	
River Orwell 2006 – 2013 inc N = Thick Lip 18; Thin Lip 26; Golden Grey 224, total grey mullet = 268	
River Stour 2006 – 2013 inc N = Thick Lip 32; Thin Lip 3; Golden Grey 59, total grey mullet = 94	
The Naze	None measured

Size frequency histograms from EA WFD data - Smelt

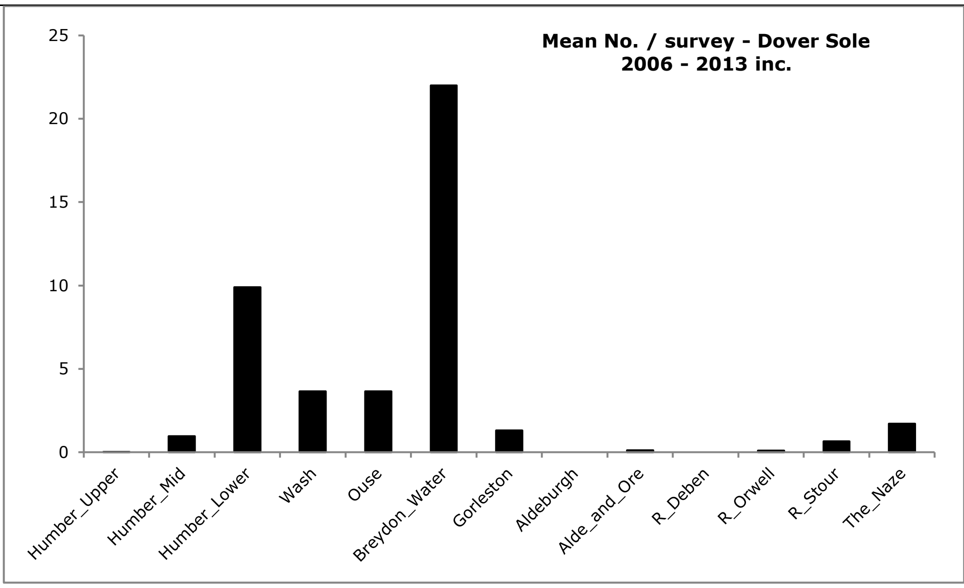
NOTE – The mean number of smelt recorded per survey is much higher for area Ouse (41 / survey) than for any other area. This high result is due to two very high survey catches, both on 10 September 2008, when one survey caught 884 smelt, and a further survey the same day 597 smelt. The third survey carried out that day at the same location ("South of Kings Lynn") recorded a catch of 6 smelt. These results were queried with the EA, to determine if there had been any error of recording or transcription. The EA confirm that the result is valid as far as they can determine.	
	
Overall all areas combined 2006 – 2013 inc, Smelt N = 536	
Humber Upper 2006 – 2013 inc, Smelt N = 19	
Humber Mid 2006 – 2013 inc, Smelt N = 26	

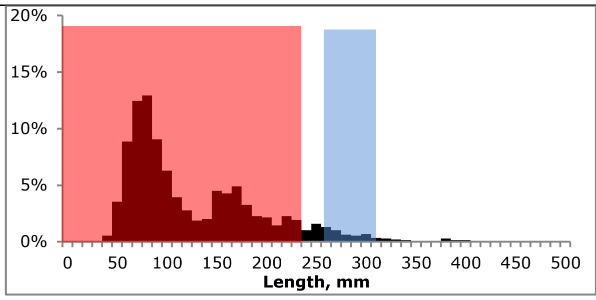
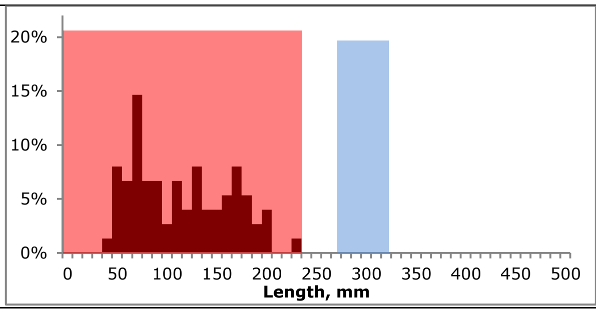
Humber Lower 2006 – 2013 inc, Smelt N = 27	
Wash 2006 – 2013 inc, Smelt N = 80	
Ouse 2006 – 2013 inc, Smelt N = 313	
Breydon Water 2006 – 2013 inc, Smelt N = 50	
Gorleston 2006 – 2013 inc, Smelt N = 8	
Aldeburgh	None measured
Alde & Ore	None measured
River Deben	None measured

River Orwell 2006 – 2013 inc, Smelt N = 3	Three measured, 65 mm, 115 mm & 125 mm length.
River Stour 2006 – 2013 inc, Smelt N = 8	
The Naze 2006 – 2013 inc, Smelt N = 2	Two measured, 170 mm & 225 mm length.

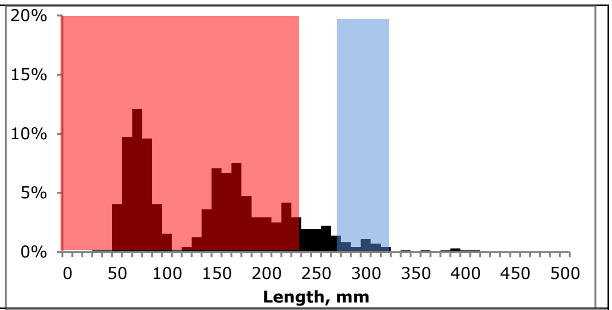
Size frequency histograms from EA WFD data - Sole

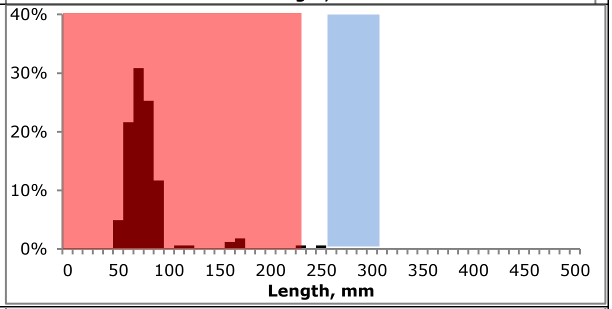
On the size frequency histograms below, shaded pink area is intended to portray those specimens below the minimum landing size for Dover Sole in the Eastern IFCA district (240 mm) and the shaded blue area the size range at which Dover Sole become sexually mature (250 - 350 mm, with males maturing at a smaller size than females). (Blue Ocean website (http://blueocean.org/documents/2012/03/sole-dover-atlantic-ocean-full-species-report.pdf)).

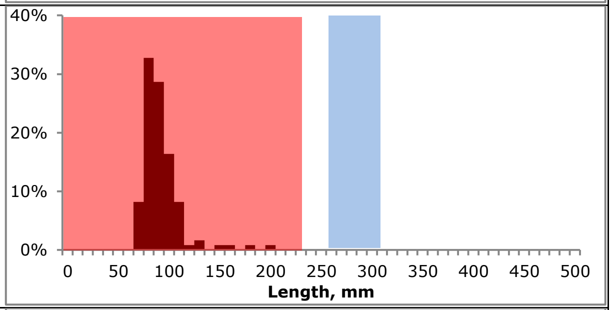


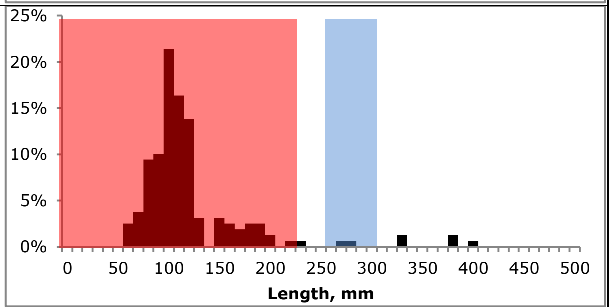
Overall all areas combined 2006 – 2013 inc, Sole N = 1445	
Humber Upper 2006 – 2013 inc, Sole N = 2	Two only recorded, 50 & 100 mm.
Humber Mid 2006 – 2013 inc, Sole N = 75	

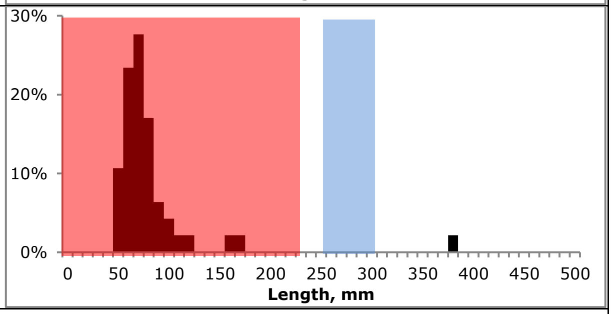
<table>
<tr><td>Humber Lower 2006 – 2013 inc, Sole

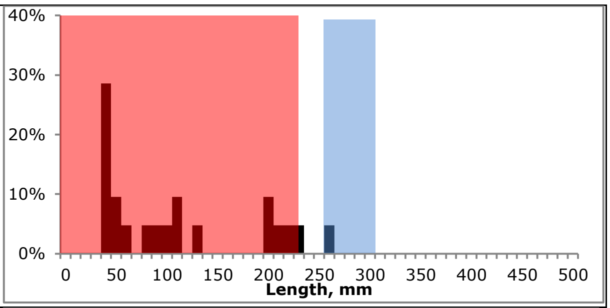
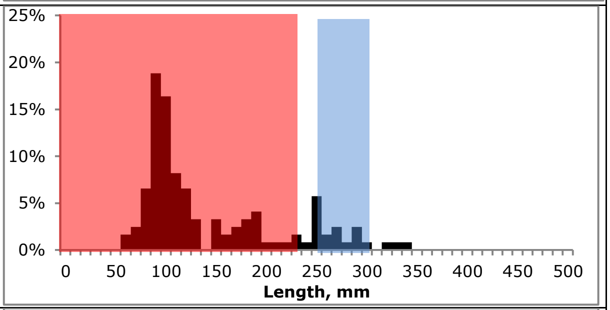
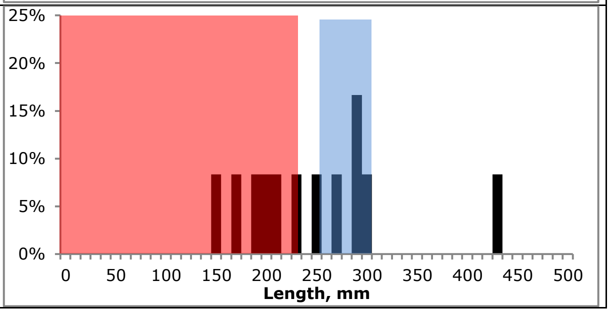
N = 720</td><td>
</td></tr>
<tr><td>Wash 2006 – 2013 inc, Sole

N = 162</td><td>
</td></tr>
<tr><td>Ouse 2006 – 2013 inc, Sole

N = 122</td><td>
</td></tr>
<tr><td>Breydon Water 2006 – 2013 inc, Sole

N = 159</td><td>
</td></tr>
<tr><td>Gorleston 2006 – 2013 inc, Sole

N = 47</td><td>
</td></tr>
<tr><td>Aldeburgh</td><td>None measured</td></tr>
<tr><td>Alde & Ore 2006 – 2013 inc, Sole
N = 3</td><td>Three only measured, 110, 120 & 280 mm.</td></tr>
<tr><td>River Deben</td><td>None measured</td></tr>
</table>

River Orwell 2006 – 2013 inc, Sole N = 21	
River Stour 2006 – 2013 inc, Sole N = 122	
The Naze 2006 – 2013 inc, Sole N = 12	

5.6 Examination of data from fish sampled at Sizewell Nuclear Power Station intake screens

Data within this section is extracted from the dataset supplied to Eastern IFCA following a request to the operators of Sizewell Power Station (EDF). The data requested was extracted from a much larger dataset held by CEFAS Lowestoft.

NOTE THAT fish lengths within this section are given as Standard Lengths (SL), rather than as Total Length (TL) as for other datasets within this report. Total Length is also used for measurement of minimum landing sizes, where applicable. A relationship between SL and TL for Bass was identified, which indicates that the Minimum Landing Size within EIFCA district of 36 cm (TL) is equivalent to a standard length of 31.5 cm. (But see note of caution in the Bass graphs section, (47)).

Relationships between SL & TL for other species have not been determined at this time.

Acknowledgements

I would like to thank CEFAS for allowing EIFCA to have access to this extremely useful data, and in particular to Dr. Sarah Walmsley for her endeavours in extracting the relevant information, and for assistance in interpreting the data.

The Sizewell nuclear power station complex is located on the Suffolk coast near Leiston. (Figure 44)

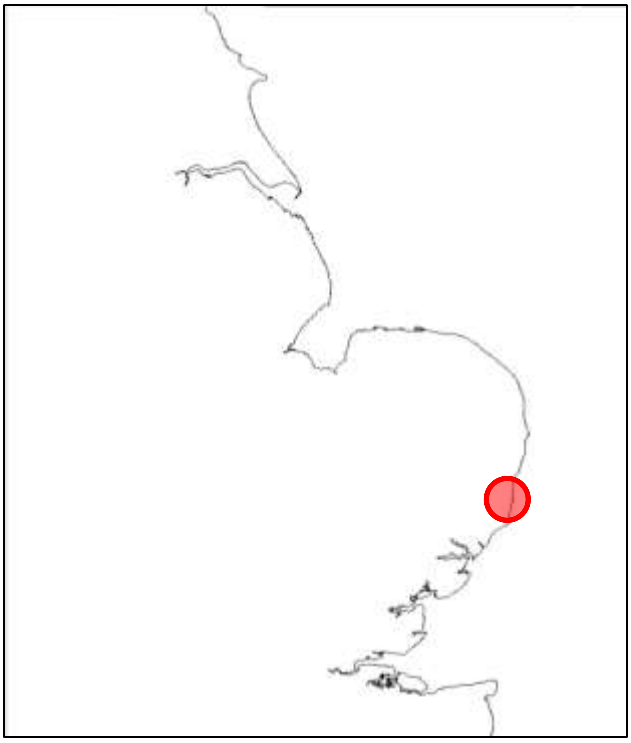


Figure 44 Location of Sizewell Power Plant on coastline of EIFCA district

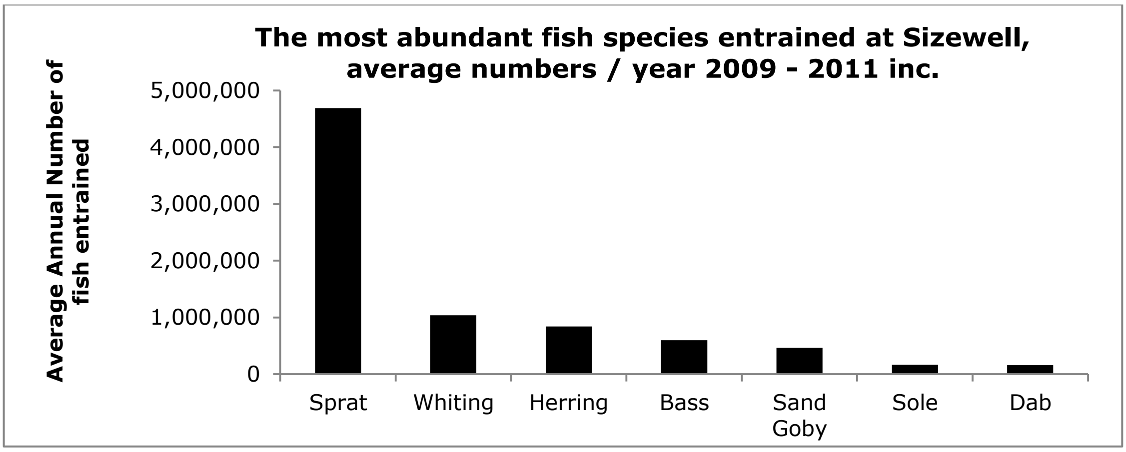
The site is a complex of stations rather than one plant. Sizewell A operated from 1966 to the end of 2006, when it was shut to be de-commissioned. Sizewell B has been operating since 1995, with a planned life until at least 2035, and the possibility to extend beyond that. Sizewell B is capable of supplying over 2.5 million homes - roughly the equivalent of the daily domestic needs of Suffolk and Norfolk, and just under 3% of the UK's entire electricity needs. The operators (EDF) plan to build a further plant, Sizewell C.

For cooling, the plant uses seawater taken from inlets in the nearshore region and used in a single pass through the plant. The incoming seawater is screened (nominal 10 mm square mesh drum screens) to remove items which could potentially damage the power plant. This includes fish, as well as macroalgae and general trash. The removed material is washed off the screens and passed along a water filled channel to a point at which it is returned to the outflow seawater stream from the power plant.

A study on the potential impacts on fish stocks in the locality was conducted when the Sizewell B reactor was commissioned. ("*An assessment of the effect of the Sizewell power stations on fish populations*" Turnpenny A.W.H. & Taylor C. Hydroecol. Appl. (2000) Tome 12 Vol. 1-2, pp. 87 – 134, accessible via {http://www.hydroecologie.org/articles/hydro/abs/2000/01/hydro00103/hydro00103.html}). This paper contains considerable detail on the total impact of the power station on local fish stocks.

CEFAS Lowestoft have for some years been monitoring the fish entrained on the intake screens at Sizewell powers station. There has been a hiatus in this data collection over the last year or so, but CEFAS hope to re-start the data acquisition programme in the future. The analysis below is based on data extracted from a dataset kindly supplied by CEFAS.

Of the total of 66 fish species recorded, whether assessed by numbers or biomass the most abundant seven species make up at least 95% of the fish entrained (Figure 45). There are differences in order of species in these rankings, and a slight difference in species in each, caused by differences in average weight of individuals of the species.



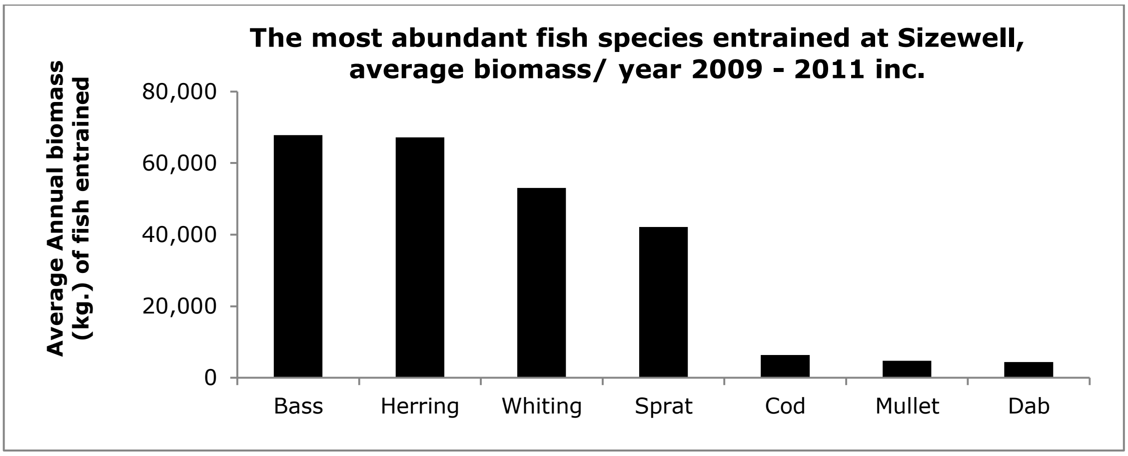


Figure 45 Most abundant fish species by number (top) and biomass (bottom) within fish entrained at Sizewell screens 2009 – 2011 inc.

Turnpenny & Taylor assessed the predicted survival for some species of fish on passage through the intake water pipe, collection on the intake screens and return to the sea via the dedicated system which had been put in place for Reactor B. The results are as in Table 8.

Species	**% survival**
Bass	89%
Dab	80%
Flounder	100%
Grey Mullet	Not tested
Smelt	Not tested
Sole	96%

Cod	94%
Whiting	48%
Sprat	0%
Herring	0%
Shrimp	94%

Table 8 Survival rates recorded for various species on passage through simulation of the screening system at Sizewell B powers station. From Turnpenny & Taylor (2000)

Combining the predicted survival rates from Table 8 with the data on total biomass of each species entrained allows estimation of the likely total mortality of various species over the course of a year (Figure 46). Note that the upper graph of this figure shows the species with the highest anticipated mortalities; for the lower graph the Y axis scale has been expanded and the highest values of mortalities omitted for ease of visualisation.

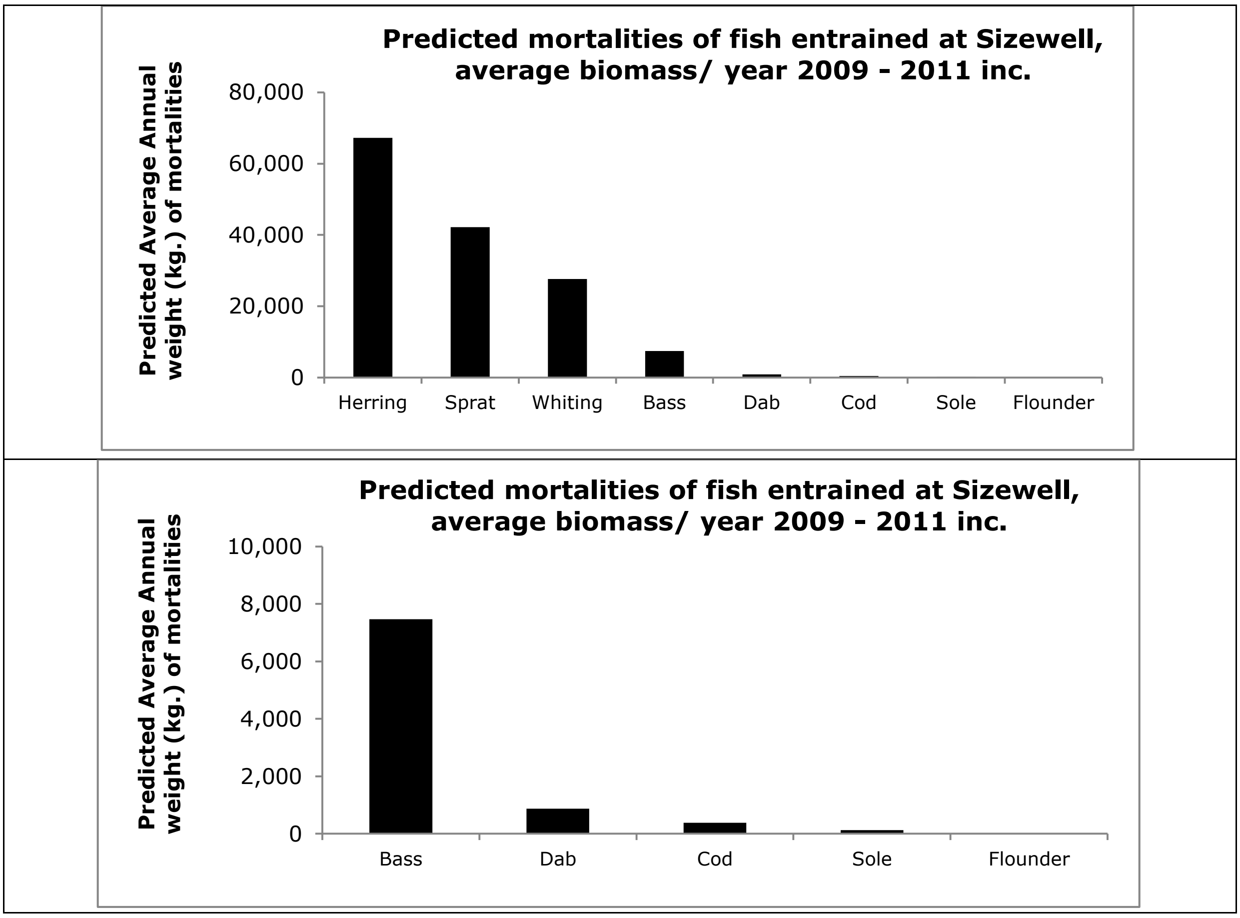


Figure 46 Ranked predicted mortalities for fish species entrained at Sizewell screens 2009 – 2011 inc. NB Note Expanded Y axis of lower graph.

Turnpenny & Taylor also examined the effect of the Sizewell power station on eggs and planktonic larvae of fish, concluding that there was no reasonable cause for concern on this score.

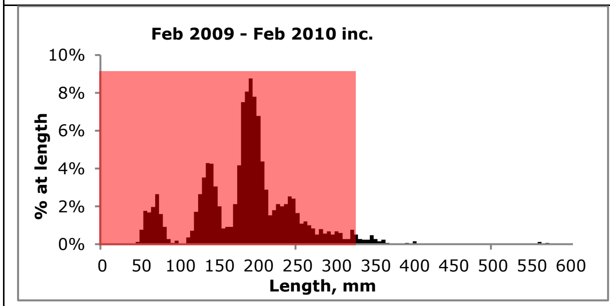
For the species of principal interest to the current project, and analysis of the length profile of fish entrained has been undertaken. Resultant graphs are presented below.

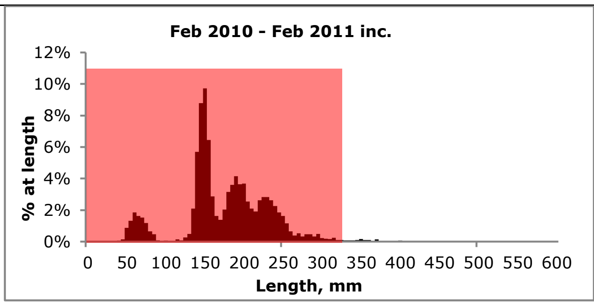
In all cases, there are length profile graphs for each of the years 2009, 2010 and 2011 for which data was supplied (small graphs in the upper part of each species table). Below, there is a line chart of the average number of each species of fish daily entrained on the intake screens during each month of the same time period. The set of graphs for Bass (Figure 47) contains some additional graphs – an overall length profile for the period 2009 – 2011 inclusive, and a line chart of the average biomass of bass daily entrained on the intake screens during each month of the same years. In addition there is marked on the Bass graphs an indication of the equivalent minimum landing size for the species.

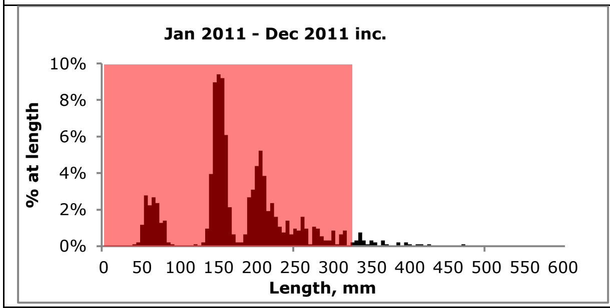
Graphs are presented for Bass (Figure 47), Dab (Figure 48), Flounder (Figure 49) Thin Lipped Grey Mullet (the only grey mullet species present in any numbers (Figure 50), Smelt (Figure 51) and Sole (Figure 52).

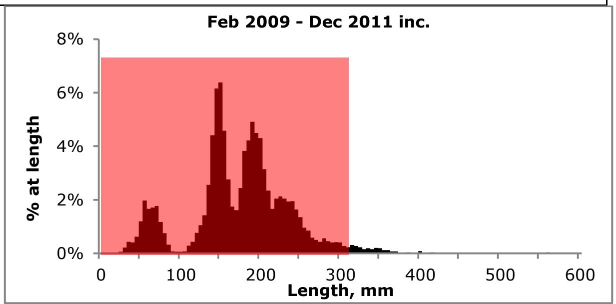
Bass

In the graphs below, the shaded pink area is intended to portray graphically the SL of 315 mm, equivalent the minimum landing size for Bass within the Eastern IFCA district (360 mm TL). (Information on the relationship between SL & TL obtained from "*External morphology of European seabass (Dicentrarchus labrax) related to sexual dimorphism*" Coban D. et al, Turk J Zool 2011; 35(2): 255-263. This paper is accessible via {http://journals.tubitak.gov.tr/zoology/issues/zoo-11-35-2/zoo-35-2-11-0810-.pdf}). This study, and the relationship between SL & TL derived from it, must be treated with some caution, as the fish examined were from farmed, Mediterranean stocks, and there may be morphological differences to the wild North Sea bass population.

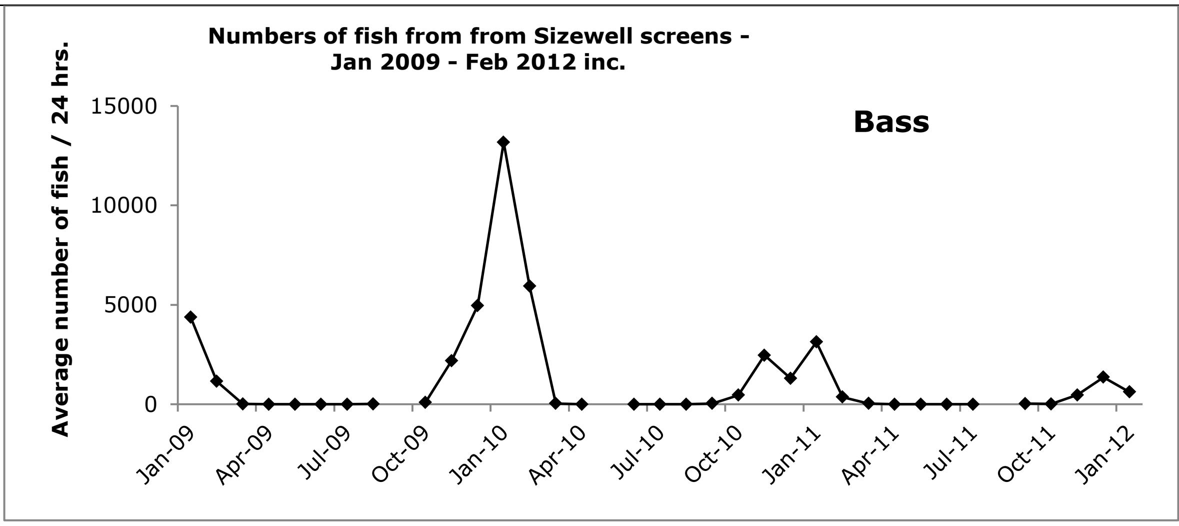


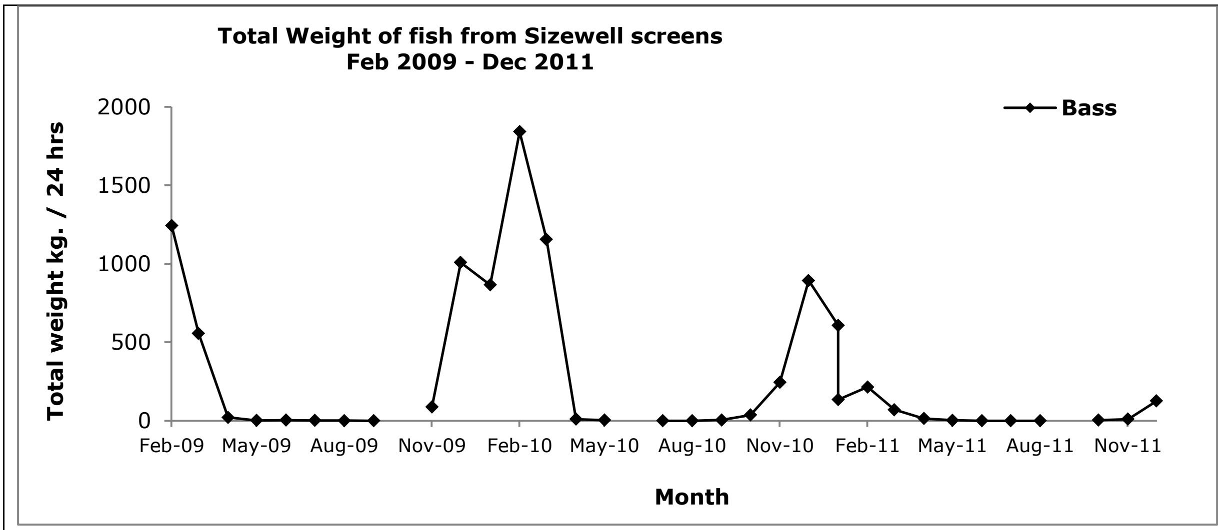






Length composition of Bass from Sizewell screens

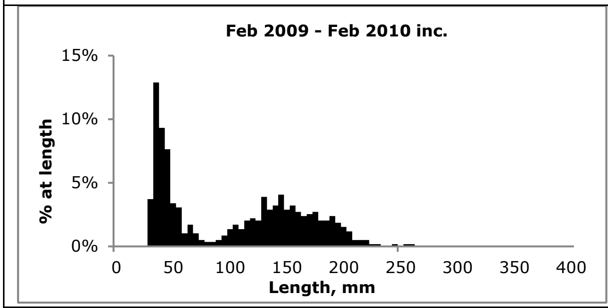


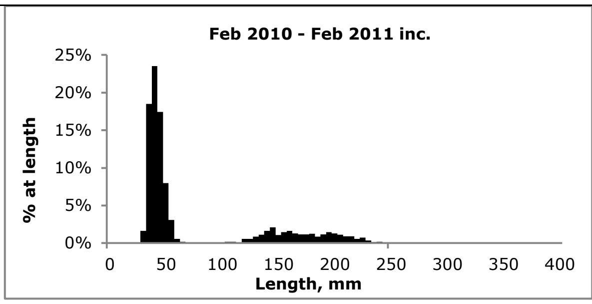


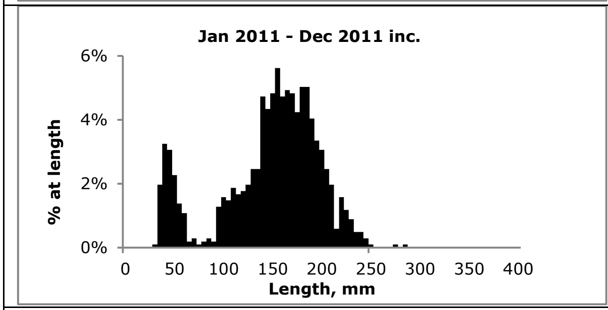
Total numbers (above) and biomass (below) of Bass from Sizewell screens February 2009 – January 2012 inc.

Figure 47 Length profile and numbers and weights per day for Bass entrained on Sizewell screens

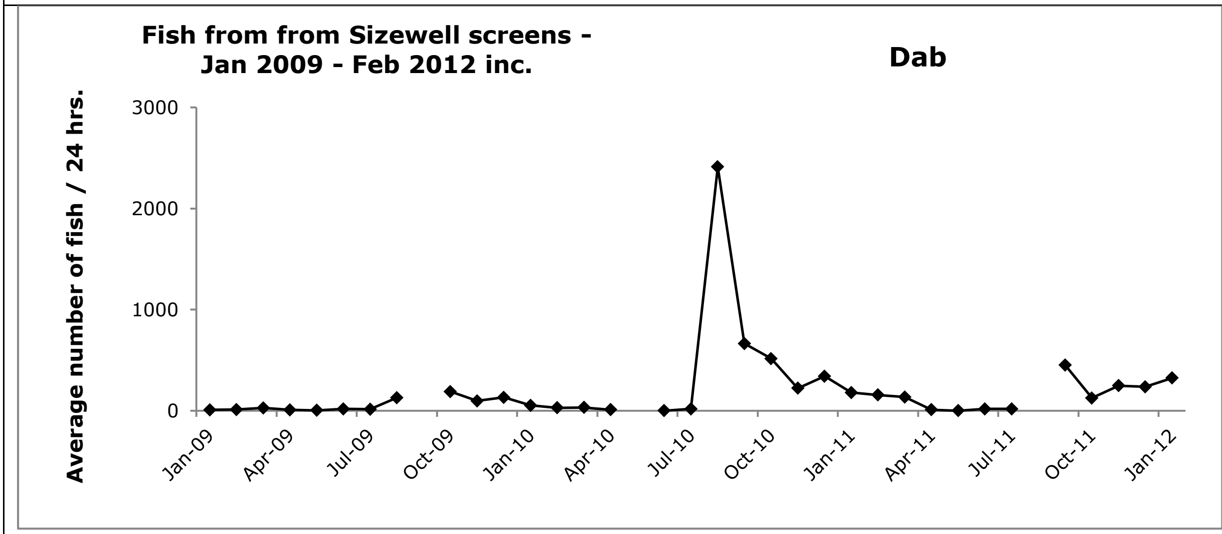
Dab







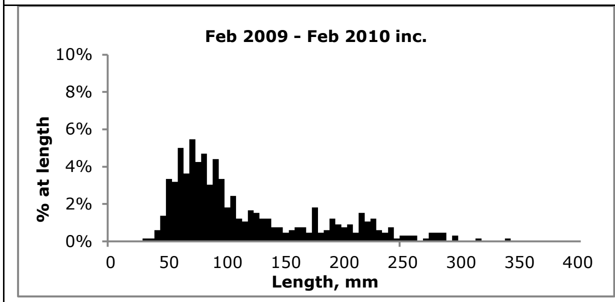
Length composition of Dab from Sizewell screens

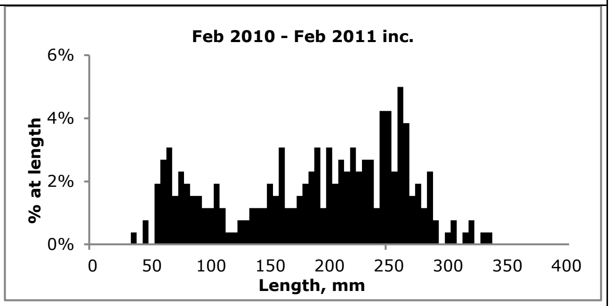


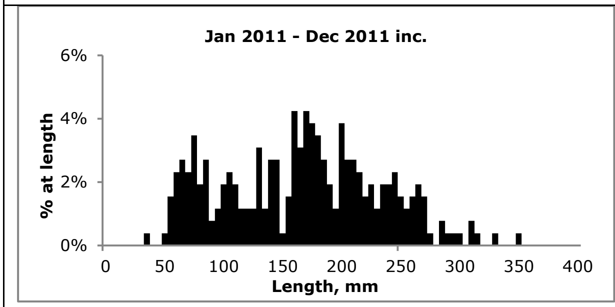
Total numbers of Dab from Sizewell screens February 2009 – January 2012 inc.

Figure 48 Length profile and numbers and weights per day for Dab entrained on Sizewell screens

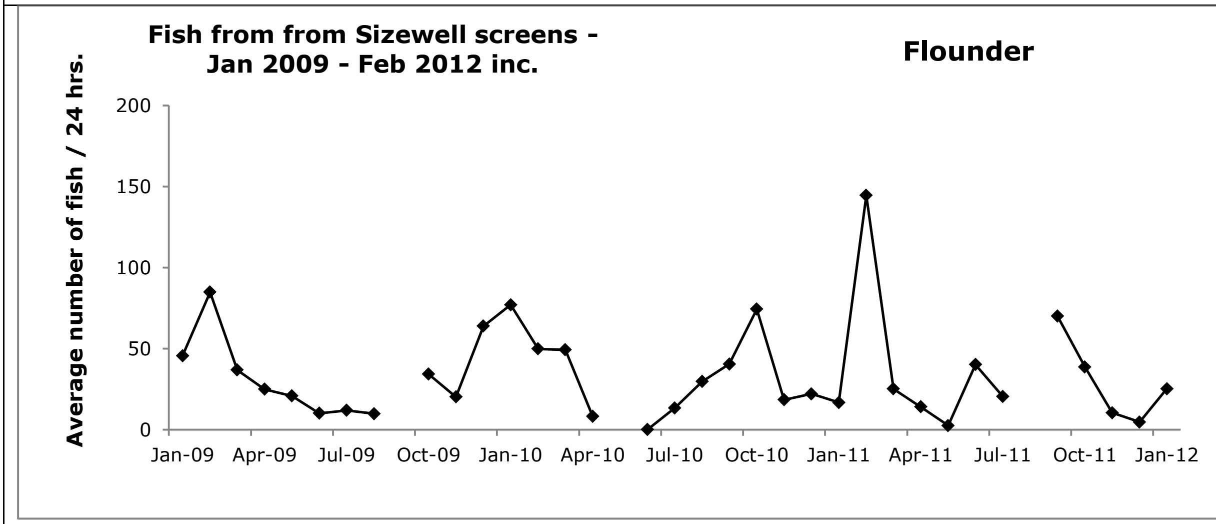
Flounder







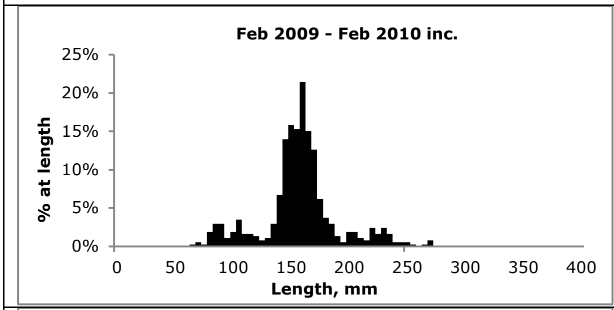
Length composition of Flounder from Sizewell screens

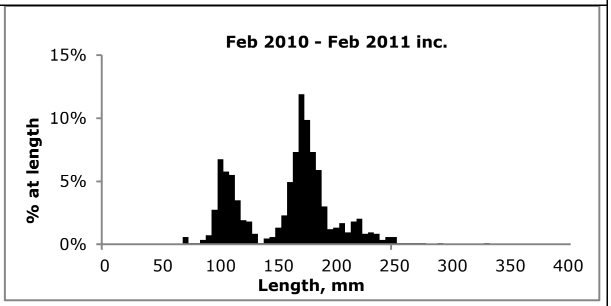


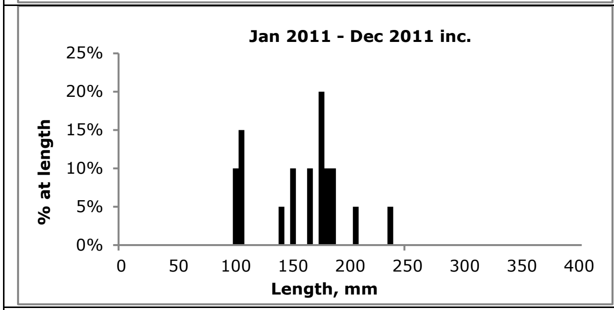
Total numbers of Flounder from Sizewell screens February 2009 – January 2012 inc.

Figure 49 Length profile and numbers and weights per day for Flounder entrained on Sizewell screens

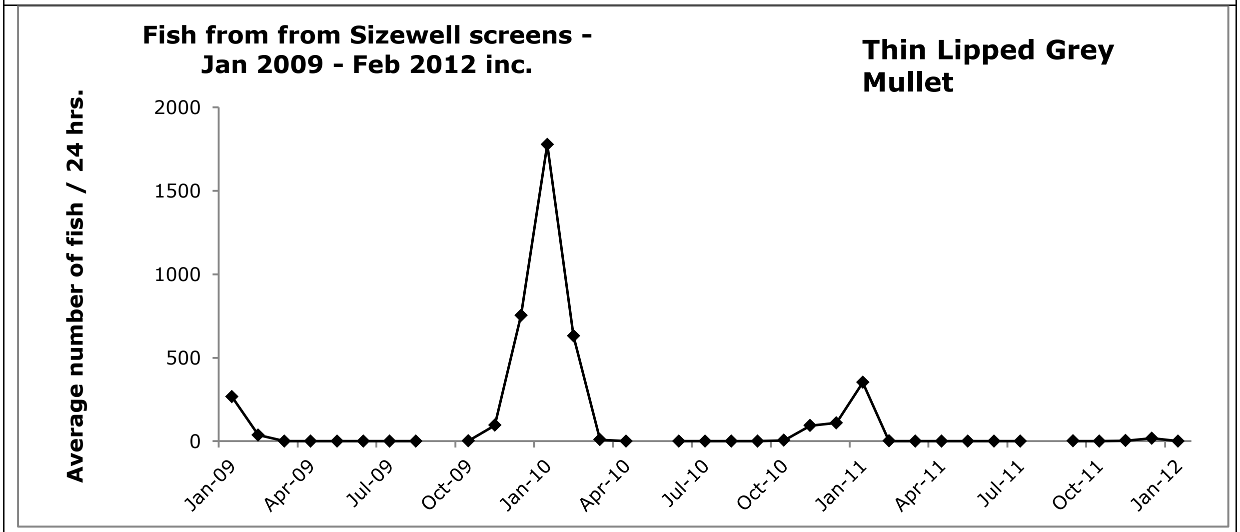
Thin Lipped Grey Mullet







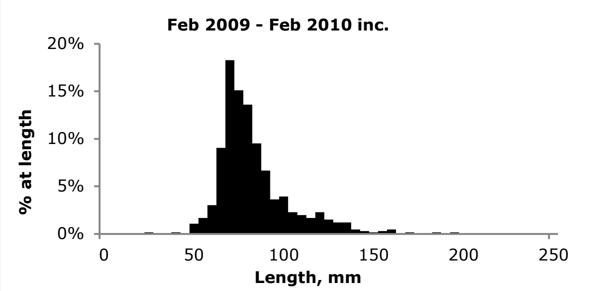
Length composition of Thin Lipped Grey Mullet from Sizewell screens

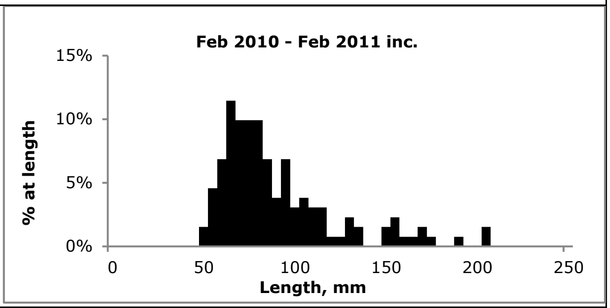


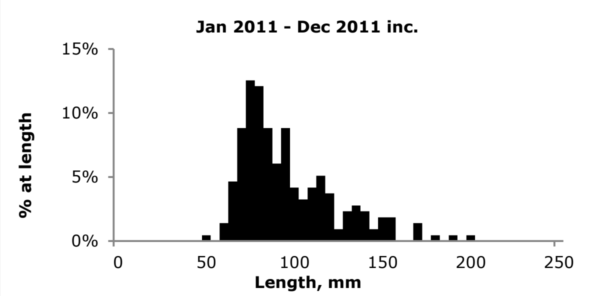
Total numbers of Thin Lipped Grey Mullet from Sizewell screens February 2009 – January 2012 inc.

Figure 50 Length profile and numbers and weights per day for Thin Lipped Grey Mullet entrained on Sizewell screens

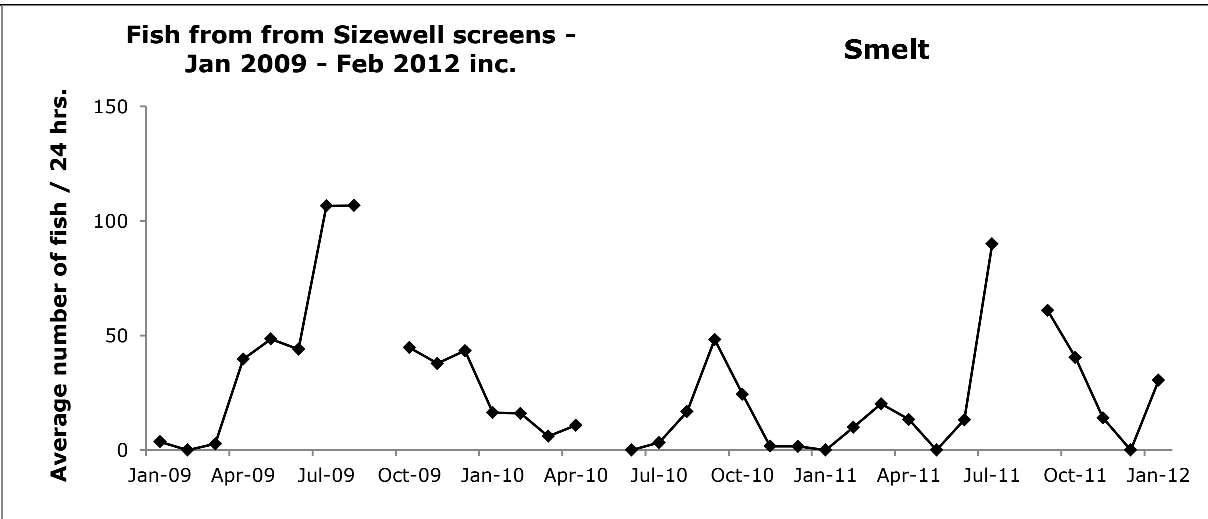
Smelt







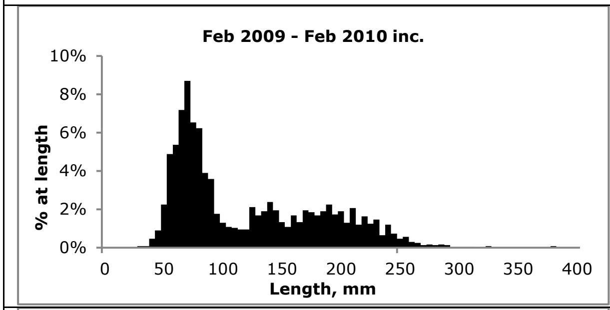
Length composition of Smelt from Sizewell screens

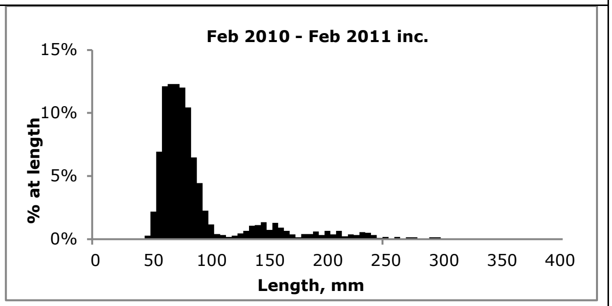


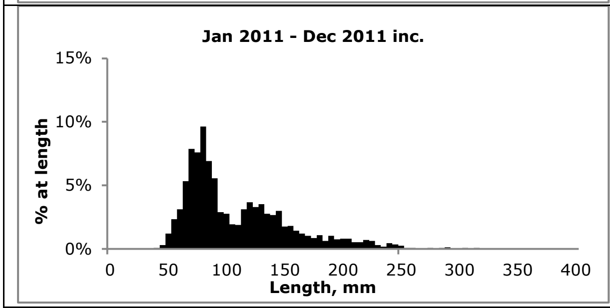
Total numbers of Smelt from Sizewell screens February 2009 – January 2012 inc.

Figure 51 Length profile and numbers and weights per day for Smelt entrained on Sizewell screens

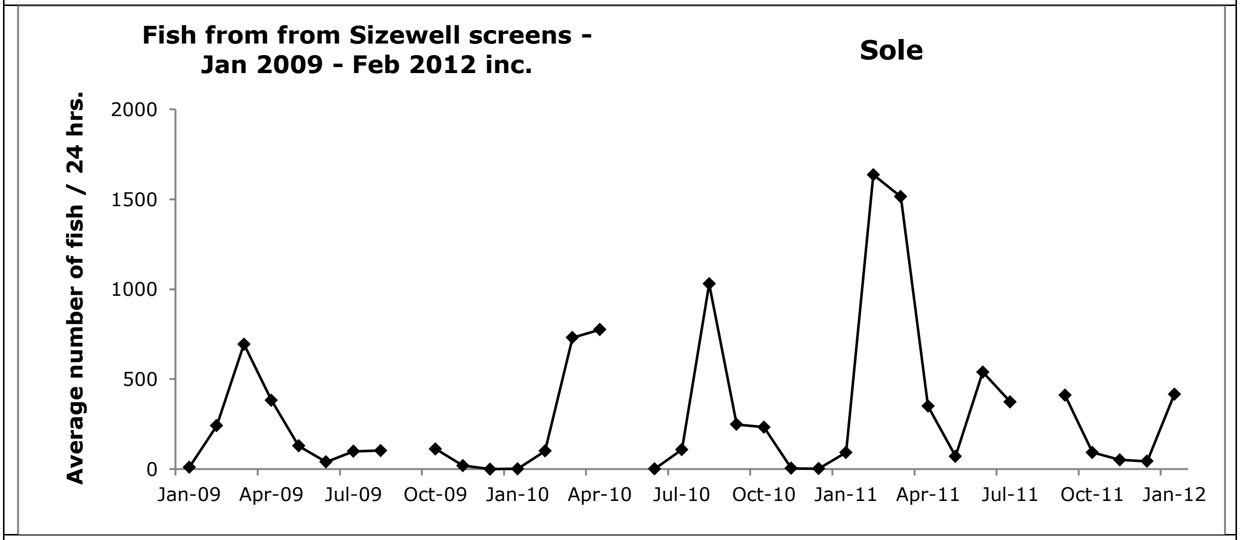
Sole







Length composition of Sole from Sizewell screens



Total numbers of Sole from Sizewell screens February 2009 – January 2012 inc.

Figure 52 Length profile and numbers and weights per day for Sole entrained on Sizewell screens

5.7 Species Summary Sheets

<u>Bass – *Dicentrarchus labrax*</u>

General biology

Mature bass aggregate in the Western English Channel to spawn, in early spring (February to May), with each female producing between 200 000 and 2000 000 eggs. As the water warms in spring, the focus of spawning moves along the English Channel, in general following the 9^{o}C isotherm. Timing and location of spawning is governed very much by water temperature, and slight changes in temperature regime can cause appreciable changes in the number and behaviour of bass populations. This is the case with much of the life cycle of bass, which is at or near the northern limit of its distribution in the North Sea. These spawning aggregations are the target of major fishing operations, principally by pair trawlers.

The eggs and larvae drift with currents into inshore nursery areas (estuaries, salt marsh areas, creeks, shallow bays etc.). The amount of fish surviving through this initial phase is variable, largely dependent on temperature and food availability. This has an impact on the ultimate recruitment of fish to the fishery (Jennings & Pawson 1992). The young fish stay in those areas for some three years, until a size of about 10 cm. At that size fish form into schools and move to deeper water areas to overwinter, returning to inshore areas and estuaries in summer. Older bass range widely between feeding areas and their offshore spawning sites. Tagging studies show that bass very often remain or return close to their point of initial capture, indicating that the fish return to a home range after making spawning migrations to areas where they mix with fish from other areas (Pawson et al 1987). This has implications for management – there is definitely an "our" population of bass.

Bass are opportunistic highly mobile predators, feeding on whichever prey item is most abundant and available in their environment at the time, including a wide range of worm, crustacean and fish species.

Spawning and nursery areas.

The CEFAS reports on spawning and nursery grounds of fish in UK water do not specifically identify Bass grounds, but there has been much work done which has identified the spawning grounds in the English Channel.

The distribution of bass recorded in the WFD dataset makes it clear that these are fish of the southern part of our district. This is very likely related to the temperature regime, in that the southern estuaries are warmer in the winter, due to the influx of water from the

English Channel. The fact that young bass stay in estuaries for some years means that they are susceptible to reduced temperatures in winter, and this fact (in addition to survival of very early life history stages) governs the level of recruitment into the fishery, making this susceptible to fluctuations in climate.

Management for sustainability of the nursery areas indicates management to conserve the habitat rather than specific stock management. Within the EIFCA area, the majority of the estuaries, and a high proportion of the shallow near shore areas, are covered by some form of MPA designation. It is likely that these designations will result in maintaining the habitat in such a state that the nursery function for bass will be maintained; however it should be borne in mind that those areas do have this function when considering plans and project.

In addition to considerations of protection of the small – up to 10 cm – bass found in estuaries, there is a requirement to manage bass once they have moved out into more open waters, but not yet become adults. These sub-adults – school bass – can be particularly vulnerable to over-exploitation when they congregate in defined areas. One such area within our district is in the vicinity of Sizewell power station. Data from fish entrained by the screening system there clearly indicates that there are – at least at certain times of the year – significant numbers of sub-adult bass there. In several other areas of the UK where there are known aggregations of sub-adult bass they are protected by designated "bass nursery areas", with varying degrees of restriction on activities.

The Fishery

Bass is a very important commercial species in EIFCA district. It has overtaken cod to become the second most valuable finfish, after sole. (see section on "Composition of Commercial Finfish catch" for more details). The Eastern IFCA region is at about the mid-point in ranked landings of sole for all IFCA regions (Figure 53).

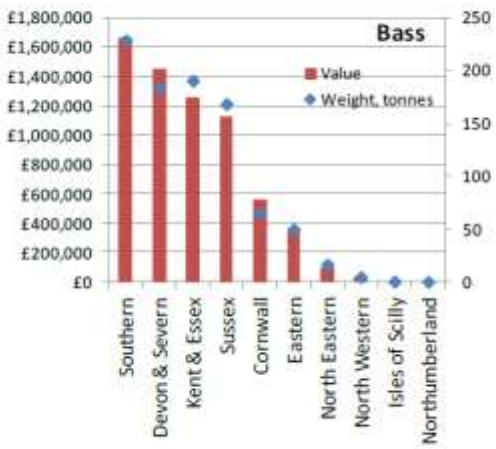


Figure 53 Landings of Bass by weight and value in 2010 by IFCA region. (Source – "Project Inshore")

Areas identified as bass grounds in the Eastern Joint Sea Fisheries Committee "Fish Mapping" project are shown in Figure 54.

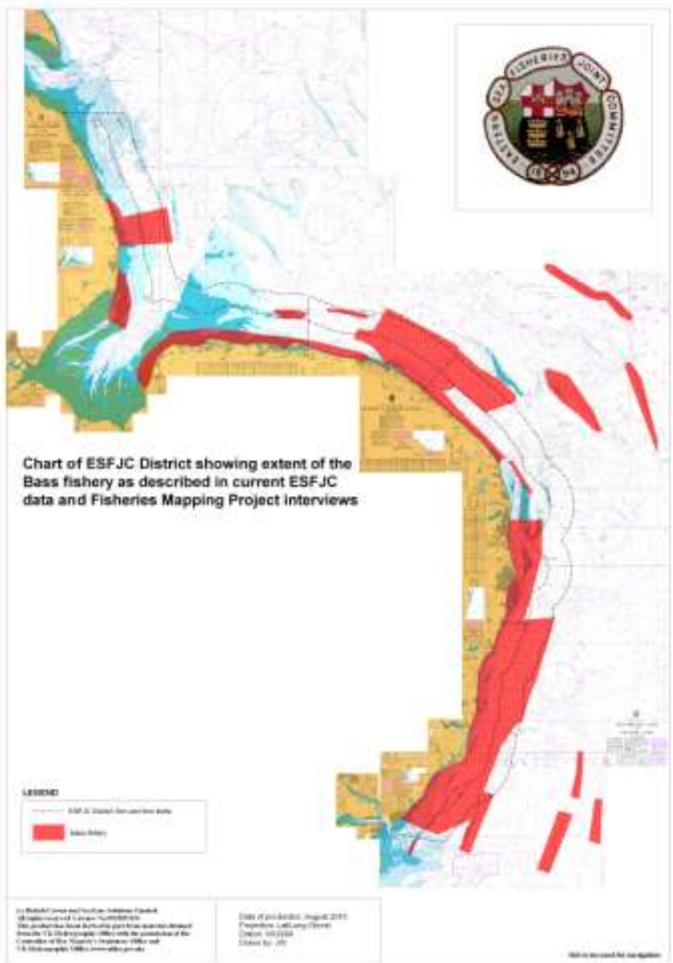


Figure 54 ESFJC "Fisheries Mapping Project" Extent of Bass fishery

There have been recent attempts to quantify the recreational sea angling catch of bass in England (Sea Angling 2012). These indicate a total catch in 2012 of some 380 - 690 tonnes, of which 230 – 440 tonnes were retained, the rest being released. The 2012 UK wide declared catch for bass to commercial vessels was 897 tonnes, so it is evident that the recreational catch for bass is at such a level that it must be taken into account in stock management.

ICES advice on Bass (June 2013) makes it clear that - although there are deficiencies in data – there are clear causes for concern. Landings and fishing mortality have been rising, and the total stock biomass falling. Recruitment to the fishery is down compared to recent years. Whilst the lower recruitment may well be due to climate conditions in recent years, there is no getting away from the fact that the fishery must be managed in the light of what is recruiting to the fishery now, rather than what has been recruiting in the past.

In the light of what data is available, ICES recommend a reduction of 20% (from 2013 levels) in landings in regions Irish Sea, Celtic Sea, English Channel, and southern North Sea, to no more than 2707 tonnes in 2014 (recorded landings 2012 from this stock was 4060 tonnes).

Importance as a Recreational Sea Angling target species

Bass are a species which attract a strong following of dedicated specialist anglers, and which arouse strong feelings in both the desire to fish for the species, and re-actions to perceived threat to the stocks. (e.g. Bass Anglers Sportfishing Society, http://www.ukbass.com/).

There is an oft expressed desire for "more and bigger bass". To a large extent, both the commercial sector and the recreational sector are looking to the same pot of fish as their resource. Balancing these pressures will present considerable challenges into the future.

Entrainment at Sizewell Power Station screens

Bass are one of the most abundant fish species entrained onto the Sizewell screens (4th both by number, 1st by biomass). On average, 600 000 bass / year can be expected to be entrained. (It must be noted that this figure includes a very high level of entrainment in February 2010. Without that result the average would be some 475 000 / year). Survival of bass on passage through the screening and return system was assessed at 89%, so it can be estimated that there are some 66 000 (52 250) mortalities anticipated from this source.

Examination of the size profile of fish from the Sizewell screens shows that there are several years classes of fish represented. On-going access to this data would allow us to assess the strength of year classes prior to them entering the fishery, and thus have a much better idea of likely bass stocks several years ahead.

It is evident that a lot of bass are entrained in the Sizewell screens. Whilst there are in place mitigation measures, and survival of these bass is assessed to be good on their return to the sea, it would be responsible to keep an eye on this. We should open dialogue with the operators of the Sizewell site (or CEFAS, if they take on board more detailed monitoring in the future).

Dab (*Limanda limanda*)

General biology

Male dab mature at 2 years of age, about 11 cm, females at 2 – 3 years, 14 cm. Mature fish aggregate in open sea to spawn between Jan and Sept, with peak spawning between Feb & April. Eggs are released into the water column, 50 000 – 150 000 per female.

After spawning fish move back into inshore waters, using tidal flow to assist. Dab potentially live to a maximum of 12 years of age, when they would be 40 cm long. The adults will eat almost any bottom living invertebrate they can catch, and larger ones will also opportunistically take small fish.

Juveniles move into inshore waters in summer, with 0 group fish usually found in 3 – 10 m. of water, 1 & 2 group in 10 – 15 m.

Dab avoid areas of very cold water (below about 3^{o}C) by migrating out of shallow waters in very cold conditions.

Spawning and nursery areas.

The CEFAS reports on spawning and nursery grounds of fish in UK water do not specifically identify Dab grounds.

It appears that much of the spawning of Dab in the North Sea is further offshore than our area, and may well be towards the South East rather than the South West of the North Sea. (Rijnsdorp et al 1992).

It is reasonable to assume that juvenile dab follow the same pattern of behaviour in our area as in the North Sea in general, in that they come into shallow water and estuaries as 0 group fish, moving further offshore as they grow. Data extracted from the WFD information confirms this, with the estuaries supporting small fish and The Wash a population containing both juveniles and adults.

Management for sustainability of the nursery areas indicates management to conserve the habitat rather than specific stock management. Within the EIFCA area, the majority of the estuaries, and a high proportion of the shallow near shore areas, are covered by some form of MPA designation. It is likely that these designations will result in maintaining the habitat in such a state that the nursery function for dab will be maintained; however it should be borne in mind that those areas do have this function when considering plans and project.

The Fishery

Dab is not a major commercial species in EIFCA district, ranking 14th by weight and 17th by value (out of 23 species of finfish for which we have data) for the period 2008 – 2012 inc. The Eastern IFCA region contributes relatively little to the overall UK dab landings (Figure 55).

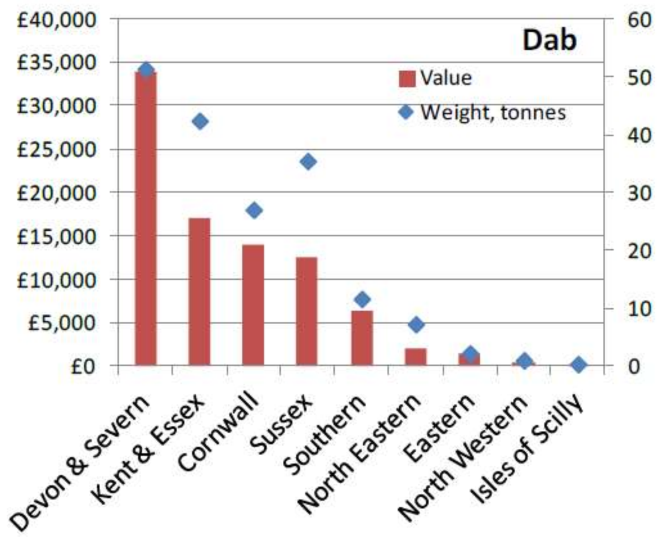


Figure 55 Landings of Dab by weight and value in 2010 by IFCA region. (Source – “Project Inshore”)

Nearshore areas in the vicinity of Gibraltar Point, and also south of Great Yarmouth, have been identified as dab grounds in the Eastern Joint Sea Fisheries Committee “Fish Mapping” project (Figure 56).

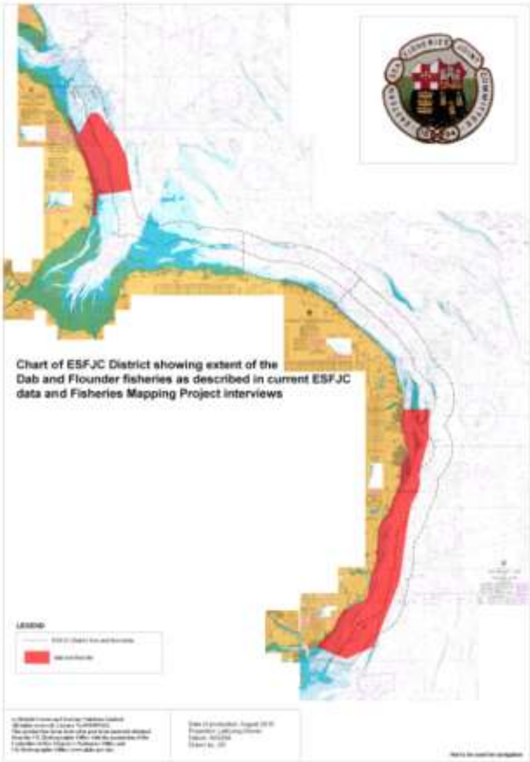


Figure 56 ESFJC “Fisheries Mapping Project” Extent of Dab & Flounder fishery

ICES data for dab is deficient, with an inability to estimate discards (although thought to be high, as dab is mainly a bycatch species). Similarly fishing mortality cannot be estimated. Total stock biomass is stable. ICES advice for 2014 / 15 for Area IV (The North Sea) is for maximum landings of no more than 7795 tonnes. Latest overall landings figure for area IV were 6673 tonnes, so it is thought that in the absence of any unforeseen sudden increase in fishing pressure there is no need to reduce catches.

Entrainment at Sizewell Power Station screens

Dab are one of the most abundant fish species entrained onto the Sizewell screens (7th both by number and biomass). On average, 70 000 dab / year can be expected to be entrained, with a mortality of 14 000 from this number.

Additional Items

“Green Dab”

A specific item of interest for Dab is the phenomenon of hyperpigmentation in dab – “Green Dab” – which results in unsightly areas of usually green pigment on the fish (Figure 57)

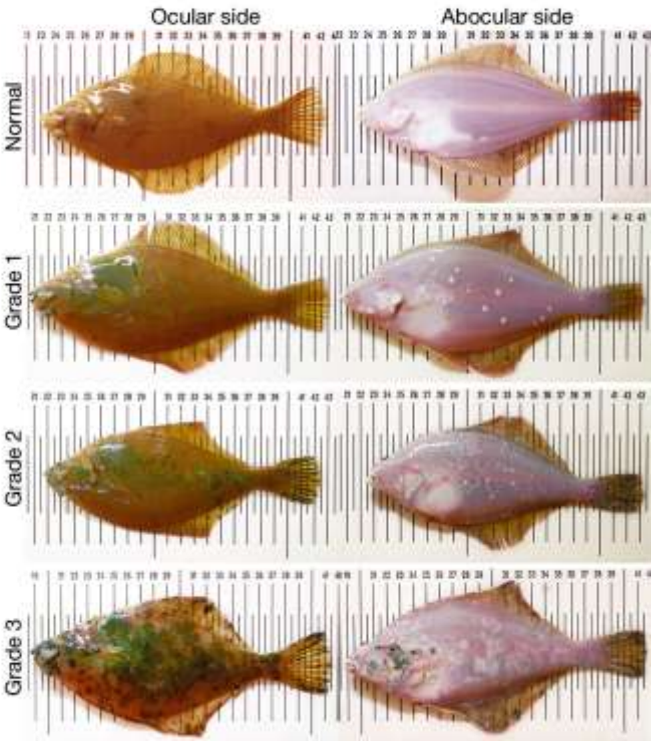


Figure 57 Examples of common dab representing hyperpigmentation grades 1, 2 and 3 (Source – Noguera et al 2013)

A major study on this phenomenon has been carried out by an international consortium of researchers (Grütjen et al 2013, Noguera et al 2013), coming to the following conclusions –

- The phenomenon has been noted in several flatfish species, but seems to be more prevalent in Dab.
- The phenomenon has been observed in the North Sea and adjacent areas, but is much more common in the North Sea than anywhere else at the moment.
- There has been no disease causing organism or agent discovered associated with the hyperpigmentation.
- The prevalence of hyperpigmentation is always higher in males than in females.
- The overall incidence of hyperpigmentation increases as the fish grow, with especially increasing incidence of the more "severe" grades with increasing body size.
- There are geographical variations, with prevalence being higher in the Dogger Bank and Firth of Forth areas than in other locations (Figure).
- Fish with hyperpigmentation showed a lower condition factor than fish without.
- It is not possible to ascribe a cause to this phenomenon; researchers considered that there are indications of the roots of the condition being at an early stage in the life history of the fish, possibly connected to nutrition or exposure to UV

radiation, themselves possibly linked to changing sea temperatures – either directly, or by affecting migration patterns.

- There may well be other, as yet unidentified cause or causes, such as some form of pollution.

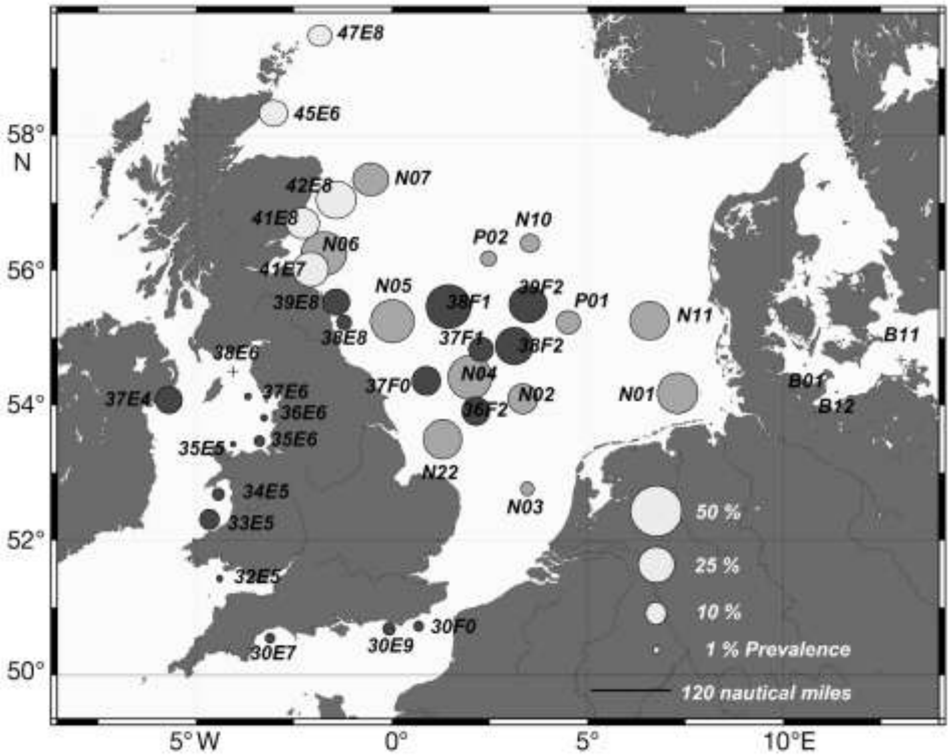


Figure 58 Mean prevalence of hyperpigmentation (indicated by size of the circles) in dab from the North Sea and adjacent waters in the time period 2002 to 2008, with prevalence of hyperpigmentation (%) as arithmetic means; all years, males and females and all size classes (>10 cm) combined. Scottish data: light grey; English data: dark grey; German data: medium grey. Source - Grütjen et al 2013)

It is evident that the examination was conducted on a large scale, with spatial resolution on a similarly large scale. In order to determine whether there are any more local effects, and therefore possibly pinpoint pollution sources, more tightly drawn spatial resolution is needed.

There may be an opportunity for the use of results from sea angling matches for this. Such an action would have the following benefits –

- Matches are held at known locations, and over small areas (one stretch of beach).
- It is possible to examine fish individually, and accurate records of size and numbers of fish are kept. This would allow for comparison of for example severity and prevalence from year to year and place to place.
- There are a range of such matches at various locations and times throughout the year.

- It would act as an early warning system should the phenomenon turn up in other species as well.
- There would be enhanced engagement with the recreational sea angling community, and the initiation of a "citizen science" project.

Such a project would require initial buy-in by those involved in organising the matches, followed by training for the marshals at the matches. I envisage that the data would be collected by those marshals, and interpreted by EIFCA staff before final results are returned to the RSA community.

Flounder (*Platichthys flesus*)

NB. The Eastern Joint Sea Fisheries Committee commissioned a literature review on Flounder from DJ Skeritt of Newcastle University, which was delivered in 2010. Entitled " A review of the European flounder *Platichthys flesus* - Biology, Life History and Trends in Population" this paper can be accessed via { http://www.eastern-ifca.gov.uk/repository/FlounderLitReviewDS.pdf}, and contains much useful expanded information.

General biology

Flounder are very much a fish of shallow waters, estuaries and even totally fresh water beyond the limit of saltwater influence (the only European flatfish to live in freshwater). They are usually found within 50 m. of the shoreline, and tend to follow the rising tide into inter-tidal areas.

Mature fish (males minimum 12 cm length, females 17 cm, 3 years old or more) leave these near-shore areas for deeper water in January and February, as a prelude to spawning there between March and June. Each female produces some 200 000 – 2000 000 eggs. After a planktonic period of about a month the larvae settle onto the seabed, seemingly preferring muddy areas to do so. Small juveniles use tidal transport to move to the upper reaches of estuaries, and then even move on into fresh water.

After spawning fish move back into inshore waters, using tidal flow to assist. Flounder potentially live to a maximum of 15 years of age, when they would be 60 cm long. Flounders are daytime feeding predators, preferring active prey to immobile. The fish are often feeding in the intertidal zone, and eat molluscs, worms and small crustaceans. Especially the larger flounders will also eat small fish.

Spawning and nursery areas.

The CEFAS reports on spawning and nursery grounds of fish in UK water do not specifically identify flounder grounds.

Both juvenile and adult flounder are predominantly fish of estuaries, with the smaller fish being found in the shallower areas, and moving to deeper water as they grow (although adults will still be found in water of only a few cm depth when they follow the tide in to feed.) The only time adults move out of these habitats is to spawn.

There is clear evidence of the distribution pattern of flounder within estuaries for the WFD data for The Humber, with only sub-adults being found in the upper estuary, some adults in the mid-section, and appreciably more in the lower Humber. Breydon Water WFD data clearly indicates the importance of such habitat for both juvenile and adult flounder, and indeed would seem to support a very high population of the species.

Management for sustainability of the nursery areas indicates management to conserve the habitat rather than specific stock management. Within the EIFCA area, the majority of the estuaries, and a high proportion of the shallow near shore areas, are covered by some form of MPA designation. It is likely that these designations will result in maintaining the habitat in such a state that the nursery function for flounder will be maintained; however it should be borne in mind that those areas do have this function when considering plans and project. It is especially important to bear in mind that flounder preferentially settle in muddy / silty conditions, which are therefore important for the species to be able to complete its lifecycle.

The Fishery

Flounder are not a major commercial species in EIFCA district, ranking 13th by weight and 15th by value (out of 23 species of finfish for which we have data) for the period 2008 – 2012 inc. The Eastern IFCA region contributes relatively little to the overall UK flounder landings (Figure 59).

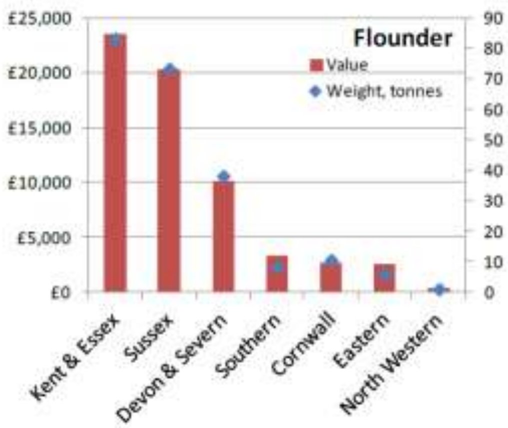


Figure 59 Landings of Flounder by weight and value in 2010 by IFCA region. (Source – "Project Inshore")

Near-shore areas in the vicinity of Gibraltar Point, and also south of Great Yarmouth, have been identified as flounder grounds in the Eastern Joint Sea Fisheries Committee "Fish Mapping" project (Figure 60).

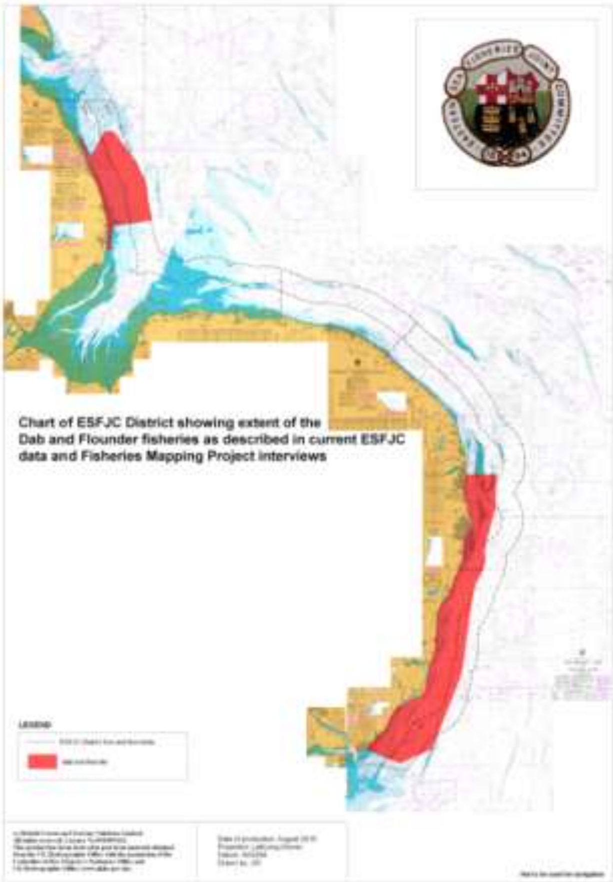


Figure 60 ESFJC "Fisheries Mapping Project" Extent of Dab & Flounder fishery

ICES data for flounder is deficient, with an inability to estimate discards. Similarly fishing mortality cannot be estimated. ICES advice for 2014 / 15 for Area IV (The North Sea) is for maximum landings of no more than 3160 tonnes.

Entrainment at Sizewell Power Station screens

Flounder are recorded as entrained onto the Sizewell screens, but not as one of the more abundant species. On average, 13 300 flounder / year can be expected to be entrained. In experimental testing it was discovered that flounder survive passage through the screening and return system extremely well, so no major mortality of flounder can be anticipated from this.

Additional Items

There has been concern expressed that large numbers of flounder are being taken from the estuaries of Suffolk (especially the Stour & Orwell) for use as pot bait, As such, the landings would not show in landings statistics, and there is seemingly a view that catches of flounder by leisure anglers have been depressed because of stock reduction.

Abundance data derived from the WFD dataset would not appear to support this. The catch / sample for these estuaries is in line with that for other estuaries in the same area, and part of the general trend for lower abundance in the south of our district compared to the north.

Grey Mullet –

Thick Lipped Grey Mullet (*Chelon labrosus*),

Thin Lipped Grey Mullet (*Liza ramada*)

Golden Grey Mullet (*Liza aurata*).

Although there are three distinct species of grey mullet found within our district, for many purposes the species are considered together. Landings data is combined for the species, and it is also possible to consider many aspects of their biology together, as they tend to behave in similar ways.

General biology

The biology of Grey Mullet in UK waters is not well known. It is known that they spawn in the English Channel and Irish Sea; however, the capture of small juveniles in WFD sampling of the Suffolk estuaries of the EIFCA district suggests additional nearer spawning sites.

Grey Mullet mature at about 3 years of age (very variable depending on where in their range – we are at the Northern limit of their distribution, so can expect late maturation), about 30 cm length. Spawning occurs in open water and after a planktonic larval phase of between two and six weeks the juvenile fish move into inshore areas, especially estuaries. Grey mullet can tolerate very much reduced salinity, and are often seen in brackish lagoons and at the head of estuaries. They rarely enter completely fresh water, but can do so at least for a short time.

Grey mullet grow to 70 cm length, at which size they are at least ten years old. These fish are predominantly grazers, feeding on very small – even microscopic – animals and plants, often by scraping the surface off mudflats, and eating the film of diatoms and other algae off surfaces. They are often quite visible at or near the surface, and the combination of large size, easy visibility and apparent ease of capture frustrates many anglers! (Apparent ease of capture only – due to their specialised diet they are usually very difficult to catch).

Spawning and nursery areas.

The CEFAS reports on spawning and nursery grounds of fish in UK water do not specifically identify Grey Mullet grounds.

The distribution of grey mullet recorded in the WFD dataset makes it clear that these are fish of the southern part of our district. This is very likely related to the temperature regime, in that the southern estuaries are warmer in the winter, due to the influx of water from the English Channel.

Management for sustainability of the nursery areas indicates management to conserve the habitat rather than specific stock management. Within the EIFCA area, the majority of the estuaries, and a high proportion of the shallow near shore areas, are covered by some form of MPA designation. It is likely that these designations will result in maintaining the habitat in such a state that the nursery function for grey mullet will be maintained; however it should be borne in mind that those areas do have this function when considering plans and project. In particular it is necessary to be aware of the need of the species for very small food items – animal or vegetal. Any action which potentially reduces the availability of these could have an impact on the viability of juvenile grey mullet in that habitat.

The Fishery

Grey mullet are not major commercial species in EIFCA district, ranking 15th by weight and 14th by value (out of 23 species of finfish for which we have data) for the period 2008 – 2012 inc. The Eastern IFCA region contributes relatively little to the overall UK grey mullet landings (Figure 61).

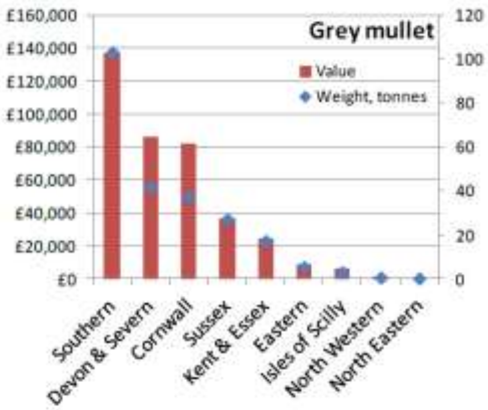


Figure 61 Landings of Grey Mullet by weight and value in 2010 by IFCA region. (Source – "Project Inshore")

However, in common with the UK as a whole, grey mullet landings have increased appreciably in recent years (Figure 62).

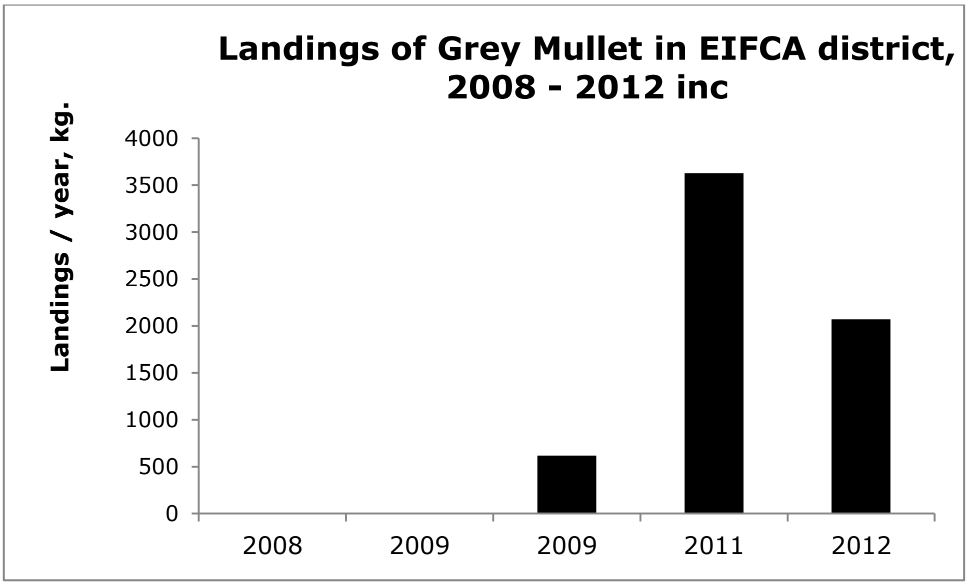


Figure 62 Annual landings of Grey Mullet in EIFCA district 2008 – 2012 inc.

Grey mullet are often the targeted species or bycatch for gill netting operations, from which it is sometimes challenging to collect accurate landings data. This could become an issue for managing the fishery should the indicated increase in pressure on stocks continue to increase. There is currently no minimum landing size for grey mullet within

EIFCA district. Whilst such would seem a sensible measure to take if the fishery develops, this action would need to be considered against the background of forthcoming adoption of "no discards" policies.

There is no ICES assessment of Grey Mullet stocks.

Entrainment at Sizewell Power Station screens

Grey Mullet are one of the most abundant fish species entrained onto the Sizewell screens (6th both by biomass). On average, 65 000 grey mullet / year – the vast majority being thin lipped grey mullet - can be expected to be entrained. Survival of grey mullet on passage through the screening and return system was not assessed, so it is not possible to estimate what level of mortality can be anticipated from this source. Such an assessment would be a very worthwhile action.

Smelt *Osmerus eperlanus*

NB –

The Smelt is a migratory fish, moving from the marine environment to freshwater to spawn. As such, it comes under the remit of the Environment Agency, who are responsible for issuing licenses to fish for the species, and collecting and collating catch return data.

Smelt are recognised as being good indicators of environmental quality, They are BAP (Biodiversity Action Plan) species, and a Focus for Conservation Importance (FOCI) species.

There has been a recent comprehensive review of all aspects of smelt biology, ecology, utilisation and – crucially – administrative and legislative status - "A Review of the status of Smelt *Osmerus eperlanus* (L.) in England and Wales – 2013", Colclough S. & Coates S. This contains far more information than can be presented here, and is recommended for further reading if more details are required. It can be accessed online at – {http://www.ifm.org.uk/sites/default/files/page/15.%20Smelt%20Steve%20Colclough.pdf}

General biology

Smelt are fish able to tolerate both salt and fresh water. They habitually live in estuaries and coastal waters, and make spawning runs to the tidal limits to spawn, usually in areas of clean gravel. Eggs are attached to a substrate – gravel, waterweeds, or a hard structure such as bridge or weir pilings. Larvae live in the estuary areas, where they are active predators. Small smelt feed on small crustaceans (zooplankton) and fish, the size of the prey item increasing as the smelt grow.

It is evident from information extracted from the WFD dataset that the estuaries in the middle of our district (especially the Ouse) are important for smelt. As the Environment Agency are responsible for the administration and regulation of any fishery for this species, our best contribution will be to liaise with and work through them. We should be aware of activities which may impact on the extent or composition of gravel beds and weed beds in the upper part of estuaries, and on the abundance or make up of smelt prey species such as copepods and small fish in estuaries and inshore waters in our district.

The Fishery

Smelt are no longer a major commercial target, although they have in the past supported very significant fisheries. Of the very limited fisheries occurring at present, an appreciable proportion take place within the EIFCA area. In 2011, 1926 kg of smelt (from a UK total of 3183 Kg.) and in 2012, 7793 kg (UK total 11 269 kg) came from waters broadly within the EIFCA district, although some were from fresh waters of the Norfolk Broads. In both years, the only other catches of smelt in the UK came from the Humber / Trent system.

There are no ICES proposals for stock management for smelt.

Smelt are not an angling target of any significance, but it is of interest that smelt are considered by pike fishermen to be one of the best pike dead-baits which can be obtained.

Entrainment at Sizewell Power Station screens

On average, 9 800 smelt / year can be expected to be entrained on the Sizewell screens. The rate of mortality of smelt passing through the screening / return system was not assessed, so it is not possible to estimate a likely mortality resulting from the entrainment.

Sole (*Solea solea*)

General biology

Sole mature at about 2.5 years of age, at a length of about 25 - 35 cm. Spawning peaks in May, triggered by rising water temperatures. Spawning occurs over well-defined spawning grounds, with fish returning to the same grounds year after year. It is not known if fish return to the same grounds as their parents used to spawn on. Females produce 100 000 – 350 000 eggs each. Sole can reach a maximum size of 70 cm, and an age of some 25 years.

Sole bury in soft sediment during the day, emerging at night to feed on worms, small crustaceans such as shrimps, and molluscs. They detect their food by smell and touch rather than by sight, and have sensory papillae on the underside of their heads to help in this.

After a planktonic phase of some 35 days sole settle on the seabed, in inshore shallow soft sediment areas, such as shallow seas and estuaries.

Very severe weather will cause sole to leave the shallower, colder areas to congregate in deeper water.

The CEFAS reports on spawning and nursery grounds of fish in UK water (Ellis et al 2012) identify important grounds for sole spawning and nursery functions within our area (Figure 63Figure).

Data extracted from the WFD information confirms that sole behave as expected within our district, with the estuaries supporting small, immature fish. Only the relatively open sea site of The Naze returned records of substantial proportions of sizeable fish. Breydon water and the lower Humber in particular are important nursery areas.

Management for sustainability of the nursery areas indicates management to conserve the habitat rather than specific stock management. Within the EIFCA area, the majority of the estuaries, and a high proportion of the shallow near shore areas, are covered by some form of MPA designation. It is likely that these designations will result in maintaining the habitat in such a state that the nursery function for sole will be maintained; however it should be borne in mind that those areas do have this function when considering plans and project.

Spawning and nursery areas.

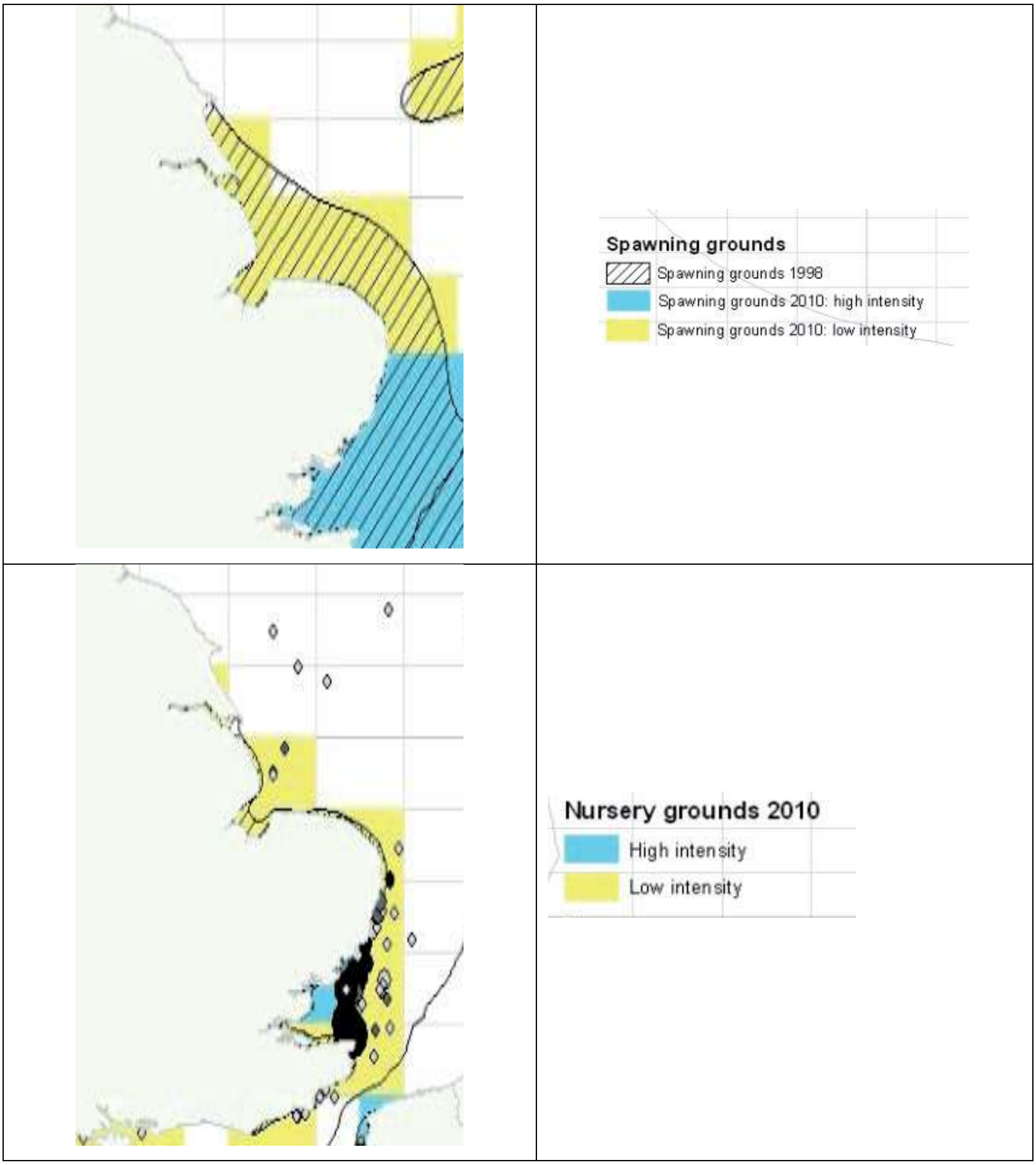


Figure 63 Sole spawning grounds (top) and nursery grounds (bottom) within Eastern IFCA district. Note that black areas within nursery grounds indicate particularly dense usage. Source – CEFAS report 147, 2012

The Fishery

Sole are subject to a minimum landing size in the EIFCA district of 24 cm – below the size at first maturity. The fishery for sole is not specifically targeted at fish on the spawning grounds, as indicated by the fact that catches are higher later in the year when the fish have already left the spawning grounds (Figure 64), but there are appreciable landings during the spawning period of April – June. It would be beneficial to understand better the numbers of fish in spawning condition being caught, especially in view of the fidelity which fish have to their spawning grounds – a mature sole about to spawn this year but which is removed before it can do so is a loss to the spawning stock not only for this year, but also for every year in the future.

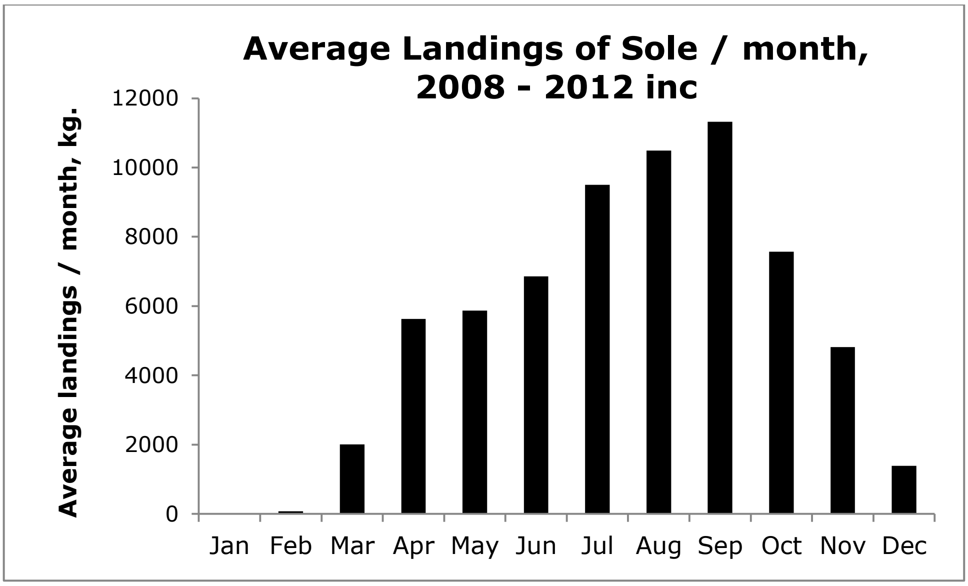


Figure 64 Average landings of sole / month across Eastern IFCA district, 2008 – 2012 inclusive.

Sole is a very important commercial species in EIFCA district, ranking top or very near top for value for the years 2008 – 2012 inc. (see section on "Composition of Commercial Finfish catch" for more details). The Eastern IFCA region is at about the mid-point in ranked landings of sole for all IFCA regions (Figure 65).

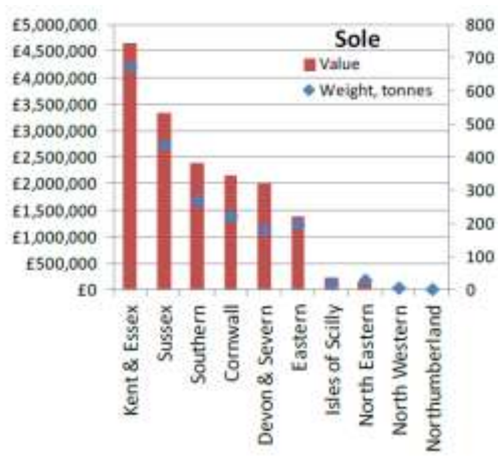


Figure 65 Landings of Sole by weight and value in 2010 by IFCA region. (Source – "Project Inshore")

Areas identified as sole grounds in the Eastern Joint Sea Fisheries Committee "Fish Mapping" project are shown in Figure 66.

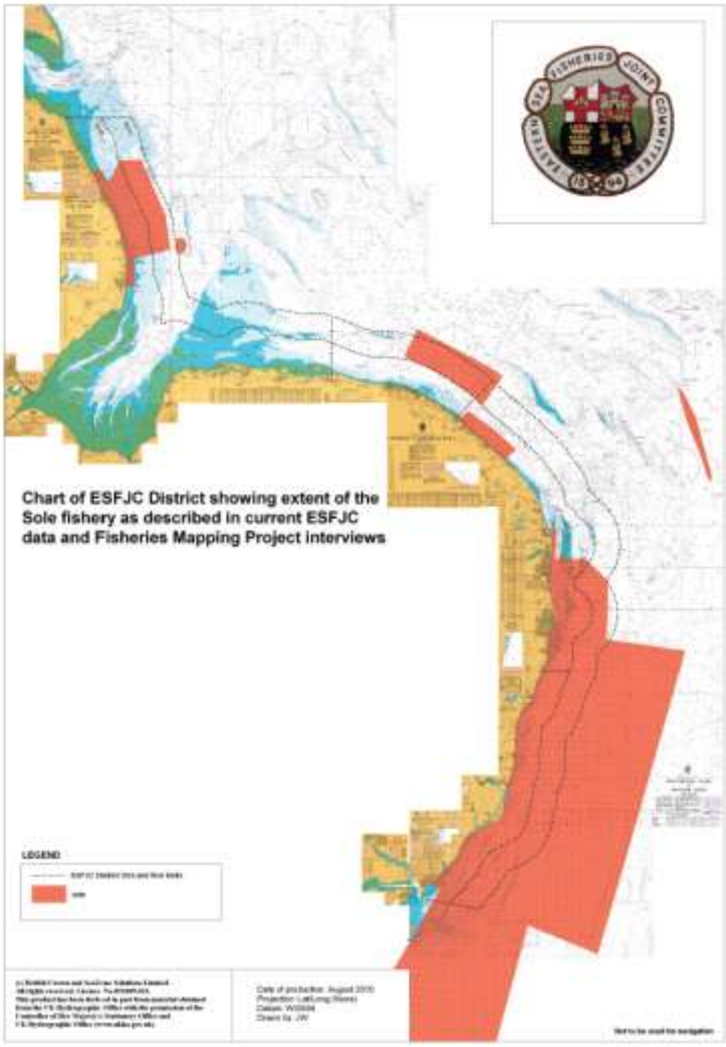


Figure 66 ESFJC "Fisheries Mapping Project" Extent of Sole fishery

The ICES assessment of the North Sea sole fishery is that current fishing mortality is above the optimal level, but not so high that insufficient young be produced to sustain the fishery. A TAC of 11 900 tonnes is proposed for 2014, down from 14 000 tonnes in 2013. In general, the North Sea stocks are considered to be "inside safe biological limits"

Entrainment at Sizewell Power Station screens

Sole are entrained onto the Sizewell screens in appreciable numbers (6th most abundant species by number). On average, 109 000 sole / year can be expected to be entrained, but as sole survive passage through the screens well a mortality of only some 4 400 would be anticipated.

6.0 ACOUSTIC SEABED SURVEYS

6.1 Introduction

Sabellaria spinulosa (Ross worm) is a colonial tube forming polychaete worm that occurs widely and commonly throughout UK shallow seas. It can be found intertidally (although rarely so within our area) as well as sublittorally. The worm lives in a tube which it builds from fine grained (sand or very fine gravel) sediment collected from the water column. These tubes when found together in large numbers form biogenic reefs which are more topologically complex than the open seabed, with many nooks and crannies. (Figure 6.1).

These complex reefs increase biodiversity in the area, and are therefore important ecological features. This has led to *Sabellaria* reefs being designated as a priority habitat under the UK's Biodiversity Action Plan (BAP); they have also been named as an interest feature of the Wash and North Norfolk Coast Marine Special Area of Conservation (SAC).

It should be noted that it is the reef features which are designated, rather than the species itself - there has been much discussion to what precisely constitutes a *Sabellaria* reef. As well as forming reefs, *Sabellaria spinulosa* is found being solitary or spreading laterally to form extensive thin crusts. Gubbay (2007) proposed criteria to determine whether *Sabellaria* was present in an area in the form of reef, and if so, whether low, medium or high reef. These criteria have been widely accepted and form the basis of management decisions.

Table 6.1 Reef scoring parameters suggested in Gubbay (2007)

Criteria	**Not Reef**	**Low**	**Medium**	**High**
Elevation (cm) (average tube height)	<2	2-5	5-10	>10
Sediment consolidation (% cover of sediment)	<5	5-10	10-30	>30
Area (m^2)	<25	25-10,000	10,000-1,000,000	>1,000,000
Patchiness (% cover within reef)	<10%	10-20	20-30	>30

Figure 6.1 General view (top) and close up (below) of *Sabellaria* forming a reef in The Wash. Unusually for this area, this particular reef is intertidal.

Sabellaria reefs are relatively fragile structures (although the tubes or fragments of them can persist in sediment for some time). They are vulnerable to damage by contact with mobile and static fishing gear, anchoring etc. Of particular concern within our district is the potential impact from beam trawl fishing for pink shrimp (*Pandalus montagui*), as this species tends to associate with *Sabellaria* reefs.

Eastern IFCA is currently finalising a flexible byelaw which will allow the closure of areas identified as in need of special protection – such as *Sabellaria* reefs – to potentially damaging fishing activities.

A recent report (Pearce et al 2011) did conclude that:

> "there is no statistically significant correlation between the density of *Sabellaria spinulosa* and the level of anthropogenic disturbance. The null hypothesis (*the density of Sabellaria spinulosa within the reef remains consistent regardless of the level of anthropogenic disturbance.*) can therefore be accepted."

but that report was based on deductive reasoning rather than experimental observation.

Side scan sonar

Eastern IFCA has recently acquired a side scan sonar system (Edgetech 4200, dual frequency 300 & 600 KHz.), together with software for acquiring sidescan data (Edgetech Discovery) and for processing the resulting images (Triton Perspective). The intent behind this acquisition was to enhance the ability to detect and define seabed habitats, both in terms of the capability to discriminate between different types of habitat, and the amount of seabed which can be surveyed within a given time.

Side scan sonar works by transmitting sound pulses laterally from a torpedo like "fish" towed behind the survey vessel, and receiving and interpreting the returning sound energy. The strength of the returning signal depends on the size, hardness, shape, orientation and reflectiveness to sound of the target. (see website identified in "Information sources" for a full explanation, which is beyond the scope of this report). A large object, with flat metal surfaces oriented perpendicular to the incoming sound pulse, and which is against a background of material of contrasting hardness, represents just about the easiest possible target to detect. This is of course a description of a shipwreck, and these do show up very well (Figure 6.2). On the other hand, small objects, with little contrast in hardness between themselves and the background, and random orientation, show up much less well. Unfortunately, this is a description of *Sabellaria*, and it is indeed very challenging to detect *Sabellaria* by side scan. It is possible to detect areas of seabed which produce returns indicative of the type of randomised seabed with weakly defined structure on a large scale, but with structure on a smaller scale. Providing this is in an area which would support *Sabellaria* (i.e. one where there is likely to be enough suspended sediment that the worms can build tubes, but not so much that they will be smothered), then the indications are that there is a high probability that there will be *Sabellaria* structure of some sort there. There is still a requirement to conduct ground truthing on a representative number of these indications in order to confirm the interpretation.

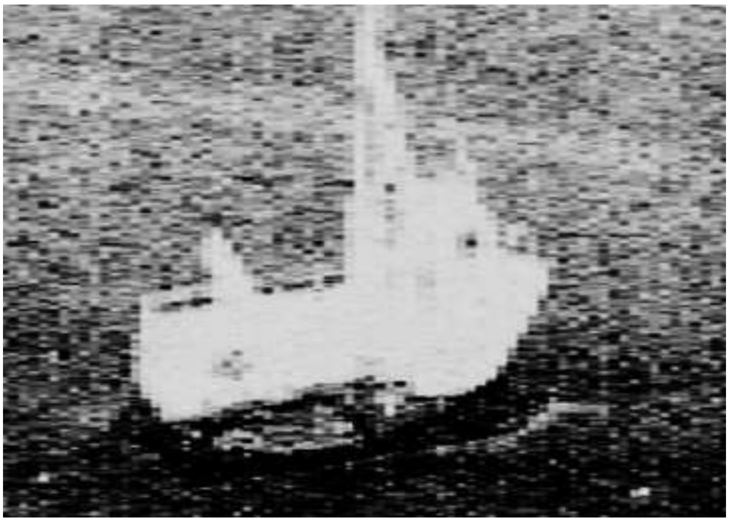


Figure 6.2 Wreck of former EJSFC research vessel "Surveyor", detected during EIFCA side scan survey.

6.2 Method

Side scan surveying involves the survey vessel steering as straight a course as possible through the survey area whilst "illuminating" (with sound) an area each side of the vessel. The process is repeated with a parallel course offset to the side which covers a different area of seabed, until as much of the seabed as has been determined in advance has been covered. The "towfish" which transmits and receives the sonar signal is trailed behind the vessel on a warp, with the signal being carried by a cable attached to the warp. It is necessary to keep the towfish within a specified range of altitudes above the seabed (in order that the sound beams "see" the seabed at the correct angle) and within a range of speeds over the ground (too fast and not enough of the sound pulses will hit each square metre of seabed to produce precise results, too slow and the survey will take an excessive amount of time).

The depth at which the towfish swims is regulated by the combination of the amount of warp paid out and the speed of the vessel through the water (the slower the speed the deeper the fish will swim). It is necessary to balance the factors of tidal flow, vessel speed and warp paid out in order to achieve the desired towfish altitude as the overall water depth varies. This is complicated by the fact that the processing software needs to know the "layback" (distance from the boats GPS sensor to the towfish position) in order to be able to calculate the exact position of the towfish, so that the individual tracks can be stitched together to form an overall mosaic. The layback can only be set once for each survey line, so it is not possible to pay out or recover towing warp during a survey line without upsetting the layback calculation.

A computer on board the vessel collects and stores the sonar data, and displays the resultant picture in real time (Figure 6.3).

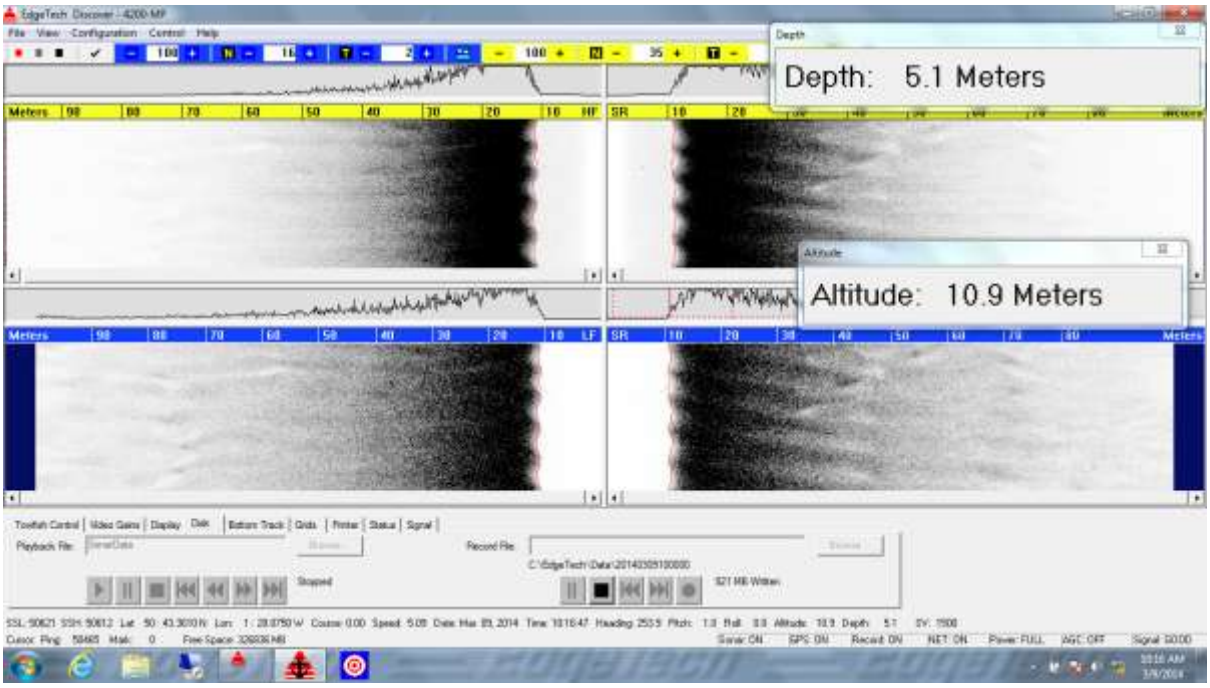


Figure 6.3 Side scan computer display during data capture

At this stage, there has been no processing of the data. It is possible to recognise large features, and get an indication of seabed type, but distances and shapes cannot be determined with accuracy.

There are limitations to the conditions in which it is possible to conduct these surveys – rough weather will move the vessel so much that the motion transmitted to the towfish via the warp will cause severe degradation of the sonar picture. It is not possible to survey in very shallow water (< 5m.) as the angle of the sonar beam is so low that insufficient seabed will be illuminated.

Following collection, the data is processed to achieve the following –

- Geo-referencing of the data, so that the finished plotted images will be in the correct location on charts. This requires calculation of the layback (distance along the direction of travel between the vessel GPS sensor and the towfish) and the lateral offset.

- Removal of the water column (the blank area in the centre of the image in Figure 6.3)
- Removal of the effect on the returned signal strength of distance from the towfish (the shading from dark to pale in Figure 6.3)
- Editing the image by adjusting contrast, brightness and greyscale such that features of interest can be detected.

Many of these stages require that a trade-off is made between for example detecting targets in deep water and those in shallow water. Processing the data is an iterative procedure; make changes to a parameter, assess the effect on the image and whether it has produced clearer information on the targets of interest, and possibly repeat several times until optimum resolution is achieved.

The "Perspective" software contains a function "Seaclass" which is intended to identify and classify seabed types. Training the software by selecting areas of seabed which are known to be of a certain type (rocky, sandy, muddy etc.) will allow the software to then examine the whole of the area surveyed and identify where the particular type of seabed occurs.

In addition to the side scan survey, enhanced ground truthing was conducted in the survey area. Previously, one grab sample per station has been taken. During this survey, two samples were taken at each station. This allowed comparison of the sediment structure and *Sabellaria* status of each sample to be compared.

6.3 Results

The area of Lynn Knock was selected, as this area has previously been sampled by grab and RoxAnn, thus providing background information on which to base interpretation of the side scan images obtained. The area surveyed is shown as the grey tracks in Figure 6.4.

RV "Three Counties" followed pre-determined tracks during the survey. Tracks were plotted at 150 m. spacings. With the side scan swath width of 100 m each side of the vessel track, a line spacing of 150 m affords total coverage of the survey area, with good overlap of the edges of tracks (where target discrimination is most difficult). During the survey in August 2013, much of the area was covered on alternate lines. This allows for large areas to be surveyed, but does leave gaps between lines. Such an approach builds up the overall picture of a site quickly, but requires that the site be re-visited at a later date to fill in the gaps left between lines to obtain complete coverage.

Figure 6.4 Locations and extent of side scan survey tracks (grey tracks within pale green area) for the Lynn Knock survey August 2013. Image from Google Earth.

Following processing of the side scan data, stations were identified which covered a range of different types of seabed image. Day grab samples were taken at these stations, two off 0.1 m^2 grabs at each station. For each sample, a photograph was taken of the sediment in the grab, and the following information recorded –

- Predominant sediment types
- Percentage volume of shell
- Percentage volume of *Sabellaria* fragments
- Height range of clumps
- Occupancy of *Sabellaria* tubes (zero, low, moderate or high)
- Percentage coverage of *Sabellaria* clumps
- Presence of faunal turfs
- Presence of other macro-faunal species present

The location of the stations, together with an indication of the percentage cover of *Sabellaria* clumps at each of these stations (two per station, each representing one of the grab samples) are shown in Figure 6.5.

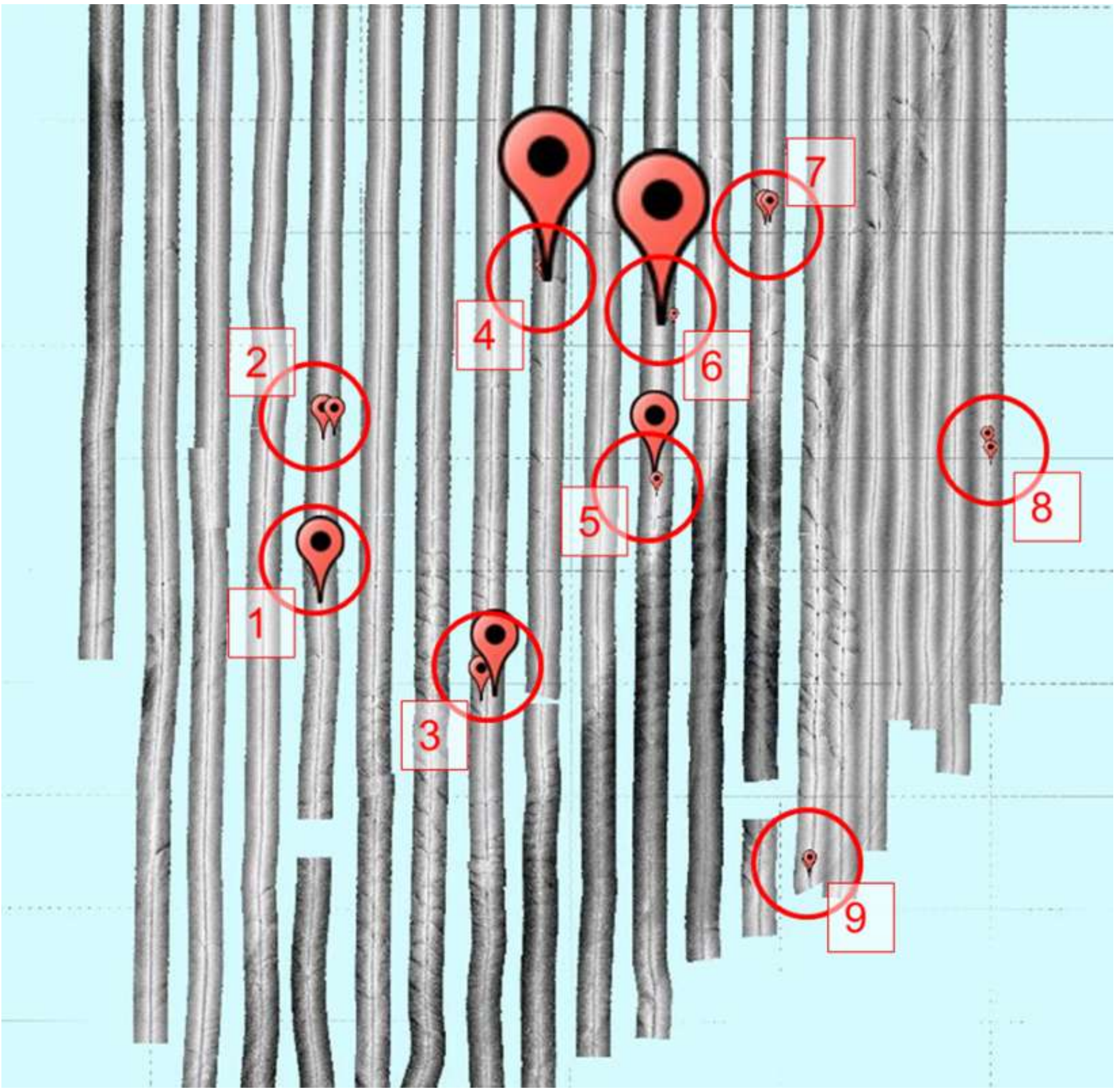


Figure 6.5 Location of stations within Lynn Knock survey area (red circles) and individual sample sites (red pins). Size of pin is an indication of % *Sabellaria* cover in that sample.

It is clear to see from Figure 6.5 how the overall picture of a site builds up as the individual survey lines are mosaicked together – for instance, the area of harder ground to the North West of Station 9 shows very clearly as a darker patch, whereas on individual lines the extent and outline of this feature is much less evident.

There are no stations from which both grab samples returned high percentage cover of *Sabellaria* – if there was a high cover from a station, this came from one only of the two grab samples (Table 6.2).

Table 6.2 Position and percentage cover of *Sabellaria* for each of the stations during the August 2013 Lynn Knock grab sample survey

Station	Degrees / Decimal Degrees Lat N	Long E	*Sabellaria* coverage, %
1	53.0695	0.4056	2.5
1	53.0687	0.4061	10
2	53.0767	0.4063	8
2	53.0770	0.4072	0
3	53.0639	0.4193	7
3	53.0641	0.4204	10
4	53.0846	0.4247	60
4	53.0847	0.4242	0
5	53.0749	0.4335	15
5	53.0740	0.4337	0.5
6	53.0825	0.4341	50
6	53.0824	0.4351	0
7	53.0873	0.4426	5
7	53.0874	0.4430	2.5
8	53.0762	0.4609	0.5
8	53.0755	0.4611	0.5
9	53.0552	0.4462	0.5
9	53.0553	0.4463	0.5

This suggests that the distribution of *Sabellaria* in these areas is patchy, with the grab landing on a patch in some instance, but missing completely only a few metres away. This has implications for planning grab sample programmes in the future; more samples per station are indicated, as one sample per station may well record the absence of *Sabellaria*, when actually it is present but patchy. There are also implications when considering past data; what may have been seen as ephemeral areas of reef, here one year and gone the next, could actually be as a result of patchy reefs being sampled positively one year and negative the next.

In the light of the fact that it had been determined that *Sabellaria* distribution is patchy, an attempt was made to identify any relationship between patchiness in *Sabellaria* distribution and patchiness in sediment type. The overall difference in sediment types between the two samples at each station were calculated (see Box 1), and this plotted on the X axis of a graph, with the maximum percentage cover of *Sabellaria* which had been recorded at that station plotted on the y axis.

Box 1 Calculation of overall difference in sediment types between two samples.

1) Record the % of each sediment type in each sample from the station
2) Calculate the difference between each of these % figures
3) Sum these differences

   E.G. -

Site 1			Difference
Sediment type	%	%	
1	30	20	10
2	30	35	5
3	10	15	5
4	0	0	0
5	30	30	0
6	0	0	0
7	0	0	0
Σ difference			**20**

This results in the graph as in Figure 6.6.

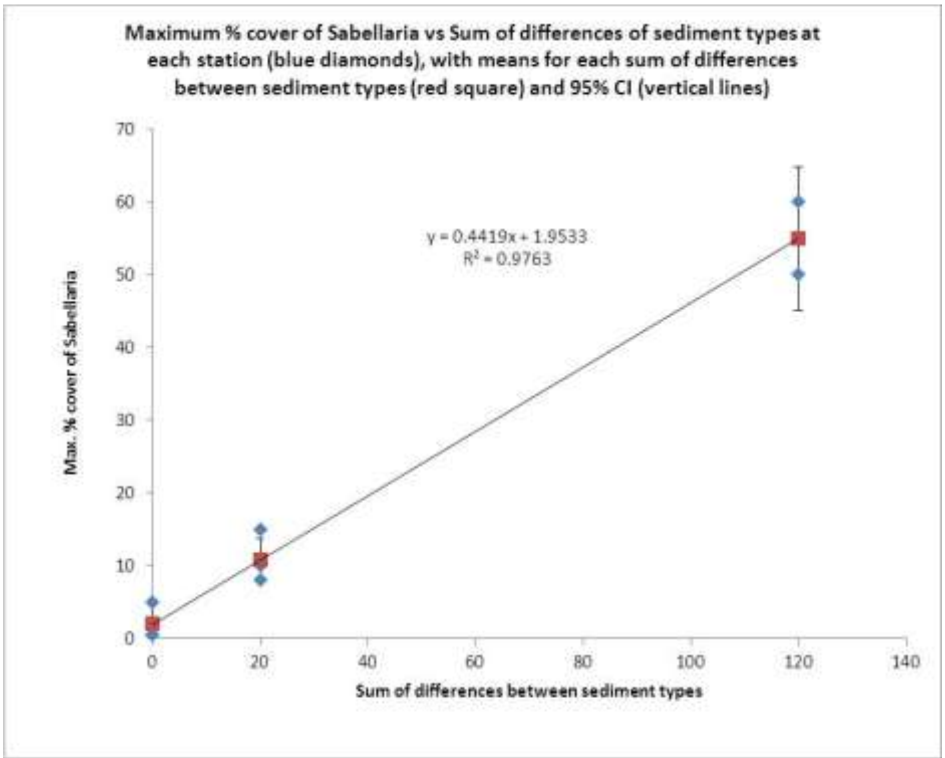


Figure 6.6 Correlation between variability in sediment composition between samples from a station and the maximum percentage cover of *Sabellaria* in samples from that station.

This is a strong indication of correlation between variability in sediment composition of the seabed and the presence of Sabellaria in that location. Note that in this instance correlation does not necessarily mean that there is a cause and effect relationship – it may be the case that that variability of sediment compositions in a location favours the establishment of *Sabellaria* reef, it may be that the presence of *Sabellaria* reef causes variability of sediment at a location.

As the stations selected demonstrated a range of seabed types, and we had confirmed *Sabellaria* sites within the sample stations, an attempt was made to run the "Seaclass" function. This was not successful, with the software failing to identify other possible areas of *Sabellaria*, probably due to the small difference in sonar characteristics between *Sabellaria* and the background sediment. Discussion with experts in the field of processing and interpreting side scan imagery indicates that it is very difficult to automate this process (although workers at the University of East Anglia are using advanced techniques to attempt to develop a protocol for this) and that examination by eye of the side scan image is the best way to achieve this.
The "signature" of *Sabellaria* is variously described as "speckled", "orange peel", "mottled", and similar phrases (Figure 6.7).

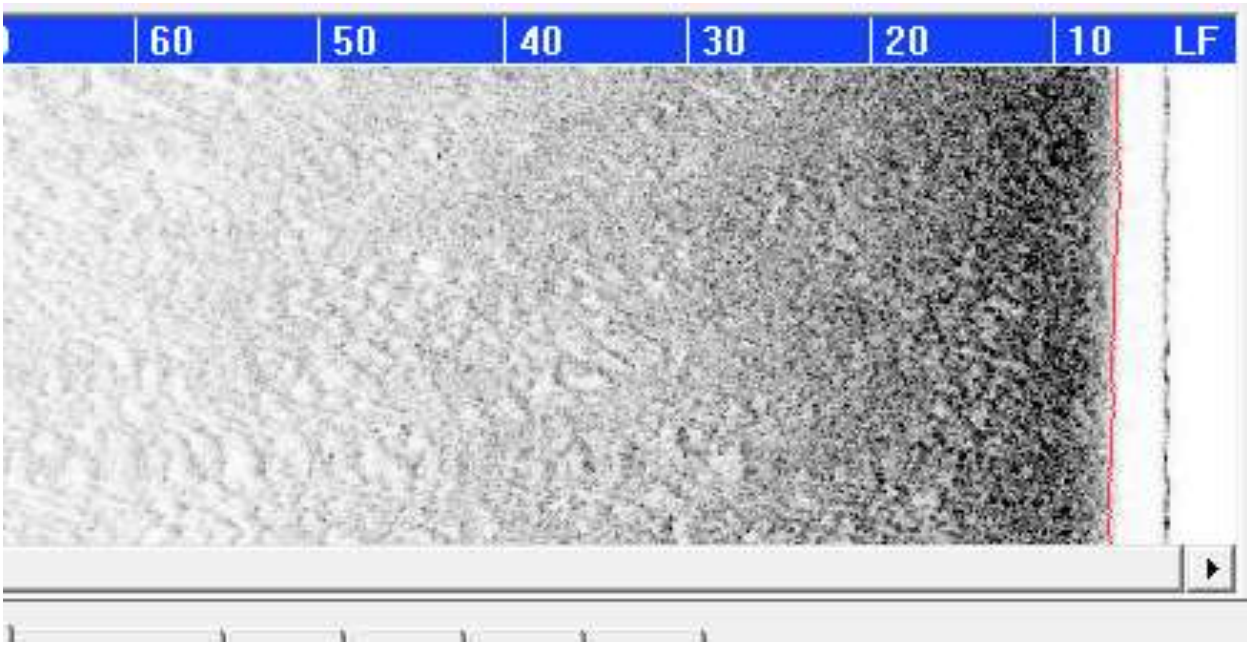


Figure 6.7 Typical appearance of *Sabellaria* reef in side scan imagery

The processing of the large amounts of data generated by side scan sonar files requires considerable computing power. Initially, we were considerably hampered by the slow speed at which we could process this data, with the processing of one survey lines worth of data (which had taken about one hour to collect) taking up to ten hours of computer time. More efficient arrangement of files on the computer improved this significantly, and the acquisition of a dedicated computer with excellent data handling capabilities has now hugely improved our capabilities.

Future Actions

- Continue and expand links with those with expertise in the field, especially in automatic recognition of seabed type.
- Ongoing training and development in the use of sidescan equipment and processing of sidescan data.
- Surveys of areas as required to support the assessment of the European Marine Sites as required.

Additional Notes

Eastern IFCA loaned the side scan equipment, and a technician to operate it, to Southern IFCA to allow Southern IFCA to conduct surveys on two MCZ sites to the north of the Isle of Wight in March 2013. This survey went well, providing benefits to both parties. We were able to gain valuable experience in the use of the equipment in shallow water, and over a wider variety of sea beds than are present in our locality.

7.0 STUDY OF THE WASH EMBAYMENT ENVIRONMENT AND PRODUCTIVITY

7.1 Introduction

7.1.1 Background

The Study of the Wash Embayment, Environment and Productivity (SWEEP) began in 2009 in response to a significant observed decline in biomass of the Wash's cockle stocks. The Wash cockle fishery is important to the local economy and any threat to the fishery would have strong local economic and social implications. Although yearly variation in cockle stock biomass is normal, with natural processes such as environmental factors and "ridging out" occurring, the 2008/2009 declines were deemed atypical with 5,000 tonnes of cockles lost from the Wrangle bed alone in 2008 (Jessop et al. 2009). In addition to the decline in cockle stocks, around the same time the growth and condition of mussels in the Wash were observed to have been relatively low over the previous years. Due to a lack of appropriate historic data, no conclusions could be drawn as to exactly what factors were driving the variation in bivalve biomass and condition in the Wash, and thus SWEEP was established to provide a baseline of water quality and productivity data, and long-term monitoring of the condition and productivity of the Wash, with the intention of providing a means to draw such conclusions.

7.1.2 History of project

Detailed accounts of the yearly iterations of SWEEP can be found in Eastern IFCA's (and Eastern Sea Fisheries Joint Committee's) annual research reports from 2009 until present, but a brief overview is given here. The project was commissioned in 2009 by the Eastern Sea Fisheries Joint committee, the predecessor to Eastern IFCA, in response to atypically large declines in cockle stocks observed in the Wash in 2008, in order to provide a baseline of water quality and productivity data to help explain fluctuations in local bivalve biomass. Existing data was lacking, and desk studies carried out by the Committee proved inconclusive, and so SWEEP was developed with the aim of conducting long-term monitoring and shorter, intensive studies to help understand the dynamics of bivalve stocks in relation to local water conditions and food availability.

2009 saw the inception of the project following the observed declines, and saw the acquisition of two YSI multiparameter water quality sondes – one hand held for spot monitoring at various locations around the Wash, and one deployed on a buoy in the Roaring Middle area of the Wash providing continuous high resolution data. The aims of the project were to establish long-term monitoring of the Wash, conduct short-term studies of localised depletion of food resources, and conduct additional research including establishing a carrying capacity for the Wash, constructing food webs, predator-prey interactions, and hydrodynamics. Long-term monitoring was successfully implemented, with seven stations being spot-monitored in addition to the continuous data set from the buoy. Short-term studies were successfully carried out, including medium and high resolution monitoring over wide areas and lays respectively, and river transects. The additional research, however was not carried out due to being reliant on an external fellowship for which funding could not be sourced, though working partnerships were established with Cefas, with sampling being carried out on their behalf in exchange for highly accurate water quality parameter calibration data.

During 2010 the long-term monitoring of the Wash continued with the sonde datasets being built upon, and Cefas' water samples being collected. Short-term studies were carried out once again, with high-resolution surveys occurring over the Ants, Toft and Scotsman's Sled, and a medium-resolution survey being carried out in the northwest of the Wash. Samples were collected at a depth of 1m. Additionally, river surveys were carried out as in 2009.

2011 again saw a continuation of long-term monitoring, with the short-term study this time being a high-resolution survey of mussel lays in the Wash. The number of long-term spot-monitoring sites was also reduced. The main development in 2011 was that it was suspected that taking readings from 1m below the surface may not provide a representative measure of chlorophyll depletion over bivalve beds, and that taking readings directly above the bed would provide a better means of yielding more accurate results. A special cage was constructed to house the sonde, which was then used to allow it to sink and take readings within centimetres of the seabed.

During 2012 the project fulfilled a more observational and less investigative role, with long-term monitoring continuing, but no short-term studies scheduled due to other projects taking priority. 2013 saw much the same approach, with long-term monitoring data being presented in this report, though it is hoped that in the future more in-depth SWEEP studies will be carried out.

7.2 Materials and methods

During 2013 water quality parameters were monitored across various sites in the Wash in order to give a representative spatio-temporal picture of salinity, temperature, chlorophyll (indicating levels of phytoplankton and thus productivity) and turbidity. Monitoring was conducted using two YSI water quality sondes, with one being permanently deployed on a buoy, and one being portable and used for spot monitoring at various locations.

The buoy sonde was deployed in open water to the north of Roaring Middle sand (52°56.509N, 000°19.104E), and set to log a sample every 10 minutes continuously throughout its deployment period. The sonde was left deployed for a month at a time (weather allowing), after which it was removed for cleaning, servicing, calibration and data download. Where the weather or other factors prevented the buoy from being retrieved, it was carried out at the next convenient opportunity. Data was downloaded into YSI's proprietary EcoWatch software, which allows for quick and convenient viewing. To allow for processing however, data was transferred from EcoWatch to Excel, where data was corrected for shift in values between calibrations using the slope of the line of the calibration shift. Additionally, any obvious anomalies such as negative values or large spikes where it is likely a sensor was blocked, were removed.

The spot sonde was deployed manually on monthly sampling trips, with samples being taken at eight sites around the Wash (Fig. 7.1, Table 7.1). The intention was to sample as many sites as possible as often as possible and as such some sites were not sampled every month. Additionally the sonde was only acquired in June after the irreparable damage of the previous unit and thus data is only present from that point on. The spot sonde is used in conjunction with a hand held data logger from which the unit is controlled and samples are logged, as opposed to the buoy sonde which holds logged samples in its internal memory. Three samples were taken at 1.0m ±0.1, and an additional sample was taken at 3m and 6m where possible. The data was then uploaded to EcoWatch and processed in much the same way as that of the buoy sonde, with the addition of removing samples that were more than 0.1m above or below the intended depth.

Table 7.1. Locations of SWEEP sampling sites around the Wash. Lat Longs are approximate.

Site name	Lat Long	Sampling carried out
Breast	52°49.917N, 000°15.552E	Hand sonde
Buoy	52°56.509N, 000°19.104E	Buoy sonde, hand sonde, Cefas samples
Mare Tail	52°54.730N, 000°08.800E	Hand sonde
Stylemans	52°52.833N, 000°23.512E	Hand sonde, Cefas samples
Toft	52°57.331N, 000°08.115E	Hand sonde, Cefas samples
Training wall	52°49.081N, 000°21.132E	Hand sonde
Wrangle	53°00.850N, 000°11.884E	Hand sonde
Wreck	52°52.500N, 000°13.100E	Hand sonde, Cefas samples

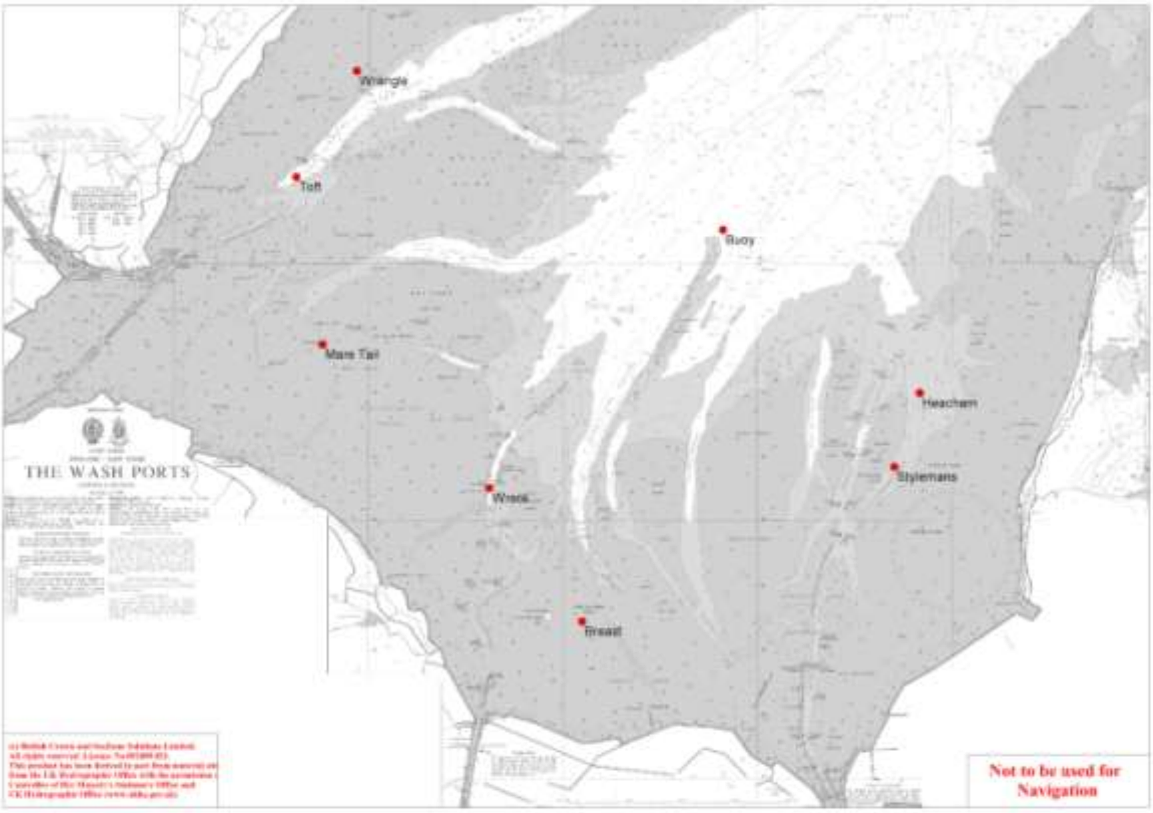


Figure 7.1. Sampling sites for the SWEEP project around the Wash. Hand sonde readings were taken at all 8 sites, Cefas samples were taken at Buoy, Wreck, Toft and Stylemans, and the buoy sonde was located at Buoy.

In addition to the sonde work, samples were collected on behalf of Cefas for various measures including plankton abundance, nutrients present, and high-accuracy salinity at 4 of the 8 hand sonde sites (Fig. 7.1, Table 7.1).

7.3 Results

7.3.1 Buoy Sonde

Figure 7.2 shows chlorophyll and temperature data for 2013 provided by the in-situ buoy sonde. The lack of data running up to March is due to the sonde being away for repair following a fault. The smaller gap in data during June and July is due to the removal of the buoy itself for servicing and removal of fouling (Fig. 7.3). A clear rise can be seen in water temperature from April onwards, falling again after September, as would be expected following the climate throughout the year. Around the beginning of June chlorophyll is seen to begin increasing, indicating higher densities of phytoplankton emerging as water temperature increases. This is followed by bloom in mid June where chlorophyll levels hit almost 100 RFU at their peak, after which levels fall sharply again, presumably as nutrients are depleted.

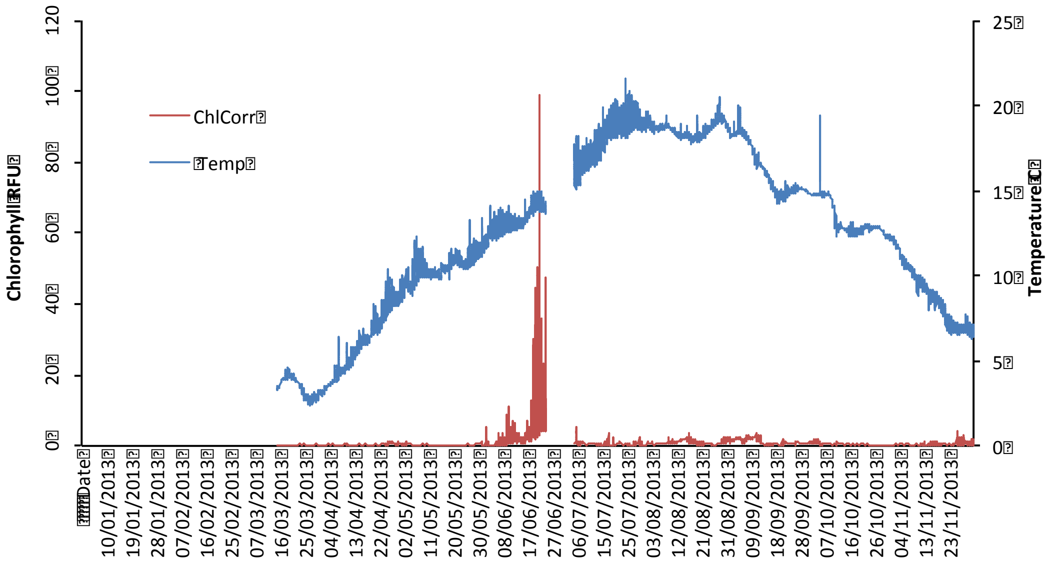


Figure 7.2. Chlorophyll levels (RFU) and seawater temperature (°C) data for 2013 from the in-situ sonde located at the buoy site at Roaring Middle in the Wash.

Figure 7.3. Extensive fouling on the sonde buoy at its removal in June 2013

Figure 7.4 shows 2013 salinity data provided by the buoy sonde, along with historic rainfall data for the closest available weather station to the buoy site, Heacham (wunderground, 2014). Salinity, whilst fluctuating somewhat, stayed fairly constant throughout the year. Drops in salinity can be seen towards the end of May and from the end of July to early October, however these drops do not seem to correspond strongly to high rainfall and it is suspected that the drops may have been caused by blocked sensors (see discussion). This is most obvious where salinity jumps from around 29 to around 35 following servicing in October. This can be seen in closer detail in figure 7.5.

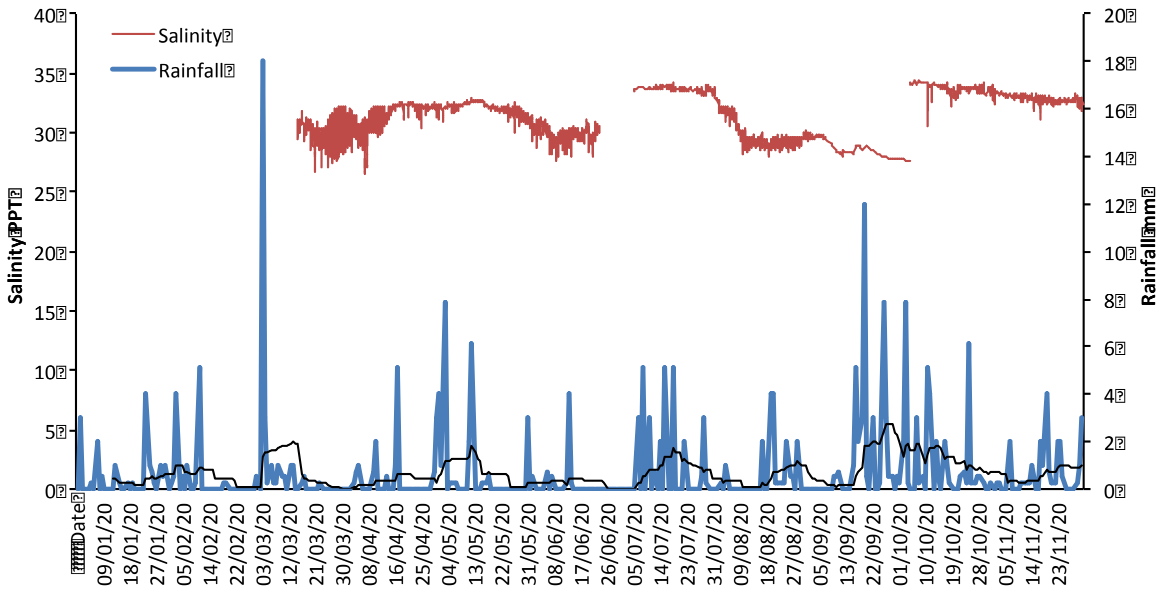


Figure 7.4. Salinity data (PPT) for 2013 from the in-situ sonde at the buoy site at Roaring Middle in the Wash, along with rainfall data (mm) from a land-based weather station at Heacham. The black line is a trend line for the salinity data denoting a 14-day average.

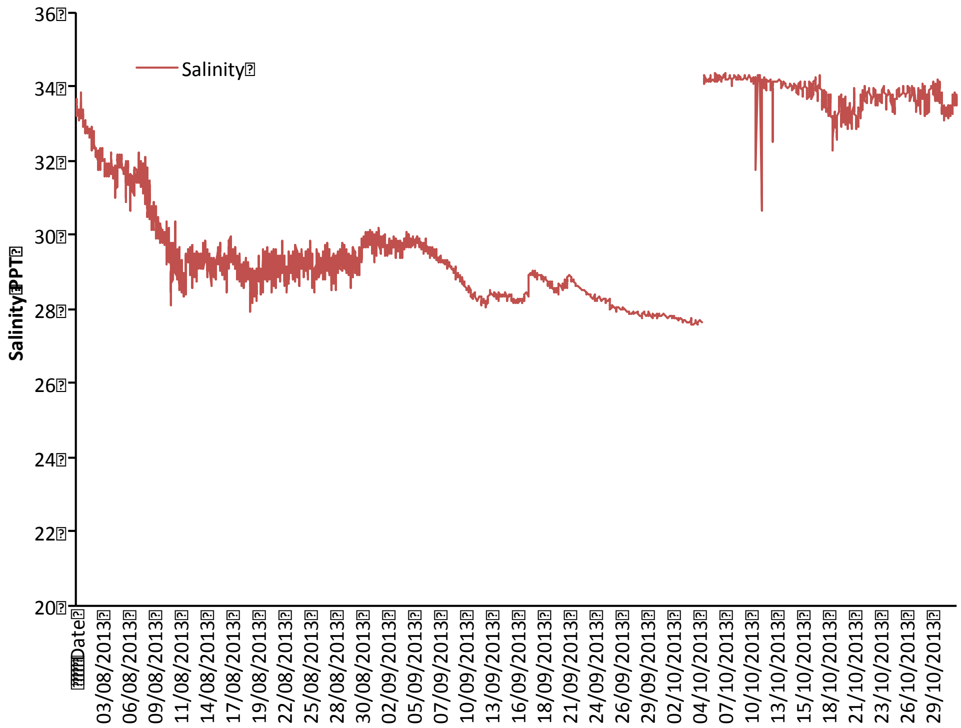


Figure 7.5. Salinity data (PPT) for August to October 2013 from the in-situ sonde at the buoy site at Roaring Middle in the Wash, showing a jump in salinity following servicing of the sonde in early October.

Figure 7.6 Shows turbidity data from the in-situ sonde along with wind speed data for Heacham obtained from the same source as the aforementioned rainfall data. It was thought that wind speed might affect turbidity by stirring up sediment, however the data does not clearly support this notion. This may be due to the fact that the buoy is located in the middle of the Wash in waters too deep to be affected by wind speed. Turbidity is seen to increase drastically in June at the same time as the observed algal bloom, and thus the bloom provides an explanation for the high turbidity. Turbidity is seen to increase drastically again in August, which may be a result of a smaller, secondary plankton bloom (see figure 7.2 and discussion). Turbidity does occasionally appear to "jump", with large spikes appearing in the data at various times, and it is suspected this may be due to fouling over the sensor.

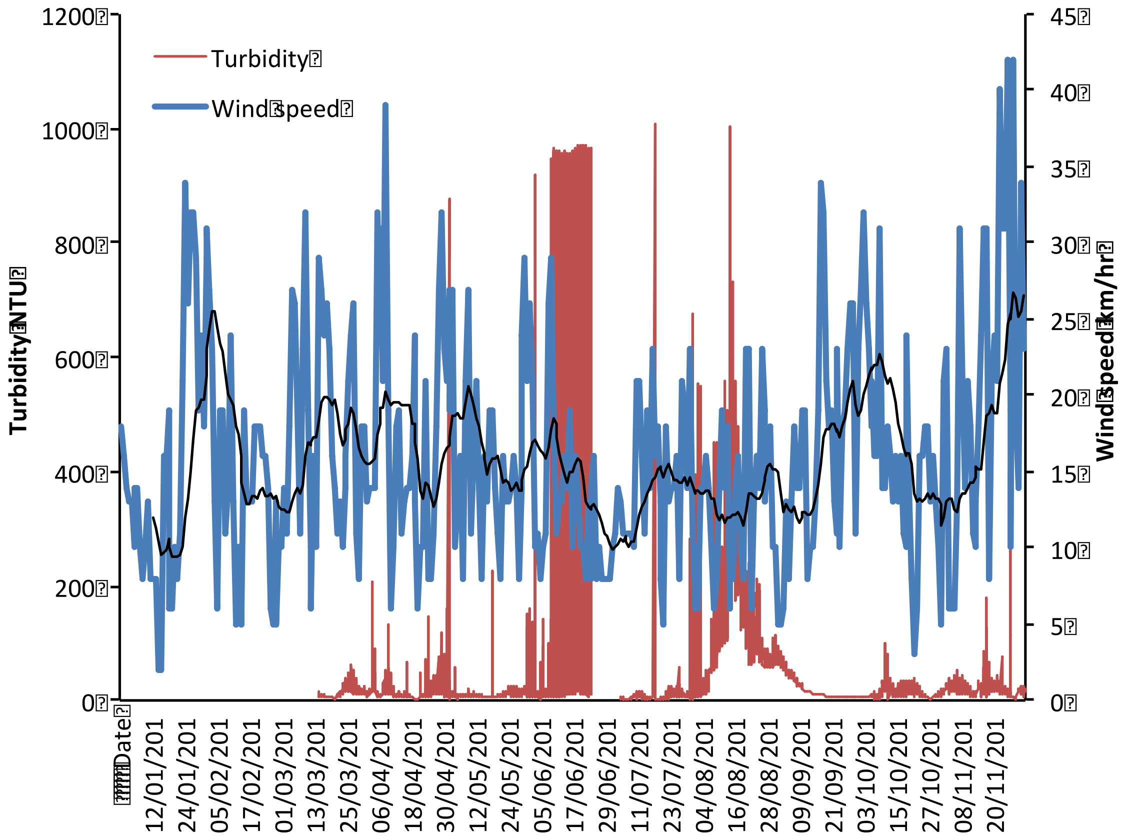
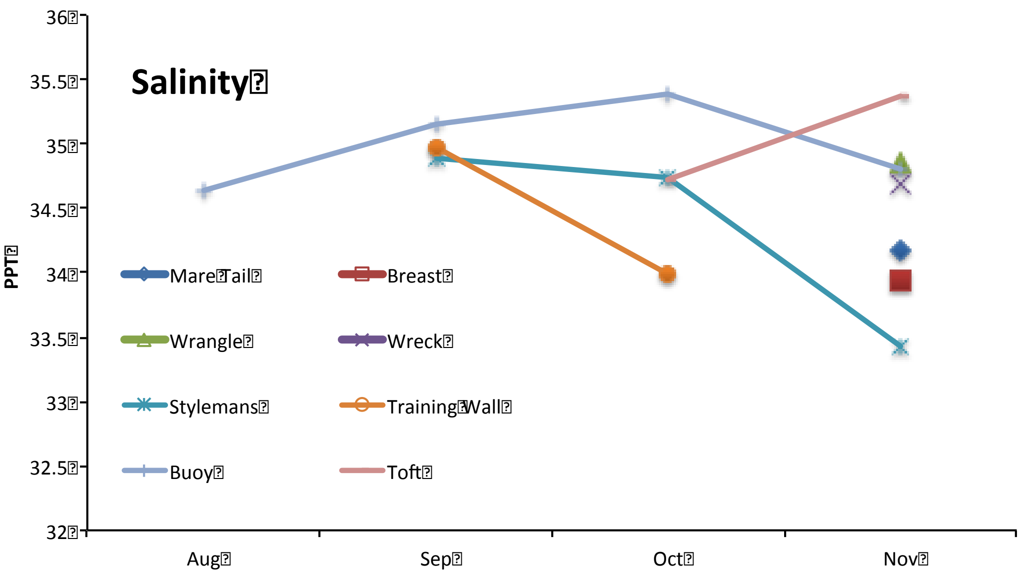


Figure 7.6. Turbidity data (NTU) for 2013 from the in-situ sonde at the buoy site at Roaring Middle in the Wash, along with wind speed data (km/h) from a land-based weather station at Heacham. The black line is a trend line for the wind speed data denoting a 14-day average.

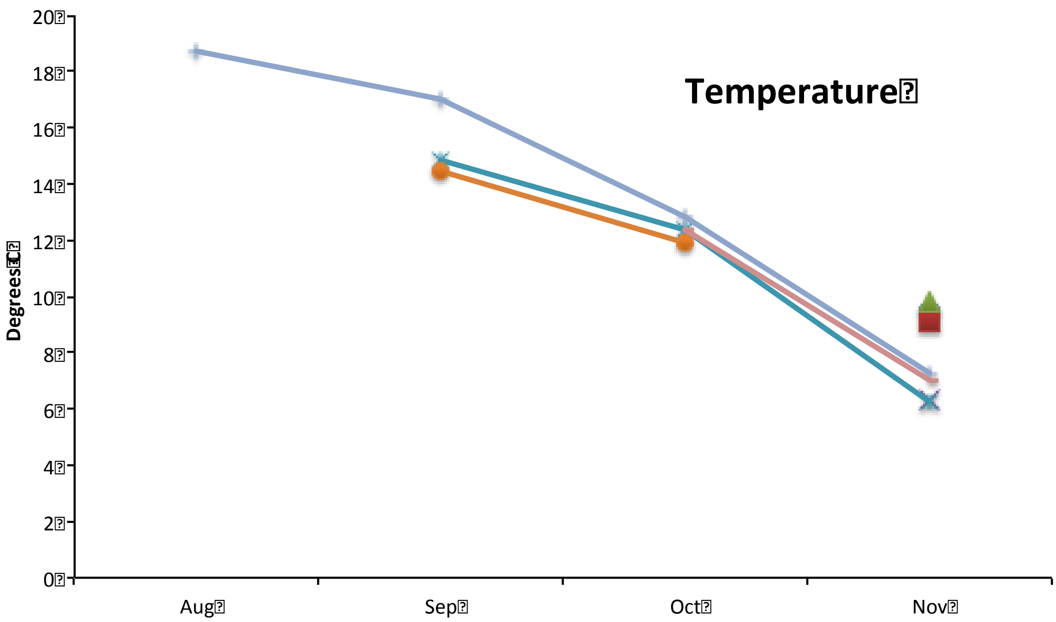
7.3.2 Spot sonde

Data from the spot sonde can be seen in figure 7.7. Spot sonde data was sporadic in 2013 for a number of reasons, discussed later. As a result, no data was collected before August, and data thereafter is lacking for certain sites. With such a small data set it is difficult to draw any meaningful conclusions, however some basic patterns can be seen. All salinity readings for all sites were within a range of approximately 33 to 35.5 PPT, indicating little variation in salinity in the Wash. This data should however be treated with caution as salinity would be expected to be lower in sites such as Training Wall, which is situated in the mouth of a river. This may be a product of the way salinity was calculated (see discussion). Water temperature shows a steady decline towards the end of the year as would be expected. Both chlorophyll and turbidity data show relatively little variation, staying within a narrow range as compared to the data from the buoy sonde, suggesting relatively constant level of phytoplankton and suspended sediment in the Wash throughout the timeframe monitored.

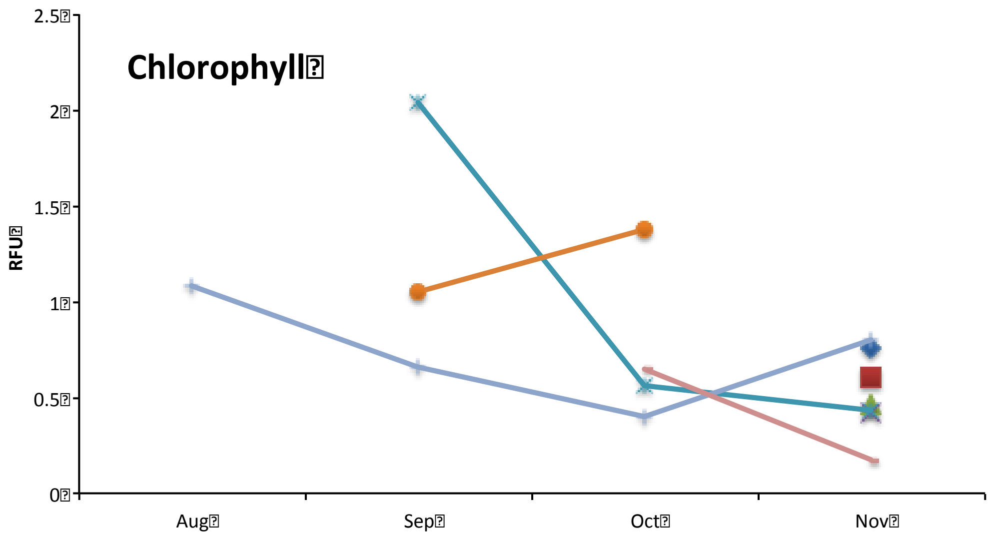
a)


Salinity
PPT
36
35.5
35
34.5
34
33.5
33
32.5
32
Mare Tail
Breast
Wrangle
Wreck
Stylemans
Training Wall
Buoy
Toft
Aug
Sep
Oct
Nov

b)


Temperature
Degrees C
20
18
16
14
12
10
8
6
4
2
0
Aug
Sep
Oct
Nov

c)



d)

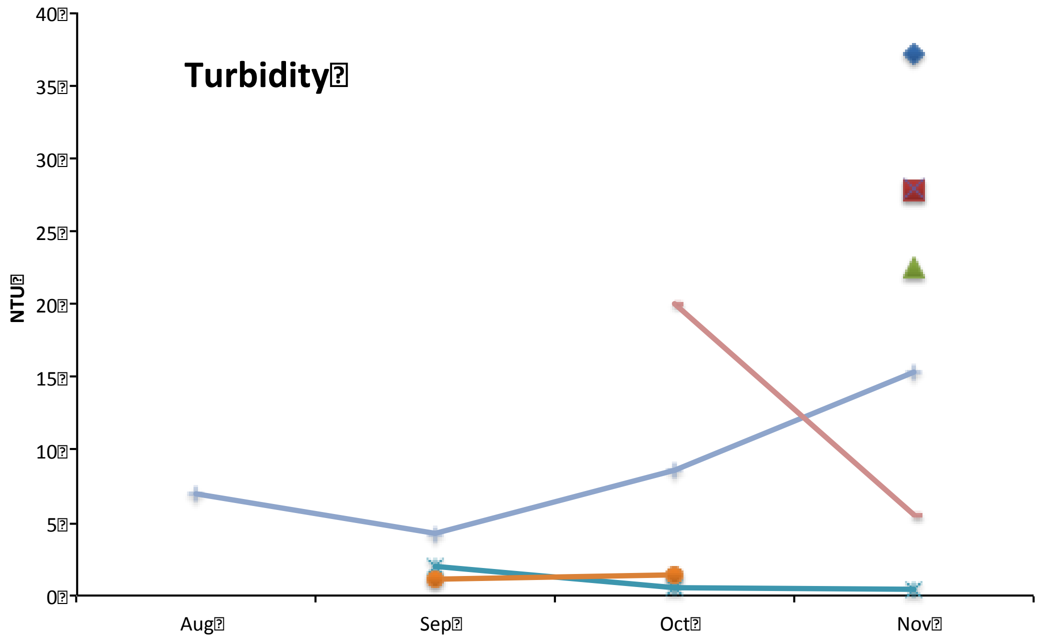


Figure 7.7. Spot sonde data from locations around the Wash for the period of August to November 2013, for the parameters a) salinity, b) temperature, c) chlorophyll and d) turbidity. Sites indicated in a) apply to all parameters.

7.4 Discussion

The main objective of the SWEEP project is to provide a comprehensive data set that provides a complete picture of productivity and water quality parameters in the Wash. During 2013 however, a number of difficulties arose which meant that data collected was somewhat sporadic and in certain cases, insufficient to draw any conclusions. The main issues that occurred were equipment or staff based, with sondes being out of action at various times, and significant changes in the research team staffing. The buoy sonde was out of use from November 2012 to March 2013, and thus no data was acquired during this time. This in itself affects the conclusions able to be drawn in terms of monitoring patterns over the course of the year. Fortunately however, the vast majority of the rest of the year was accounted for, with the exception of 24th June to 5th July when the buoy itself was out of the water for servicing and removal of fouling.

Problems were encountered with the buoy sonde data when it was not removed for servicing frequently enough. Temperature and chlorophyll readings seemed to remain relatively unaffected, showing meaningful results including a clear algal bloom in June (see figure 7.2), however turbidity and particularly salinity seemed sensitive to the level of fouling present on the sonde. This can be seen with turbidity in figure 7.6, with turbidity readings repeatedly jumping up and down around the time of the algal bloom in June. After removal of the sonde for servicing, the readings seemed to stabilise. Turbidity readings also saw occasional incongruent spikes, and it is suspected that these incidences are a result of fouling moving in front of the sensor.

In the case of salinity, levels are occasionally seen to drop gradually, followed by a jump after the buoy is serviced. This is most apparent when levels dropped sharply around the end of July and stayed around 4PPT lower until the buoy was serviced, at which point the levels immediately jumped back up (Fig. 7.5). The drop was not explained by rainfall (Fig. 7.4). The salinity sensor in the sonde consists of a tube with a hole through which the water passes, and it is suspected that if this hole gets blocked then readings can be affected. With the sonde being permanently deployed, it fouls up quickly and the results highlight the importance of monthly servicing of the buoy sonde, especially in summer when fouling is accumulated quickly.

Turbidity and salinity data was compared with basic weather data for the closest weather station to the buoy at Heacham. Turbidity was compared with wind speed as it was thought that increased wind might stir up sediment, increasing the level of turbidity. No obvious link was observed between the two, as can be seen in figure 7.6, and it is therefore suspected that either the effect is too small to be detectable with the methods used, or that the buoy is in water too deep to be affected by the wind. Turbidity can be seen to follow a cyclical pattern with higher readings occurring at spring tides owing to the higher rates of tidal flow stirring up sediment. It is likely that any effect of the wind is negligible compared to the tide, which accounts for the majority of the variation in turbidity. It appears from the results that chlorophyll has a far higher effect on turbidity at the buoy than suspended sediment. This can be seen in the figures when observing the large plankton bloom in June and a much smaller one in August, as turbidity levels can be seen to rise accordingly with chlorophyll.

Levels of rainfall did not appear to reduce salinity at the buoy as would be expected (Fig. 7.4). This could be a result of unreliable data or the fact that the weather station used might not be representative of the weather at the buoy, however it is more likely that the surface dilution occurring during periods of rainfall is minimal, and thus its detection using changes in salinity is unlikely. The opposite of the expected effect was in fact observed, with salinity seemingly reducing in periods of lower rainfall. It is suggested that this is a result of a delay between rainfall and the entry of the subsequent fresh water into the marine system through rivers, due to the time it takes for the land to drain and the runoff of fresh water to enter the river systems. This would explain the peaks of rainfall being out of phase with reductions in salinity, as reductions would occur a period after the rainfall. Studying figure 7.4 supports this theory. In the figure, variation in salinity appears to reduce with increased rainfall, and if the same assumption of a delay between rainfall and the fresh water entering the marine system is made, then this could be explained as variation increasing with rainfall, but again being out of phase due to the delay. It is suggested that increased variation in salinity would occur after periods of heavy rainfall due to fresh water entering the marine environment, causing the salinity to fall with the ebbing tide and subsequently rise again with the flooding tide. A period after the bout of rainfall, waters will be more mixed due to less fresh water entering the system, leading to more consistent salinities and thus less variation in the salinity readings.

The original hand sonde was damaged beyond repair early in the year and a replacement was only up and running from August, meaning that hand sonde data is absent before this, and as such few if any conclusions can be drawn from this data. In addition to technical issues, many staff changes occurred to the research team during 2013, with a complete replacement of the team by July. Naturally, with all of EIFCA’s other research being carried out in conjunction with training and the new staff settling in to their roles, sampling was occasionally missed even after the acquisition of the new sonde, either due to confusion with regards to sampling activities, or due to logistical difficulties. As a result, hand sonde data for 2013 is sporadic and only covers August to November, and thus care should be taken when drawing conclusions from it. It should also be noted that after the acquisition of the replacement hand sonde, salinity measurements were disabled and this was not realised until data was processed. Salinity is calculated by the sonde with an algorithm using the specific conductance measurement taken, and so a suitable algorithm was sourced to calculate salinity retrospectively: $S=0.4665x^{1.0878}$ where S is salinity and x is specific conductance at 25°C (specific conductance is already compensated for temperature at 25°C by the sonde) (Williams, 1986).

7.5 Conclusions and Future of the Project

2013 has seen the lowest level of activity thus far for the SWEEP project, with only basic monitoring being carried out. Originally the aim of the project was to investigate depletion of bivalve food resources by fishery lays, but over the years the project has been stripped back to the bare essentials. It is difficult to draw any real conclusions with the data for 2013, especially given the gaps in data caused by technical and staffing issues. In addition, no mussel meat yield data was collected in 2013, meaning water quality parameters could not be compared to mussel condition. The project has however continued the useful baseline monitoring, and the data collected does provide a basic picture of the Wash through the year, especially from the buoy sonde data. It is intended that a more comprehensive data set will be collected in 2014 (including meat yields) such that more meaningful results can be produced and the original aims of the project can be met.

8.0 SUFFOLK RIVER SURVEY

8.1 Introduction

The Stour and Orwell estuaries support major concentrations of waterbird species (including important numbers of breeding Avocet *Recurvirostra avosetta* in the summer), for which they are designated a Special Protected Area (SPA) under the European Birds Directive (79/409/EEC 1979). The area is also designated a Site of Special Scientific Interest (SSSI), a Ramsar site (for wetland habitats), forms an important part of the Suffolk Coast and Heaths Area of Outstanding Natural Beauty (AONB) and is included in the schedule of Natura 2000 European Marine Sites (EMS). In 2013 they were considered during the first tranche of Marine Conservation Zones (MCZ's) but failed to be designated. Although there are currently no commercial shellfisheries active in these rivers, the Authority (and its predecessor, Eastern Sea Fisheries Joint Committee) have conducted regular surveys in the area in recognition of their environmental importance.

Between 1997 and 2011 seven surveys have monitored the cockle (*Cerastoderma edule*) stocks that are present on the inter-tidal banks of both rivers. During these surveys, significant numbers of Manila clams (*Vererupis philippinarum*) were identified in 2009, warranting them being included in the monitoring programme alongside the cockle stocks. Regular surveys have also been conducted monitoring the extent of colonies of peacock worm (*Sabella pavonina*) in both rivers, a population of native oysters (*Ostrea edulis*) in the Holbrook Bay area of the River Stour and a population of blue mussels (*Mytilus edulis*) at North Mistley. Due to high workloads and competition from other projects, the cockle and clam surveys were not conducted during 2013, the surveys in these rivers being limited to monitoring the native oyster and blue mussel stocks.

8.2.0 Holbrook Bay Native Oyster (*Ostrea edulis*) Survey

8.2.1 Introduction

Historically, the Gallister's Creek area of Holbrook Bay on the River Stour has supported a small population of native oysters *Ostrea edulis.* This colony is believed to have originated from an oyster farm that was once present in the bay. In 2002 an application was submitted to ESFJC to fish these oysters but until a stock assessment could be completed, the area was temporarily closed to shellfish fishing. A stock assessment was conducted in February 2004, in which the oyster population was estimated to be between 11.5 and 17.3 tonnes (Jessop, Lowry, Graves, 2003). This was considered too small to support a fishery that would be both sustainable and commercially viable so the temporary closure was kept in place. In 2005, a further survey found the oysters to be suffering from an unidentified abnormal shell condition, and the stock had fallen to between 6.5 and 10.8 tonnes (Jessop, Graves, 2005). Subsequent surveys recorded a gradual decline of oysters in this bay, with last year's survey estimating the stock to be less than 1 tonne.

Although the stock has declined in Holbrook Bay itself, in 2010 a population of juvenile oysters was identified on the south side of the River Stour between Wrabness Point and Copperas Bay. The following survey, in 2012, also identified population of Pacific oysters (*Crassostrea gigas)* to be present in Holbrook Bay.

8.2.2 Method

Samples are collected using a 90cm commercial oyster dredge towed behind a vessel. A small commercial fishing vessel had been chartered for the surveys conducted between 2004 and 2010, while for the 2012 and 2013 surveys, Kent & Essex-IFCA's research vessel, RV *Tamesis*. was used. Tows are not of a fixed length, but care is taken not to extend the length of tow beyond the holding capacity of the dredge. Tows in which the dredge is considered to have been fishing inefficiently, or has totally filled with mud, are classed as void and the data discarded. Figure 8.1 shows an oyster dredge with a partially filled bag. Positions are recorded using a portable GPS at the start and end of each

Figure 8.1 – Oyster dredge

tow. These positional data are then analysed using MapInfo™ GIS to determine the length of each tow. All oysters caught are measured and individually weighed aboard the vessel.

8.2.3 Results

<u>Native Oysters, *Ostrea edulis*</u>

A total of 70 tows were conducted over the two-day period. Of these, five were determined as being "void" after the dredge either filled with mud or was thought to have not fished efficiently. Figure 8.2 shows the position of the remaining 65 valid tows.

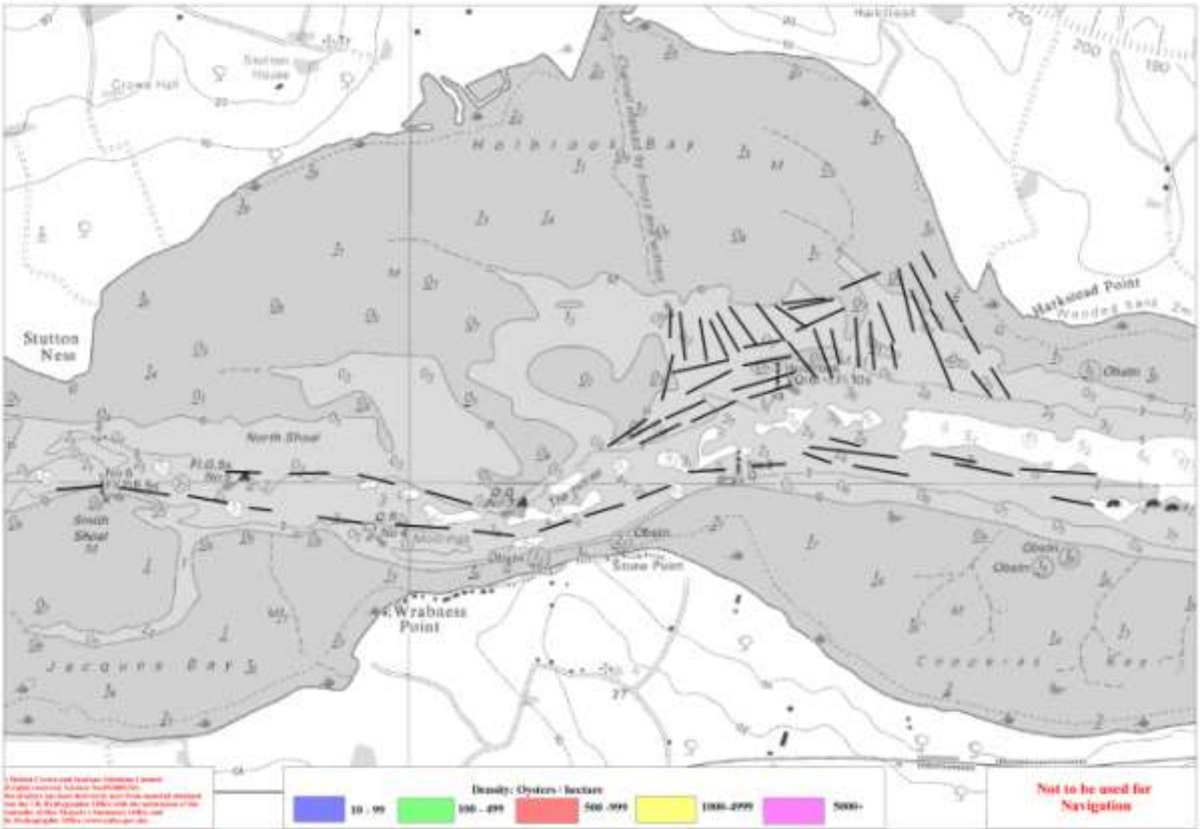


Figure 8.2 - Distribution of dredge tows conducted during the 2013 oyster survey.

25 of the tows were found to support live native oysters (range 1 – 3 oysters/tow). These were calculated to be present in densities between 0.30 oysters/100m^2 and 1.85 oysters/100m^2. This is significantly less than the previous survey in 2012, when oysters were estimated to be present in densities up to 21.11 oysters/100m^2. The greatest reductions had occurred on the south side of the river at Copperas Bay, which since 2010 had supported a healthy stock.

The data from the tows were analysed using MapInfo™ GIS, from which a distribution chart of the oyster beds was created (see figure 8.3). From this chart 38.74 hectares were found to support native oysters. This is a decline from the previous year, when the coverage had been 48.55 hectares.

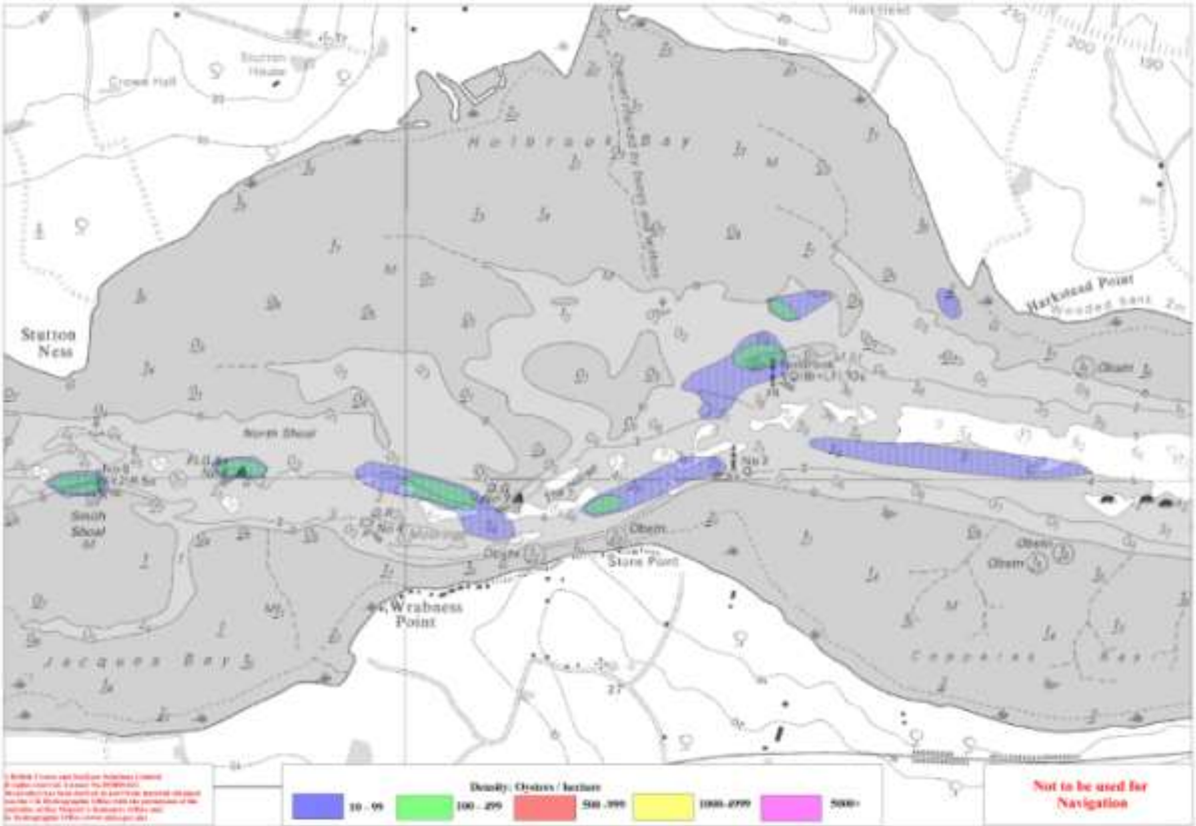


Figure 8.3 - Distribution of native oysters, *Ostrea edulis*, found during the 2013 surveys.

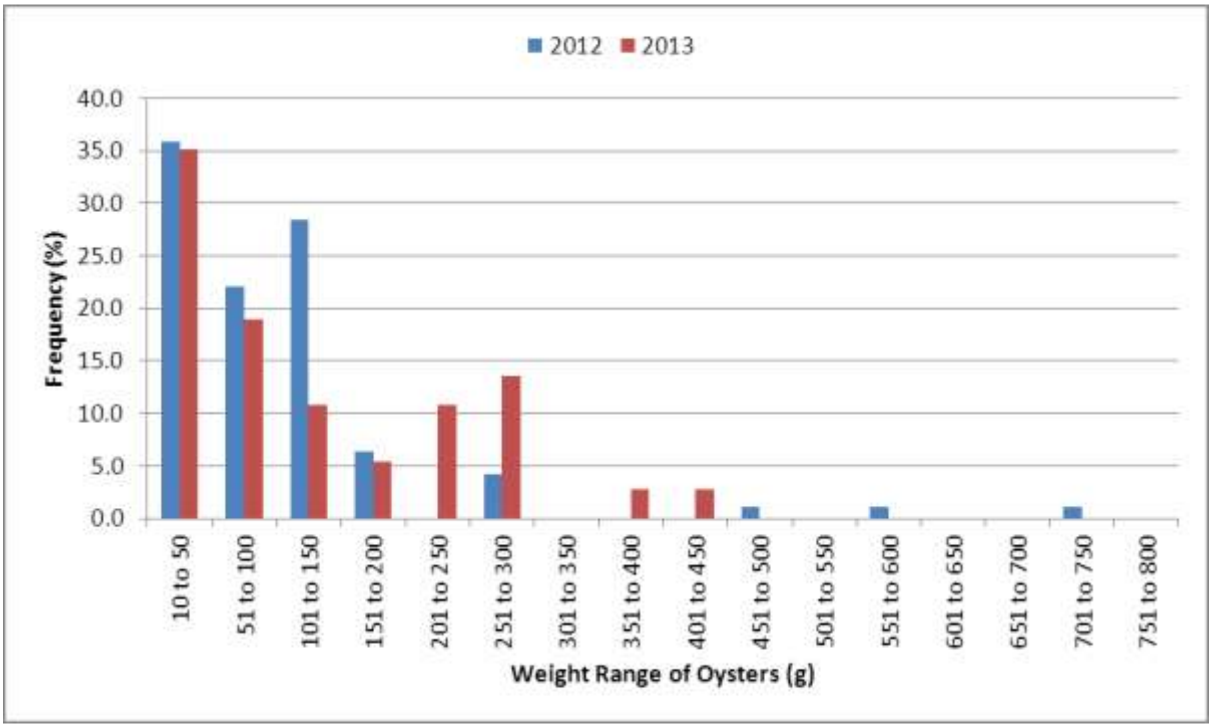


Figure 8.4 Weight ranges of native oysters, *Ostrea edulis*, found at Holbrook Bay during the 2012 and 2013 surveys.

Figure 8.4 shows the weight ranges of the oysters caught during the 2012 and 2013 surveys. Both populations have a similar proportion of 10-100g individuals, but appear to vary at sizes beyond that. The mean weight of the 2013 samples was 129g. Although this is higher than the 105g recorded the previous year, the differences are not significant at a $p<0.05$ confidence level.

Assuming a 100% catch efficiency of the dredge, this area was estimated to support 431kg of oysters. Even under ideal conditions, these dredges are thought to be no more than 30% efficient, with an average efficiency of only 20% more likely. If these inefficiencies are taken into account, a more accurate estimate of the stock would be between 1,293kg and 2,155kg. Of these, between 924kg and 1,540kg are present in Eastern-IFCA's district at Holbrook Bay and between 369kg and 615kg in Kent & Essex-IFCA's district at Copperas Bay. While this is a slight recovery over the year at the Holbrook Bay site, it is a 82% decline at the Copperas Bay site.

<u>Pacific oysters, *Crassostrea gigas*</u>

In addition to *Ostrea edulis*, three of the tows conducted in the Holbrook Bay area were found to contain Pacific oysters, *Crassostrea gigas* (range 2 – 10 oysters/tow). These were estimated to be present in densities between 1.13 oysters/100m^2 and 7.94 oysters/100m^2.

Figure 8.5 shows the distribution of *C. gigas* found during the surveys. These were estimated to cover an area of 3.0 hectares, less than half the 6.6 hectares recorded in 2012. Assuming a 100% catch efficiency of the dredge, this area was estimated to support 342kg of Pacific oysters. Adjusting the figures to account for a dredge efficiency of between 20% to 30%, the area is estimated to support a stock of between 1,026kg and 1,710kg. This is only a third of the 2,973 - 4,945kg estimated to be present the previous year.

Figure 8.6 shows the weight ranges of *C.gigas* caught during the 2012 and 2013 surveys. Whereas the predominant size range in 2012 was oysters weighing between 51-100g, no oysters smaller than 101g were found in 2013. This indicated there had been poor recruitment between surveys. The mean weight of these individuals was found to have increased from 199g in 2012 to 241g in 2013 but this was not significant at a $p<0.05$ level of confidence.

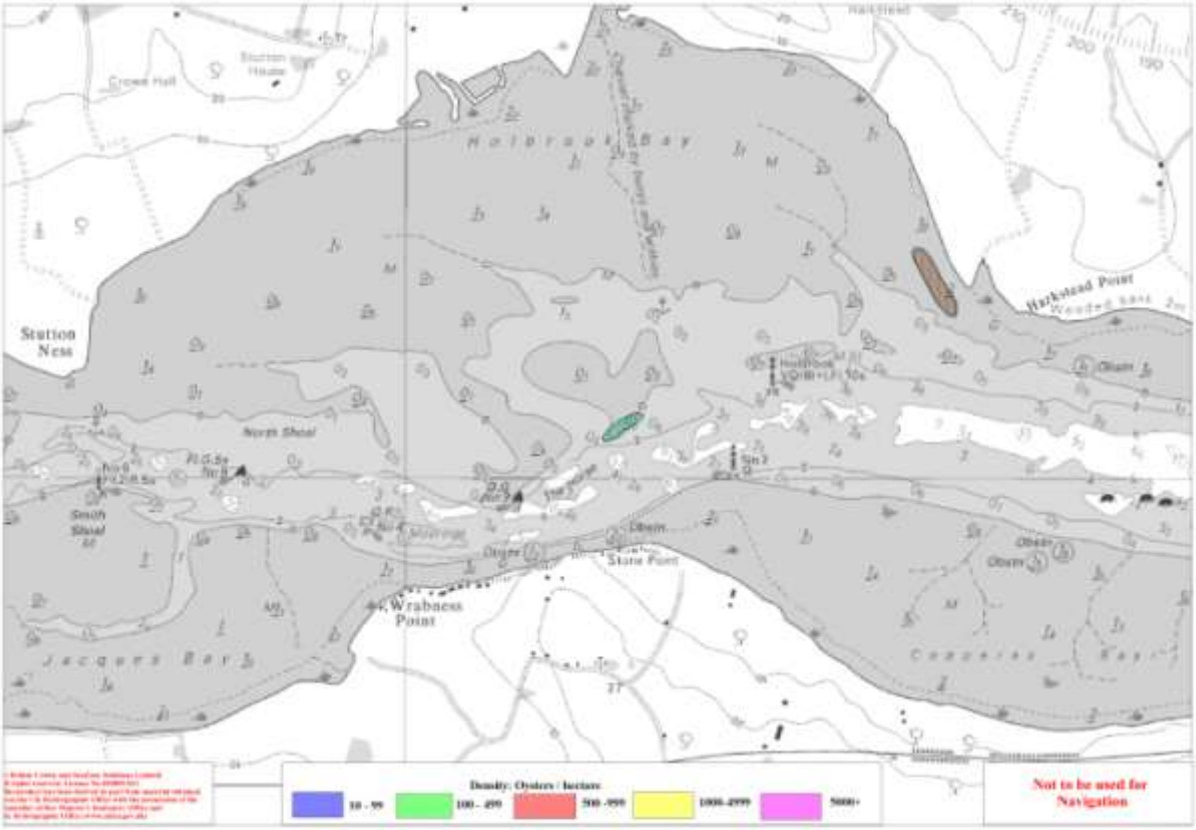


Figure 8.5 - Distribution of Pacific oysters, *Crassostrea gigas*, found during the 2013 surveys.

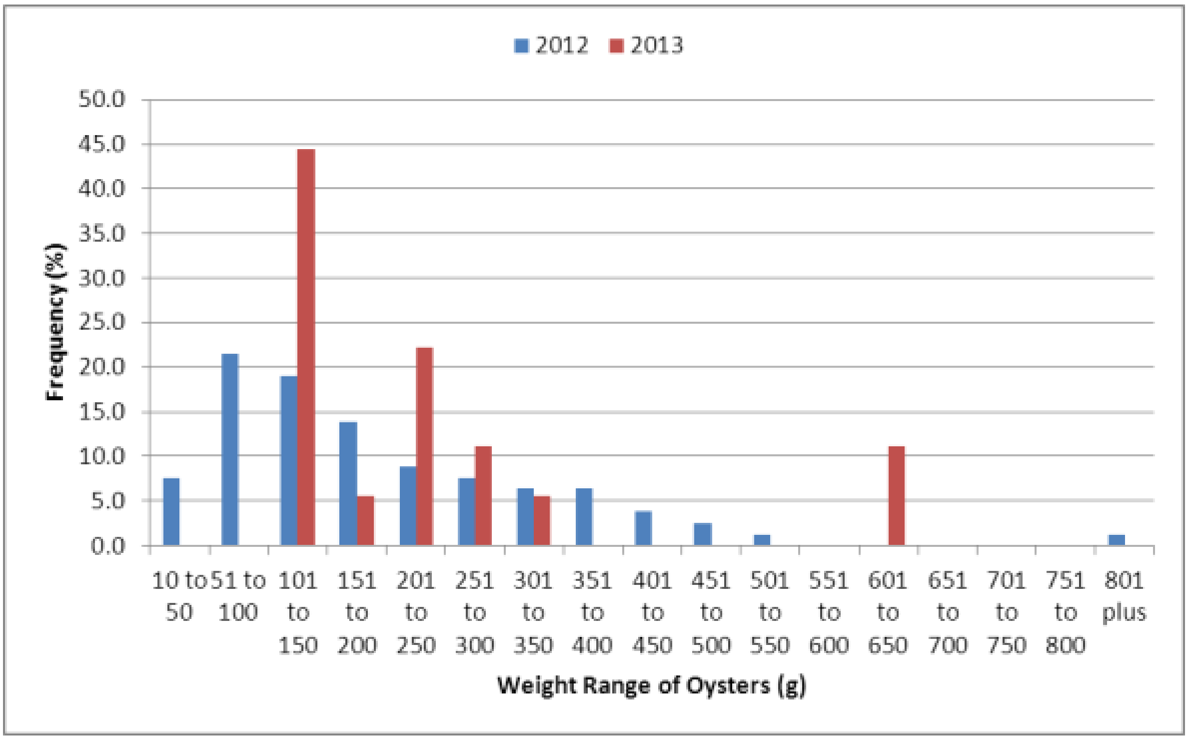


Figure 8.6 - Weight ranges of Pacific oysters, *Crassostrea gigas*, found at Holbrook Bay during the 2012 and 2013 surveys.

The oysters in this river were found to be located predominantly on ground composed of gravel and cobbles over muddy sand. There is a rich biodiversity at the site, with Slipper Limpet, *Crepidula fornicata*, being the predominant species.

8.2.4 Discussion

Table 1 shows the estimated biomass of native oysters, *Ostrea edulis*, present at Holbrook Bay between 2004 and 2013. From this table it can be seen that the population has declined by more than ten-fold during this period. The cause of this decline is not clear, but might be associated with an abnormal shell condition that was first noticed on the oysters in 2005. Although Cefas were not able to identify pathogenic cause for the condition, many of the older oysters exhibited soft, sponge-like outer edges to their upper valves. This condition was still present in 2006, when the stocks were found to have declined further. The incidence of this condition has been greatly reduced on subsequent surveys, but apart from a slight recovery in 2007, the stocks have continued to decline.

Table 8.1 - Estimated biomass of native oysters present in Holbrook Bay between 2004 and 2013, the mean weight of individual oysters and the proportion of Year-0 juveniles

Year	Total Oyster Stock (tonnes)	Mean Weight (g)	Proportion Year-0 (%)
2004	11.55 – 17.33	149.43	15.1
2005	6.47 – 10.80	160.88	13.8
2006	3.33 – 5.00	124.14	23.7
2007	6.63 – 11.05	136.25	18.2
2008	3.48 – 5.80	132.45	18.6
2009	1.9 – 3.2 (*)	205.42	9.2
2010	3.73 – 6.21	124.13	32.7
2011	n/a	n/a	n/a
2012	0.58 – 0.96 (**)	175.47	15.8
2013	0.92 – 1.54 (**)	128.00	34.5

** Survey results likely to have been under-estimated due to poor weather*

***. Whereas a commercial fishing vessel had been used for all of the surveys prior to 2012, the Kent & Essex-IFCA research vessel, Tamesis, was used for the latest two surveys. This change in vessel is not thought to have had an impact on the survey results, as the same dredge and sampling protocols were used as during previous surveys. Although the faster deployment and recovery of the dredge from the commercial boat allowed slightly more tows to be conducted, the coverage of the surveys remained similar. As the results from the full series of surveys indicate the stocks have been declining since 2004, the recent declines are believed to be real rather than artefact associated with the vessel being used.*

In 2010 a population of young oysters were found to have settled on the southern side of the river at Copperas Bay. From table 8.2, which shows the details of the oysters on this bed, their population appeared stable during the first two surveys but then declined 82% by 2013.

Table 8.2 - Estimated biomass of native oysters present in Copperas Bay between 2010 and 2013, the mean weight of individual oysters and the proportion of Year-0 juveniles

Year	Total Oyster Stock (tonnes)	Mean Weight (g)	Proportion Year-0 (%)
2010	2.14 – 3.57	105.10	26.3
2012	2.03 – 3.38	87.45	40.8
2013	0.37 – 0.62	132.67	33.3

Although there is no clear reason for this recent decline, it could be due to a change in substrate. When initially surveyed in 2010, the oysters were found to have settled on a gravel bank that contained little mud. When surveyed in 2013, more mud was present in the samples (RW Jessop, Pers com). Similarly, when first surveyed in 2004, the samples collected from Holbrook Bay were relatively free of mud compared to later surveys. Because oysters cement themselves to the substratum, this change of sediment could have been deleterious to the population. In addition to potentially smothering adults, suitable substrata for larval settlement could also have been smothered. Slipper limpets, *Crepidula fornicata*, which are common in the River Stour, could also be having an adverse impact on the oyster populations. Not only do they compete for space and food with oysters but the accumulation of their faeces and pseudo-faeces smothers oysters and renders the substratum unsuitable for settlement (Blanchard, 1997; Eno et al., 1997). The settlement at Copperas Bay in 2010, while indicating oysters are still successfully settling on favourable sites in the River Stour, also demonstrates their vulnerability.

In 2012 high densities of Pacific oysters, *Crassostrea gigas*, were found to be present within a localised area on the eastern side of Holbrook Bay. Although this was the first survey in which the bed had been identified, the size structure of the population suggested the bed was not from a recent settlement, and could have been present at the time of the earlier surveys. Although once established, colonies of Pacific oysters can rapidly colonize an area, potentially competing with *Ostrea edulis*, their current presence in just one part of the bay does not suggest they are responsible for the decline of the native species in Holbrook Bay. Instead, the results from the 2013 survey would suggest their own population is declining, too.

8.3 North Mistley Mussel Bed

8.3.1 Introduction

In 2013 the Stour and Orwell Estuaries were collectively put forward as a recommended Marine Conservation Zone through the Balanced Seas project. In addition, a section of the upper Stour estuary, referred to as North Mistley, was put forward as a recommended Reference Area through the same process. Blue mussel beds were listed as a Habitat of Conservation Importance for this Reference Area. Eastern-IFCA regularly survey the Stour & Orwell estuaries to assess the distribution and estimate the biomass of commercial bivalve shellfish populations therein, but until 2012 these surveys did not extend as far upriver as North Mistley. In recognition of the fact that North Mistley had been proposed as a Reference Area, with *Mytilus edulis* beds named as a Habitat of Conservation Importance, the Authority conducted two surveys in the area in 2012 (Jessop, Akesson & Smith, 2012). The first of these surveys was conducted in February, but due to poor light conditions during the low water period, no mussel beds were identified. During the second survey, which was conducted in better light conditions in July, three small beds were identified and a survey conducted on one of them (see figure 8.7). In order to gain greater knowledge of these beds, a further survey was conducted in September 2013.

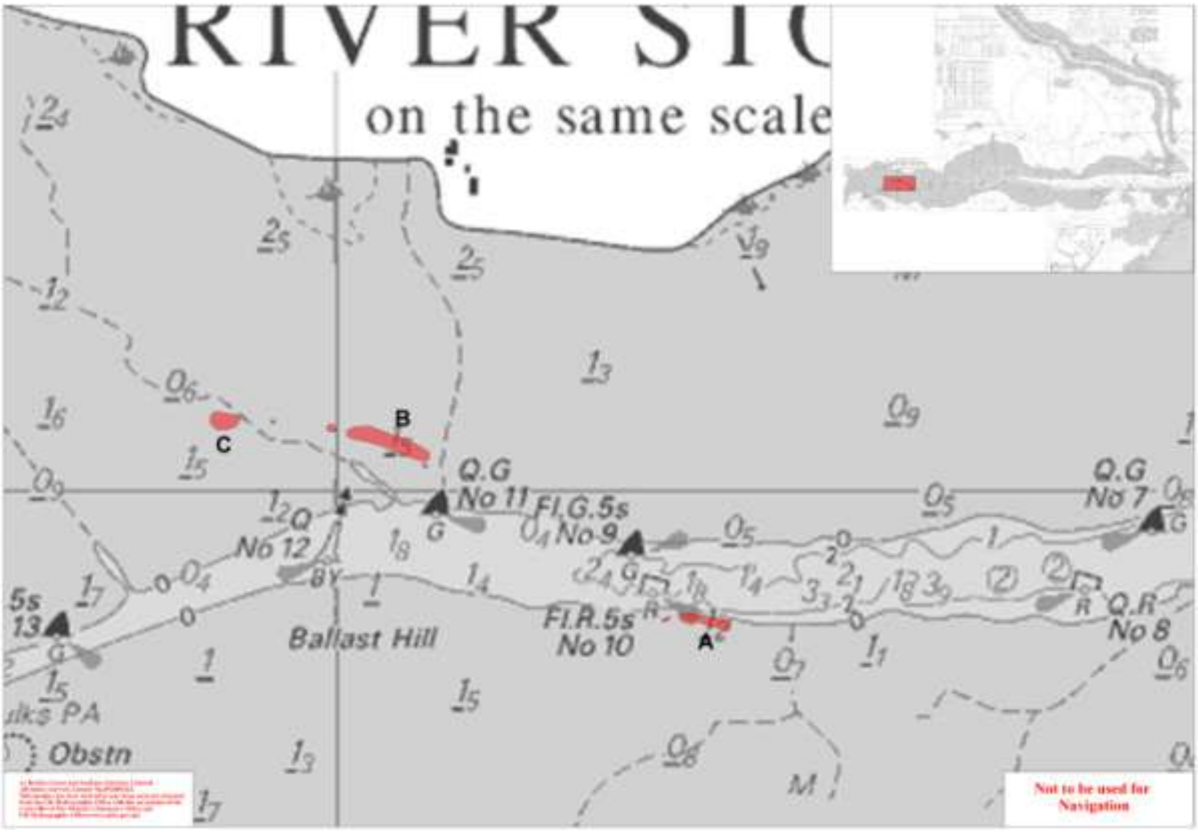


Figure 8.7 - Chart showing the three mussel beds identified on 11 July 2012

8.3.2 Method

The surveys conducted in 2012 had attempted to access the beds on foot at low water from the nearby channel using a Rigid Inflatable Boat. The soft muddy conditions around the beds had made this difficult, however, necessitating some of the beds being observed from a distance. For the 2013 surveys, a slightly different approach was used. Rather than attempting to reach the beds at low water from the channel, a small tender was used on the ebbing tide to access them directly as they emerged from the water, negating the need to wade through mud (see figure 8.8). Although this method proved easier and safer than before, it was only possible to access two of the beds in this manner before the tide fell too low. For the beds that were unable to be reached, observations were made from the nearby channel.

Figure 8.8 – Accessing emerging mussel bed from channel using tender

The two beds that were accessed had their perimeters were measured using a hand-held GPS. These data were later analysed using MapInfo GIS to chart their positions and to determine their areas. Their small size did not warrant a full foot survey, has conducted on the Wash inter-tidal beds (see Section 2, Wash Mussel Stocks). Instead the mussel coverage within each bed was determined by throwing random quadrats into the bed and recording the proportion of hit/misses. Samples from the hits were then used to determine patch density.

8.3.3 Results

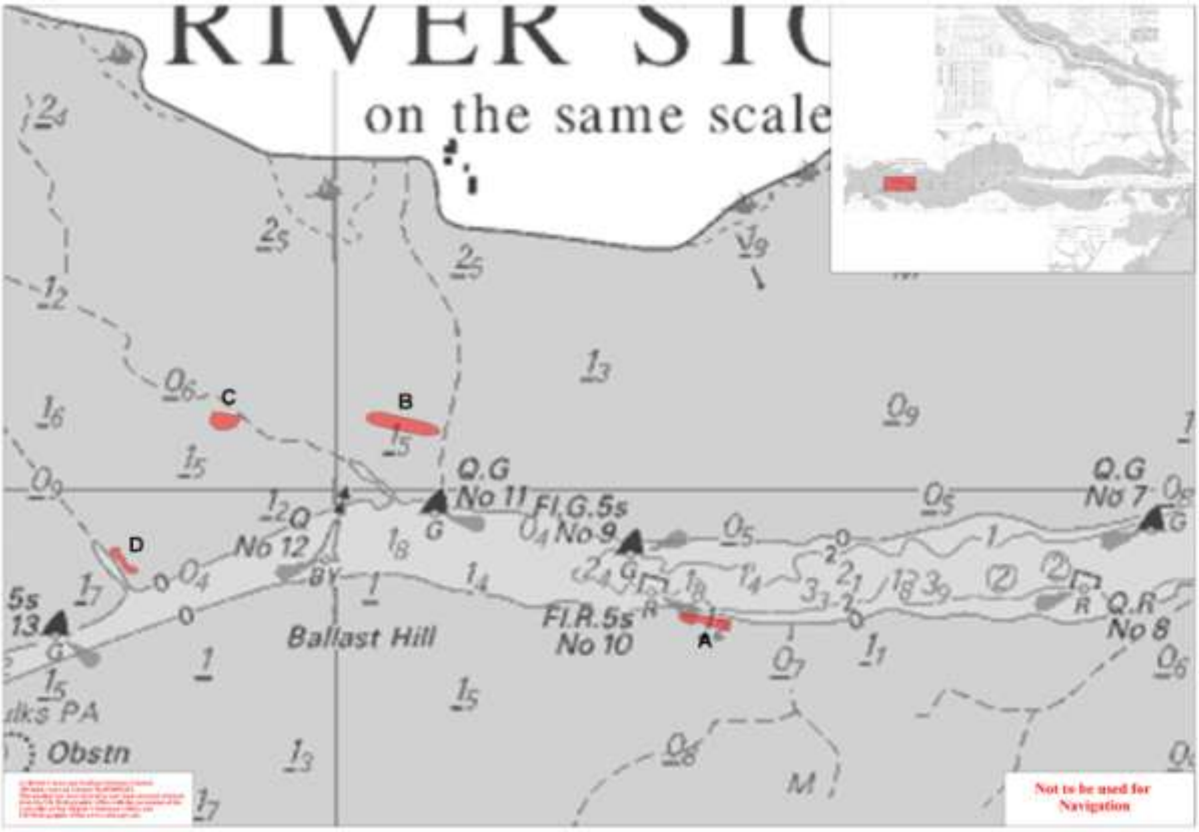


Figure 8.9 - Chart showing the four mussel beds identified on 30 September 2013

Figure 8.9 shows the position of the four beds surveyed on 30 September 2013. This chart is comparable with the one made following the 2012 surveys (see figure 8.7), which had previously identified beds A-C, but also includes a further bed, D, identified during the 2013 survey. In 2012 a foot survey had been conducted on bed A, but it had not been possible to access the other two beds on foot (Jessop, Akesson & Smith, 2012). During the 2013 survey, beds B and D were accessed on foot, while beds A and C were observed from the nearby channel. Table 8.3 details the results and observations made during the 2012 and 2013 surveys. Figures 8.10 and 8.11 show the size distributions of the mussel populations at sites B and D in 2013.

Table 8.3 Observations made during survey of North Mistley mussel beds – September 2013

Bed	Observations
A	The perimeter of this bed had been recorded during a foot survey conducted on July 2012. The area of the bed was calculated to be 150m^2. At that time a sparse coverage of old mussels were found to be present attached to a bed of gravel, shell and mud. The bed was only observed from the channel during the September 2013 survey but mussels were still seen to be present.
B	The position of this bed had been estimated from the channel during the July 2012 survey. It was accessed on foot during the 2013 survey and its position recorded using a hand-held GPS. This more accurate positioning placed the bed 30 metres further north than had been previously estimated. The area of the bed was calculated to be 310m^2. From the occupancy of randomly thrown quadrats, the mussel coverage was calculated to be 14%. From a measured sample the patch density was calculated to be 3.15 kg/m^2 of which 1.48 kg/m^2 had attained a size of 50mm length. The biomass of mussels on this bed was calculated to be 1,371 kg of which 642 kg had attained a size of 50mm.
C	This bed was not accessed on foot during either the July 2012 or September 2013 surveys. A sparse coverage of mussels was observed from the nearby channel during both surveys. The position of the bed was estimated during the July survey.
D	This bed had not been identified during either of the surveys conducted in 2012 but had been mentioned in the North Mistley Assessment Document. It was accessed on foot during the 2013 survey during which its perimeter was recorded using a hand-held GPS. The area of the bed was calculated to be 80m^2 From the occupancy of randomly thrown quadrats, the mussel coverage was calculated to be 20%. From a measured sample the patch density was calculated to be 2.66 kg/m^2 of which 1.44 kg/m^2 had attained a size of 50mm length.The biomass of mussels on this bed was calculated to be 425 kg of which 230 kg had attained a size of 50mm.

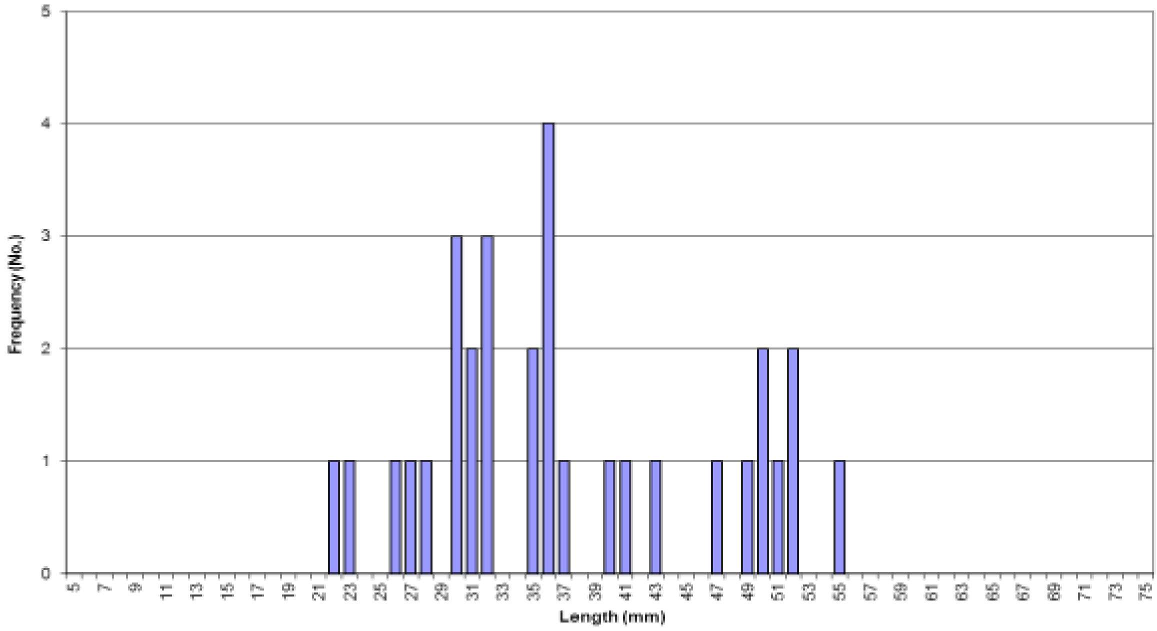


Figure 8.10 Mussel size frequency at Site B – September 2013

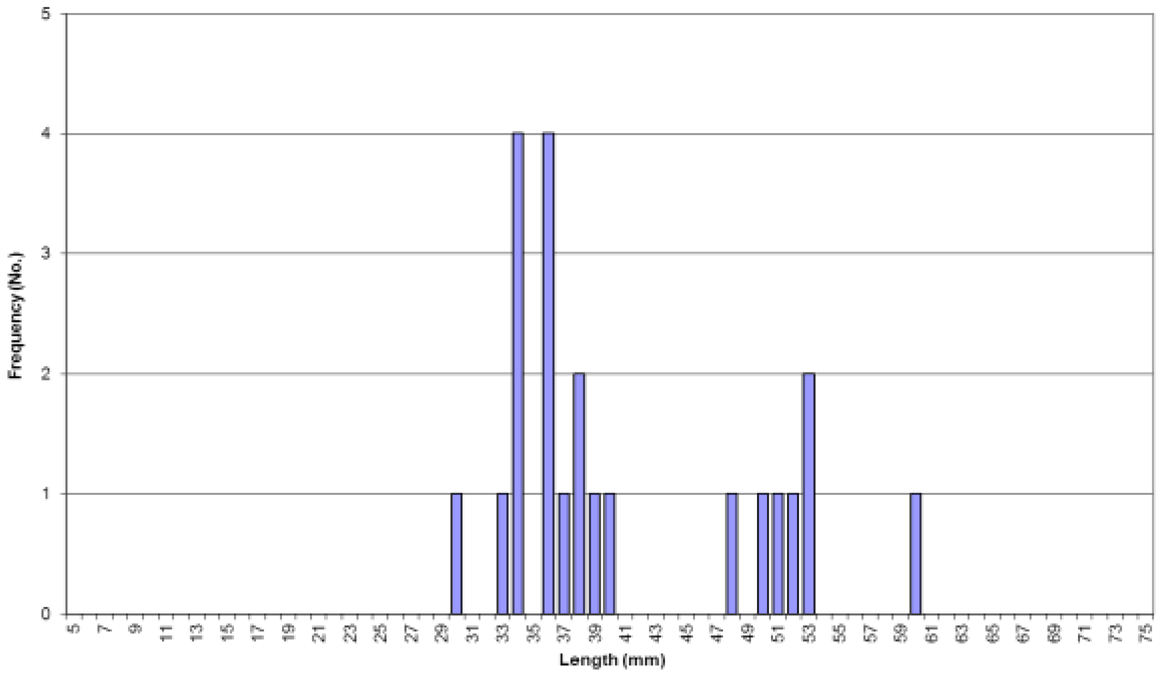


Figure 8.11 Mussel size frequency at Site D – September 2013

8.3.4 Discussion

The muddy bank edges of the River Stour support several small mussel beds at North Mistley. The Authority has attempted to survey these beds on three occasions during 2012 and 2013, but has found access to them difficult due to the soft mud that surrounds the beds. Nevertheless, during these surveys four discrete patches of bed have been charted, of which three have been surveyed. The results of these surveys show the beds range in size between $80m^2$ and $310m^2$, in which sparse populations of mussels grow amidst large numbers of old mussel shells. Together, these help form a firmer substrate than the surrounding mud flats. Also interspersed with the mussels are occasional slipper limpets, *Crepidula fornicata*, Pacific oysters, *Crassostrea gigas*, and native oysters, *Ostrea edulis*.

All of the mussels sampled from the beds were relatively large and heavily encrusted with barnacles, indicating they were old. There is an absence of any small mussels in the size distributions shown in figures 8.10 and 8.11, indicating there has been no recent recruitment on the two beds from which samples were taken. The lack of recent settlement could mean these beds are in decline.

9.0 DISTRIBUTION OF LANICE CONCHILEGA AND MACOMA BALTHICA ON THE INTERTIDAL SANDBANKS OF THE WASH

9.1 Introduction

The intertidal sandflats and mudflats of the Wash are numerically dominated by infaunal organisms of the polychaete and bivalve groups. Since 2007 the distribution of the burrowing polychaetes, sand mason worm (*Lanice conchilega*), lug worm (*Arenicola marina*) and the infaunal bivalve (*Macoma balthica)*, have been monitored. These three species are of particular interest because they occupy the same habitats as the cockle (*Cerastoderma edule*) and could therefore be affected by the hand-worked and hydraulic suction dredge cockle fisheries. Because these fisheries could potentially have a deleterious impact on the associated invertebrate population, the monitoring of these three invertebrate species has been incorporated into the annual spring cockle surveys along with descriptions of the sediment type present at each survey station.

While evidence of *Lanice* and *Macoma* can be collected using either Day grabs or quadrats, *Arenicola* burrow too deep to be collected in Day grab samples and their casts are too delicate to survive collection with a grab. The only data collected for *Arenicola* distribution, therefore, have come from foot surveys conducted at low water. These foot surveys are less extensive than the grab surveys, and their extent and location varies each year. Although the surveys have found *Arenicola* to have a wide distribution over the inter-tidal areas of the Wash, the disparity between the coverage of foot surveys makes comparison of *Arenicola* distributions from one year to the next difficult. For this reason, although *Arenicola* data were still collected during the 2013 surveys, this information has not been included in this report.

9.2. Methodology and Results

Sediment and infaunal invertebrate data were collected as additional information from each of the sample stations visited during the course of the spring cockle surveys (see section 3). These surveys were conducted between March 25th and May 9th, during which period 1,296 stations from a total of 21 sands were sampled. Of these 920 were collected over high water periods using a Day grab and the remaining 376 were collected at low water using a quadrat. Figure 9.1 shows the coverage of these sample stations.

The additional environmental data gathered during these surveys were entered into MapInfo GIS. Vertical Mapper software was then used to create interpolated models depicting the distribution of *Lanice, Macoma* and the sediment characteristics over the survey area. A Natural Neighbour interpolation method was used for this modelling process.

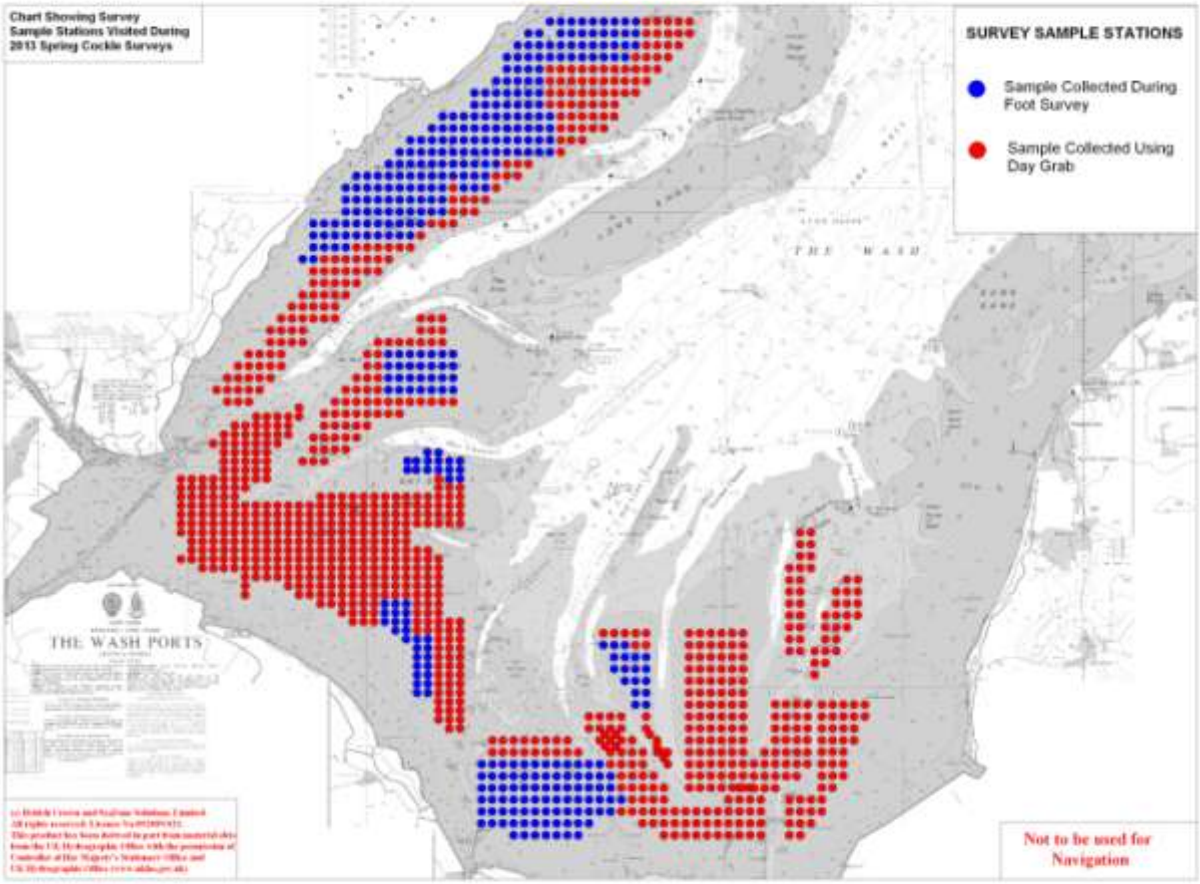


Figure 9.1 Chart showing the positions of the sample stations surveyed during the 2013 spring cockle surveys. Stations in red were sampled at high water using a Day grab. Stations in blue were sampled at low water with a quadrat.

6.2.1 Sand mason worm (*Lanice conchilega*)

Tubes constructed by the sand mason worm *Lanice conchilega* are readily visible at low water (Figure 9.2) and can be used to determine this species' presence. At each site visited on foot, three quadrats (0.1 m^2 per quadrat) were deployed, and the presence or absence of *L. conchilega* tubes was recorded for each. The density of *Lanice* at each site was determined by how many of the three quadrats the tubes were present in (see Table 9.1).

Table 9.1 Scale used to represent *Lanice conchilega* density within the survey areas.

Number of Quadrats per Sampling Site containing *Lanice* Tubes	**Density Scale in Models**
0	Absent
1	Low
2	Moderate
3	High

Figure 9.2 Tube of the polychaete *Lanice conchilega* at low tide in the Wash.

As *Lanice* tubes are sufficiently resilient to survive collection with a Day grab, it was also possible to record data on their distribution from sites sampled using Day grabs. Due to time constraints, however, samples were restricted to one grab per site. Densities were classified as either absent, when no *Lanice* were found in the grab, or moderate, when one or several *Lanice* were found in the single grab sample.

Figures 9.3 to 9.5 show the interpolated models of *Lanice* distribution within three areas of the Wash; Boston Main, south-west Wash and south-east Wash. These figures show the distribution of *Lanice* is more extensive in all three areas than during any of the previous surveys. This can be clearly seen in figure 9.6, which shows the proportion of stations in each area that have supported *Lanice* since 2008. The reason for this sudden increase is not believed to be due to any recent changes in fishing practices in the Wash. Although the harvesting method for the cockle fishery changed in 2008 from a predominantly dredged fishery to a hand-worked fishery, had this change been responsible for the recovery of *Lanice*, it would have occurred earlier.

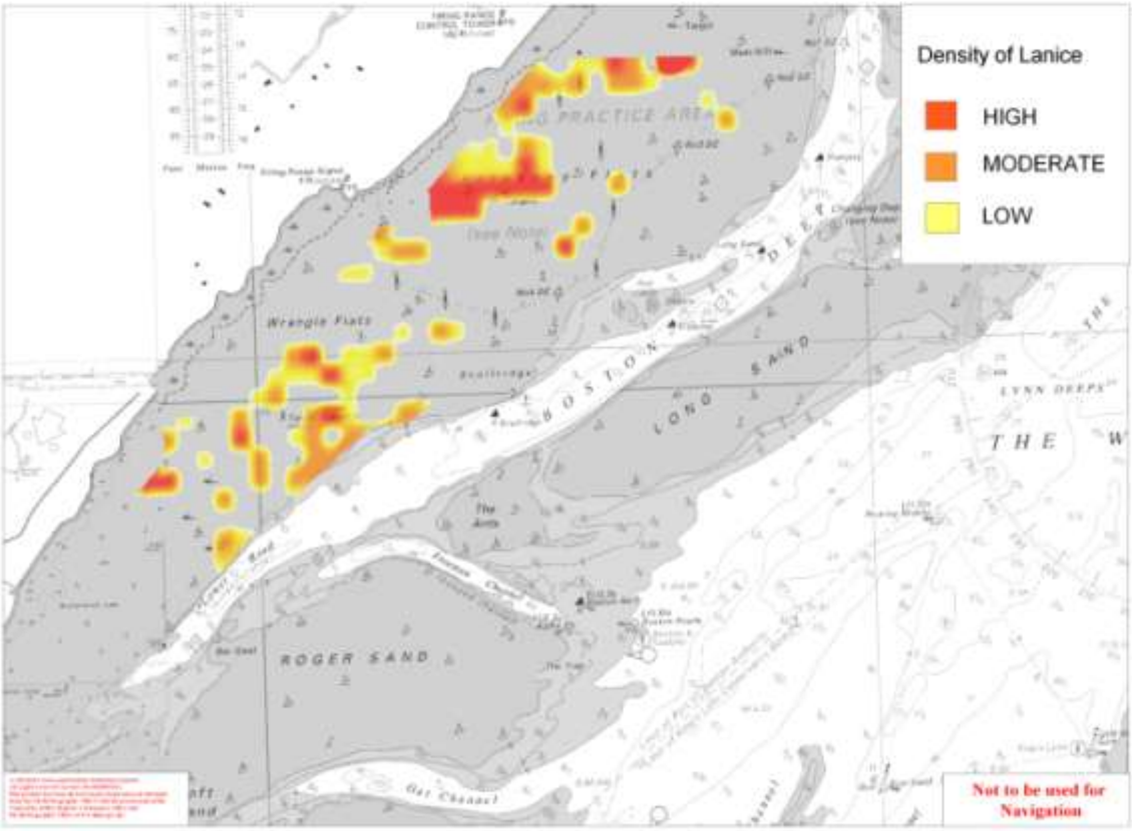


Figure 9.3 Distribution of *Lanice conchilega* within the survey sites of the Boston Main area sampled during the 2013 spring surveys

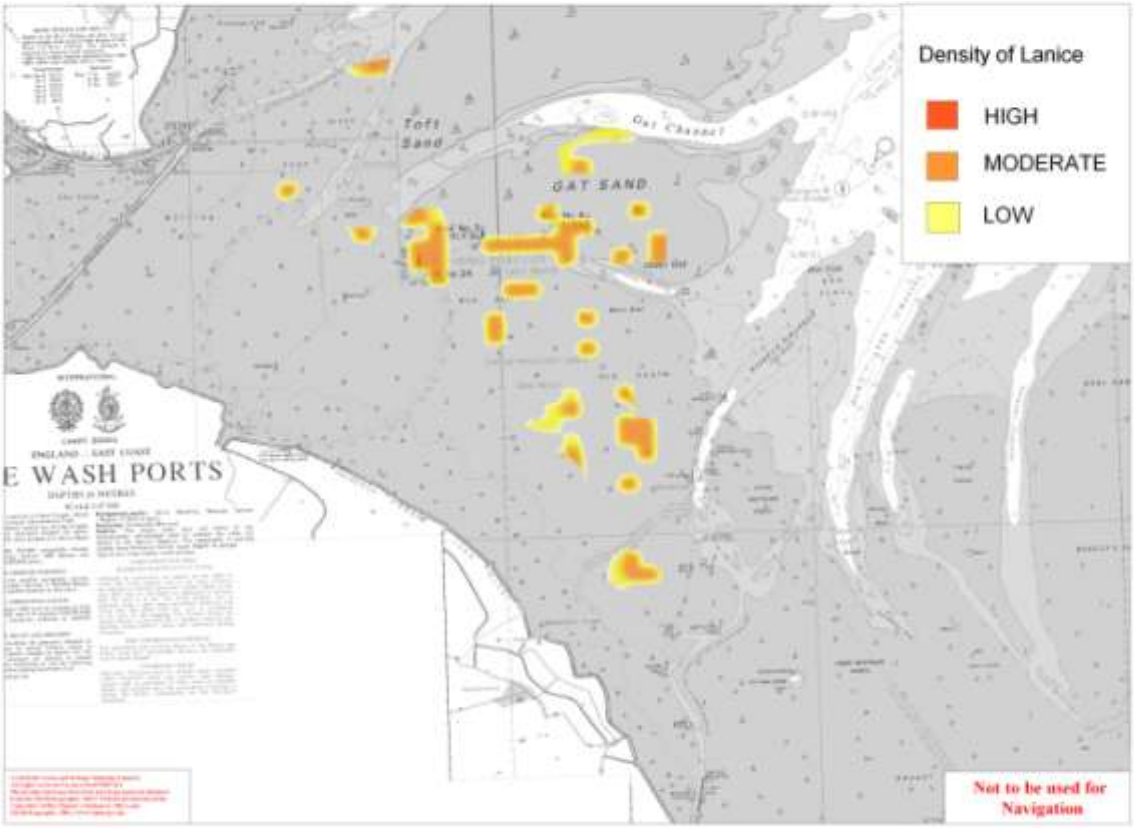


Figure 9.4 Distribution of *Lanice conchilega* within the survey sites at the southwest Wash areas sampled during the 2013 spring surveys

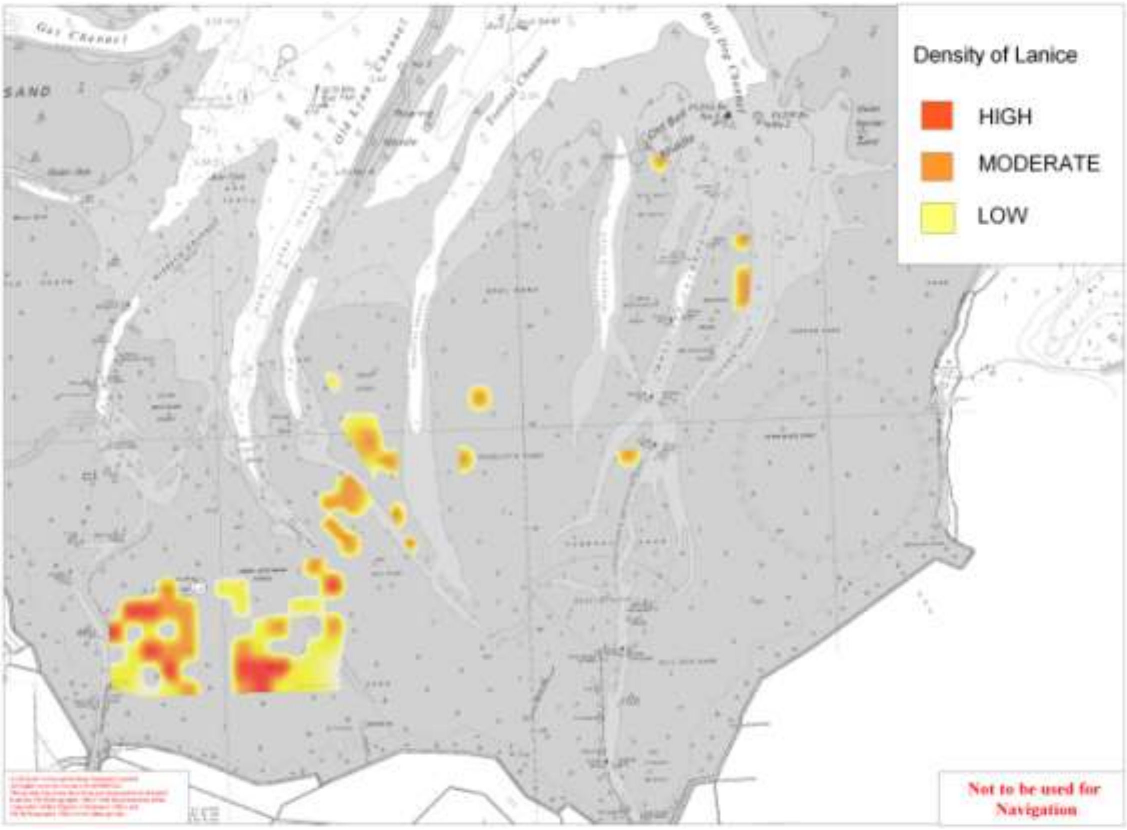


Figure 9.5 Distribution of *Lanice conchilega* within the survey sites at the southeast Wash areas sampled during the 2013 spring surveys.

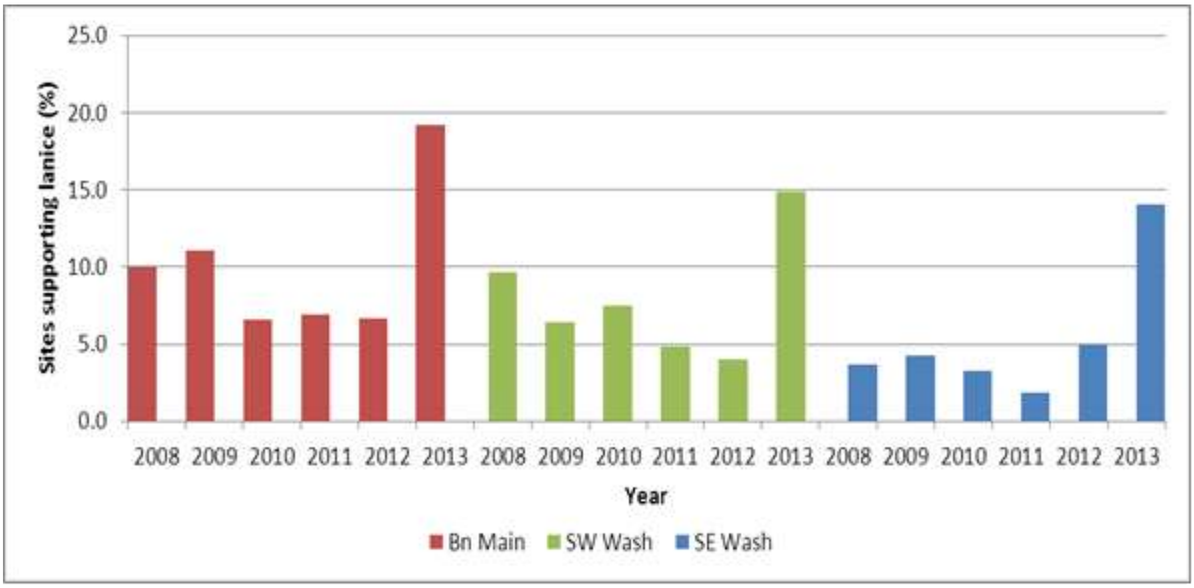


Figure 9.6 The proportion (%) of sites in each area that have supported *Lanice* since 2008

9.2.2 Baltic Tellin (*Macoma balthica*)

To collect data on the infaunal bivalve *Macoma balthica* one sample was collected per site with either a quadrat (0.1 m^2), if a foot survey was conducted at that particular site, or a Day grab (0.1 m^2). The number of *Macoma* present in each sample was recorded and density was established. Using Vertical Mapper^{TM} software, the data were spatially interpolated to create models depicting the distribution of *Macoma* over the survey area. The graduated scale used in these models to represent *Macoma* density is shown in Table 9.2. Figures 9.7 to 9.9 show these distribution models, while figure 9.10 shows the proportion of survey stations in each area that have supported Macoma each year since 2008.

Table 6.3 Densities of *Macoma balthica* found at each sampling station and density scale used in the models.

***Macoma* Density/m^2**	**Density Scale in Models**
0	Absent
1 - 10	Low
11 - 50	Moderate
>51	High

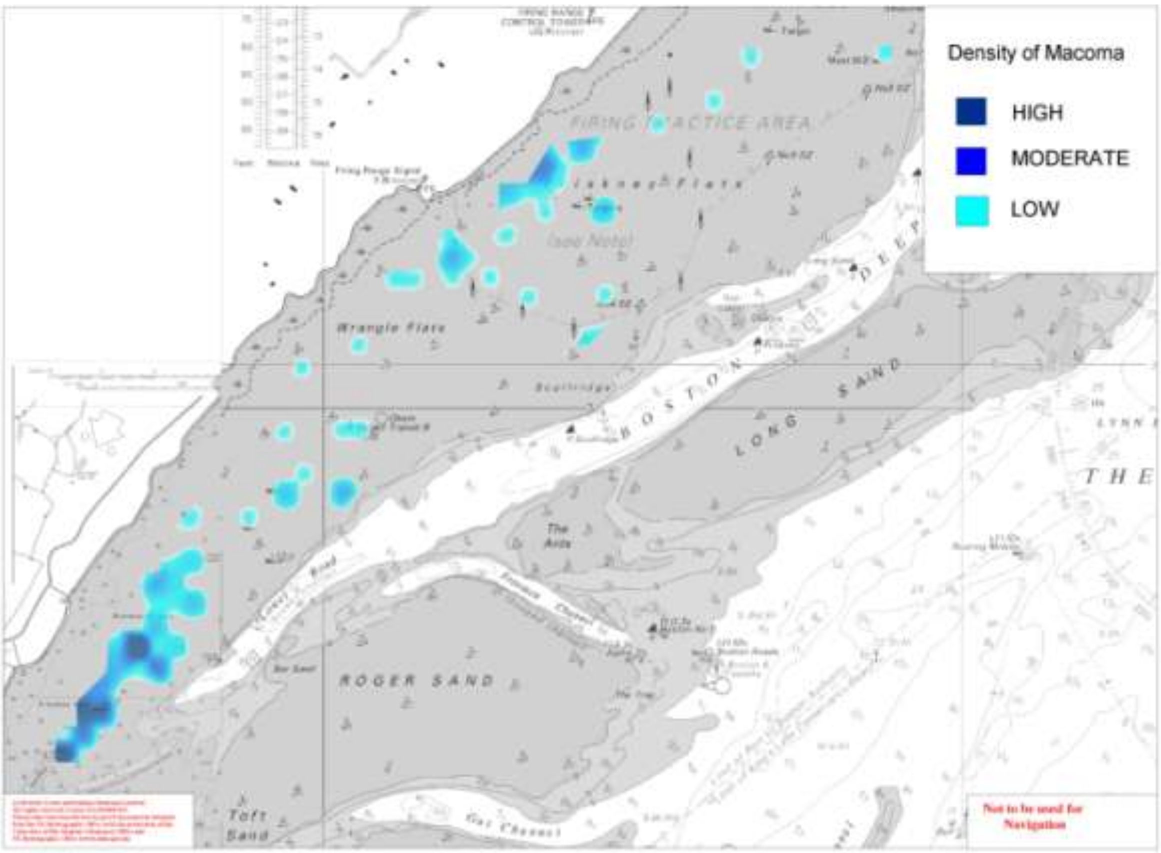


Figure 9.7 Distribution of *Macoma balthica* within the survey sites of the Boston Main area sampled during the 2013 spring surveys

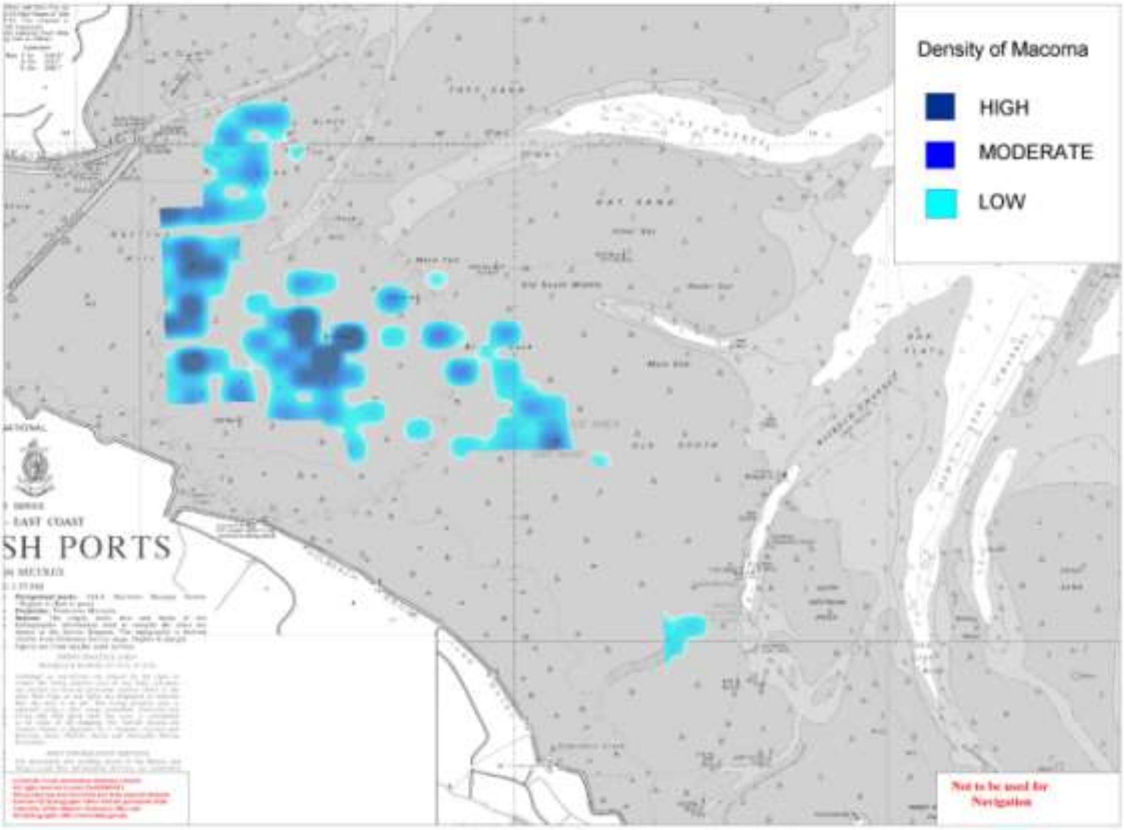


Figure 9.8 Distribution of *Macoma balthica* within the survey sites of the southwest Wash area sampled during the 2013 spring surveys.

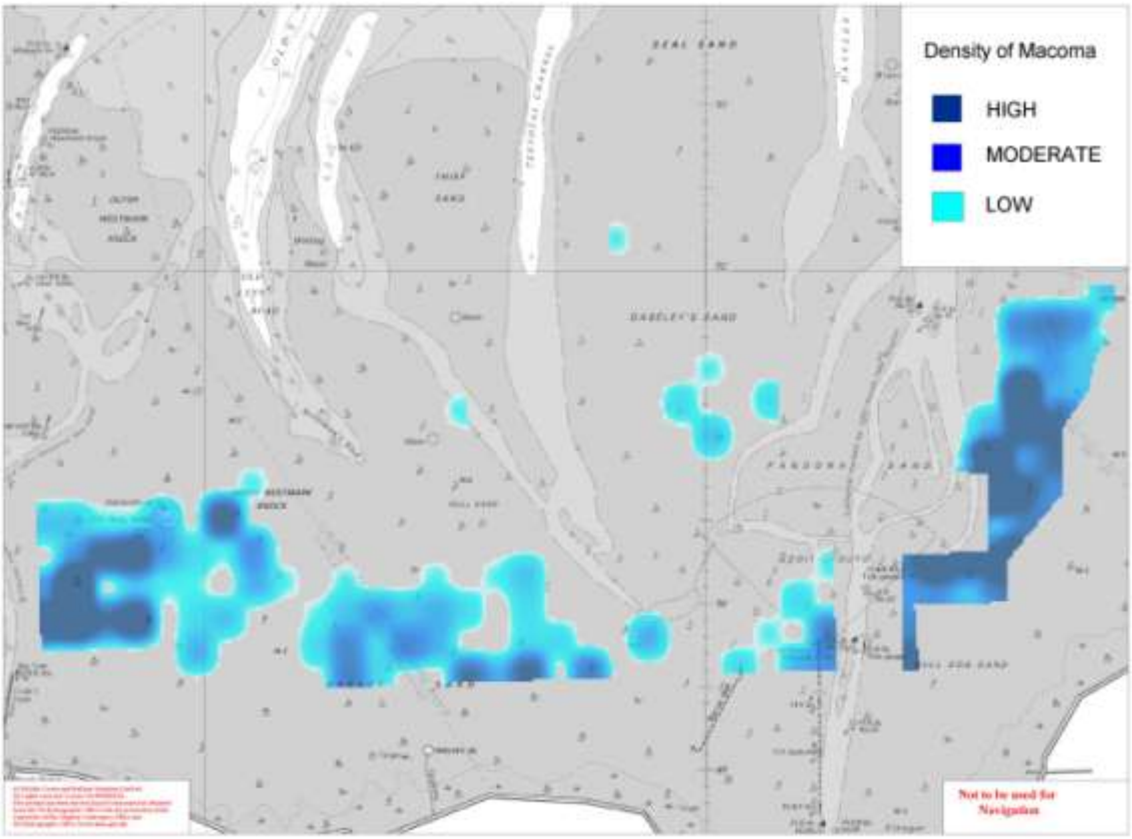


Figure 9.9 Distribution of *Macoma balthica* within the survey sites of the southeast Wash area sampled during the 2013 spring surveys.

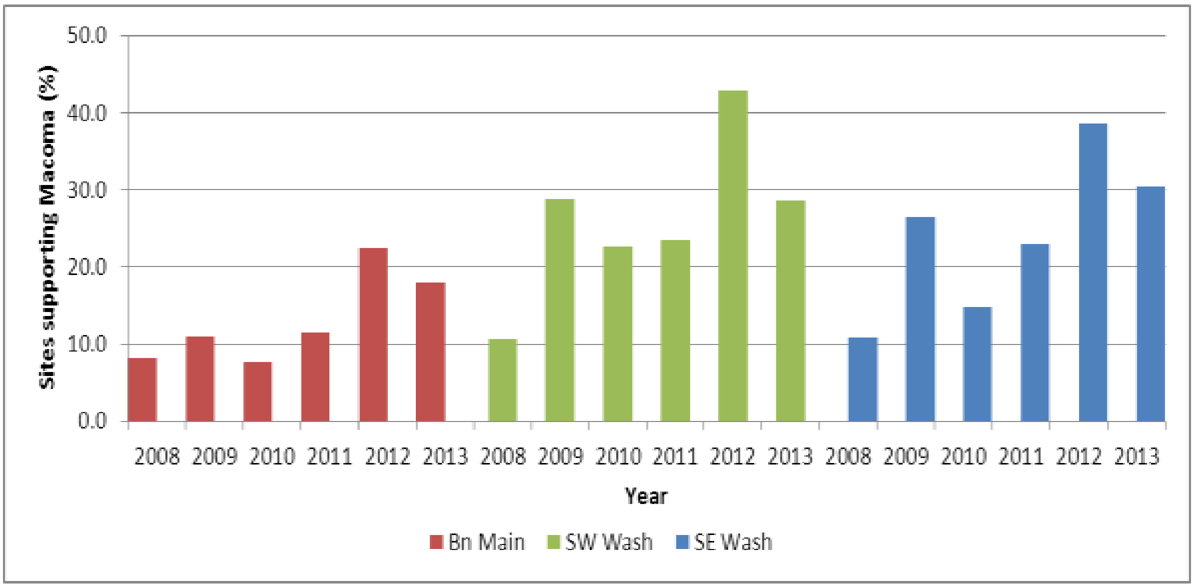


Figure 9.10 The proportion (%) of sites in each area that have supported *Macoma* since 2008

From figure 9.10 it can be seen that all three areas showed elevated distributions of *Macoma* in 2012. In all three areas the extent had declined from their 2012 peaks, but nevertheless remained above average. As had been the case with the elevated distribution of *Lanice* in 2013, the reason for these recent increases can only be guessed at. As both *Macoma* and cockles are burrowing bivalves, however, there will be competition between the two species for available space. This will be particularly so in the muddier areas favoured by *Macoma.* Following high levels of atypical mortality, cockle stocks were low in 2011. This reduced level of competition could have facilitated good settlements of *Macoma* during that summer that was subsequently seen in the 2012 survey.

6.2.4 Sediment

During the foot surveys and day grab sampling, notes on the sediment types encountered were recorded. The scale used to classify the sediment at each site has been used at ESFJC since 2006 and categories range from sand (coarsest) to anoxic clay (finest sediment type). Using Vertical Mapper^{TM} software, the data were spatially interpolated to create models depicting the sediment distribution over the survey area. A chart showing this sediment distribution can be seen in figure 9.11.

The sediment distribution was found to be similar to that of previous years. In the more exposed areas the predominant sediment types are sand and silty sand, while finer sediments dominate the more sheltered areas.

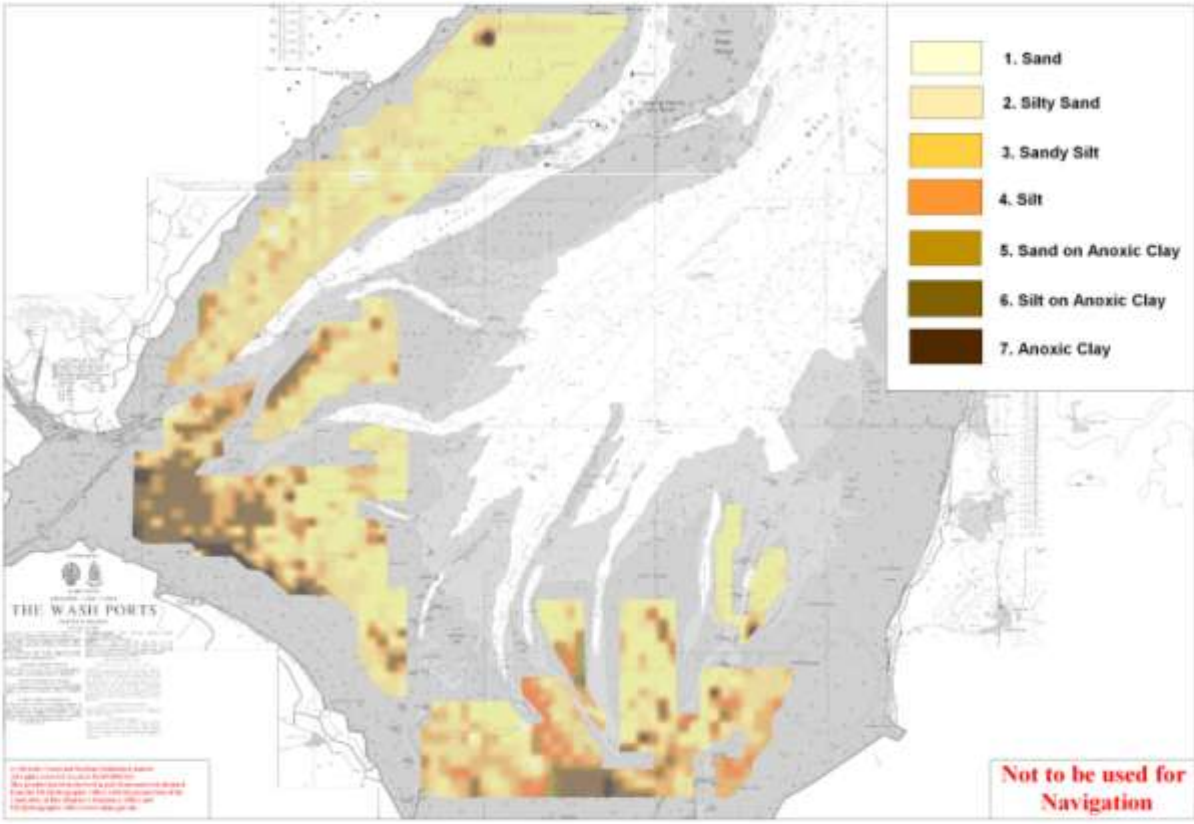


Figure 9.11 Sediment distribution in the areas of the Wash surveyed during the 2013 cockle surveys

9.3 Discussion

The distributions of *Lanice* and *Macoma* have been monitored each spring since 2008. When overlaid with the sediment distributions, the results from these studies have shown that *Lanice* has a preference for coarser sediments while *Macoma* has an overall preference for finer sediment. Due to these preferences, *Lanice* has been found in more abundance in the sandier areas of Boston Main and Holbeach, while *Macoma* had been found in the muddier areas of the south-east Wash and on Herring Hill and Mare Tail. Since 2012 the extent of the *Macom*a distribution has increased, while the extent of *Lanice* greatly increased in 2013. The reasons for these recent changes are unclear, but may be due to the low level of cockle stocks that were present in the Wash in 2011. The data do not suggest there is any relationship between these changes and the absence of a dredge cockle fishery since 2008.

10.0 BACTERIOLOGICAL AND BIOTOXIN SAMPLING

10.1 Introduction

Shellfish harvesting areas are required to be classified by the competent authority, the Food Standards Agency (FSA), to ensure food safety and public health in accordance with EC regulations 852/2004, 853/2004 and 854/2004 (The European Parliament and the Council of the European Union, 2004). The analytical approach is two-pronged and includes bacteriological analyses of shellfish meats (for the purposes of bed classification) and biotoxin analyses by means of both meat and water analyses.

10.2 Bacteriological Sampling - Bed Classification

Bed classification involves initial desktop and coastline studies to ascertain the degree of potential pollutant sources in and around a shellfish production area. Potential sources of contaminant include farmland, treatment plants and boats. Outlets near and into rivers and streams facilitate the transport of faecal coliforms onto shellfish beds where the degree and rate of deposition is affected by a host of physical and environmental factors such as bathymetry of the seabed, seasonality, wind and rainfall.

Based on this information, sanitary surveys are devised to optimise sampling representation and aim to quantify the presence of *Escherichia coli*, as a proxy of the concentration of faecal coliforms in a shellfish sample. Other viruses such as Norovirus are also tested for. This allows for a more rapid response to outbreaks, especially during very cold weather when shellfish filter-feeding, and therefore the purging of such contaminants, is at a minimum.

Under the current scheme, Local Action Groups and Local Action Plans provide an immediate and responsive mechanism for the investigation of *E. coli* sample results exceeding regulatory levels. There are government targets that aim to improve water quality in shellfish harvesting areas under the Water Framework Directive (European Commission, 2013). There has been significant investment in the improvement of sewage systems, although very few shellfish harvesting areas currently achieve an A-grade classification. Ultimately, water quality is one of the most important concerns for the shellfish industry and can cause significant issues for producers.

The testing procedure in the EIFCA district uses samples of *Cerastoderma edule* (common edible cockle), *Mytilus edulis* (blue mussel) and *Crassostrea gigas* (Pacific oyster) and at times has included *Ostrea edulis* (native or flat oyster) and *Ensis directus* (razor clam). Samples are collected monthly by a number of organisations, including the EIFCA, on behalf of Local Councils. EIFCA itself is currently responsible for collecting *C.edule* and *M.edulis* only.

Table 10.9 Classification criteria for harvesting areas (Cefas. 2014).

Class	**Microbiological standard**	**Treatment level**
A	All samples contain ≤ 230 *E. coli*/100g shellfish flesh.	None required (direct human consumption).
B	90% of samples must be ≤ 4600 *E. coli*/100g shellfish flesh; all samples must be less than 46000 E. coli/100g shellfish flesh.	Depurate (using approved methodology), relayed in an approved Class A relaying area or heat treated by approved methods before being sold for human consumption.
C	All samples must not exceed ≤ 46000 *E. coli*/100g shellfish flesh.	Must be relayed (minimum of 2 months) to meet Class A or B, or be heat treated.
D	Do not conform to at least class C.	Prohibited.

10.3 Biotoxin Sampling

C.edule, *M.edulis* and water samples are collected by EIFCA as part of this sampling regime on a monthly basis. Meats are used in the testing of Amnesic Shellfish Poisoning (ASP) associated with *Pseudo nitzchia*, Diarrhetic Shellfish Poisoning (DSP) caused by *Dinophysis spp*. and *Prorocentrum lima*, and Paralytic Shellfish Poisoning (PSP) caused by *Alexandrium spp*.

Unusually high biotoxin concentrations can often be triggered by plankton blooms where an influx of phytoplankton to a system may bring with it toxic algal species. The presence of these may cause a temporary increase in the detection of toxic species associated with ASP, DSP and PSP. Although the occurrence of one is not necessarily preceded by the other, they can give an indication as to whether a toxic event may be imminent in results.

Phytoplankton monitoring in England and Wales is being carried out by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of the Food Standards Agency. Water samples are collected from designated shellfish growing areas and analysed, by light microscopy, for various species of phytoplankton. These samples are collected concurrently with the meat samples.

Table 10.10. Action levels of flesh, water toxic algae levels and methods of analysis (Food Standards Agency, 2014).

	Flesh	Method of Analysis	Water	Method of Analysis
ASP	20µg/g flesh	High Performance Liquid Chromatography (HPLC)	Producing algae: 150,000 cells/L	Utermöhl method (Light microscopy and electron microscopy)
DSP	Presence	Liquid Chromatography Mass Spectrometry (LC-MS)	Producing algae: 100 cells/L	
PSP	80µg/g/100g flesh	High Performance Liquid Chromatography (HPLC)	Producing algae: presence >0 cells/litre	

Previously, the method for detecting potentially harmful PSP and lipophilic toxins was based on a test called the mouse bioassay (MBA). In 2006, the UK was the first European Union country to introduce HPLC (High Performance Liquid Chromatography) methodology into a statutory monitoring programme. This significantly reduced the reliance on the MBA test. In 2011, the FSA approved the replacement of the MBA for the detection of lipophilic toxins, including toxins responsible for Diarrhetic Shellfish Poisoning (DSP) with Liquid chromatography mass spectrometry (LC-MS) (Food Standards Agency, 2012). The introduction ensures increased confidence in monitoring results and addresses the scientific and ethical concerns identified with the mouse bioassay currently used in the monitoring programme.

10.4 Current Sampling Regime

Based on the current programme of monitoring, Table 10.11 outlines the current sample requirements from each site in the Wash from which Officers collect organisms. Figure 10.4 depicts the locations of these sampling sites. During site visits, water quality readings are taken using a YSI data sonde. Such concurrent data collection provides water quality parameter details utilised by Cefas. Samples are delivered to Cefas using temperature controlled biotherm boxes.

Table 10.11. Current bacteriological sampling requirements for The Wash.

Sample type	**Area**	**Zone**	**Species**
EHO	Friskney / Wrangle	1	*Cockle*
	North Lays / Witham Bank	1	*Mussel*
	Mare Tail	2	*Mussel*
	Breast	3	*Cockle*
	Breast	3	*Mussel*
	Stylemans	4	*Mussel*
	Training Wall	5	*Mussel*
	Welland Wall	6	*Mussel*
Biotoxin	Friskney / Wrangle	1	*Cockle*
	Mare Tail	2	*Mussel*
	Breast	3	*Cockle*
Water	Friskney / Wrangle	1	
	Mare Tail	2	
	Breast	3	
	Heacham South	4	

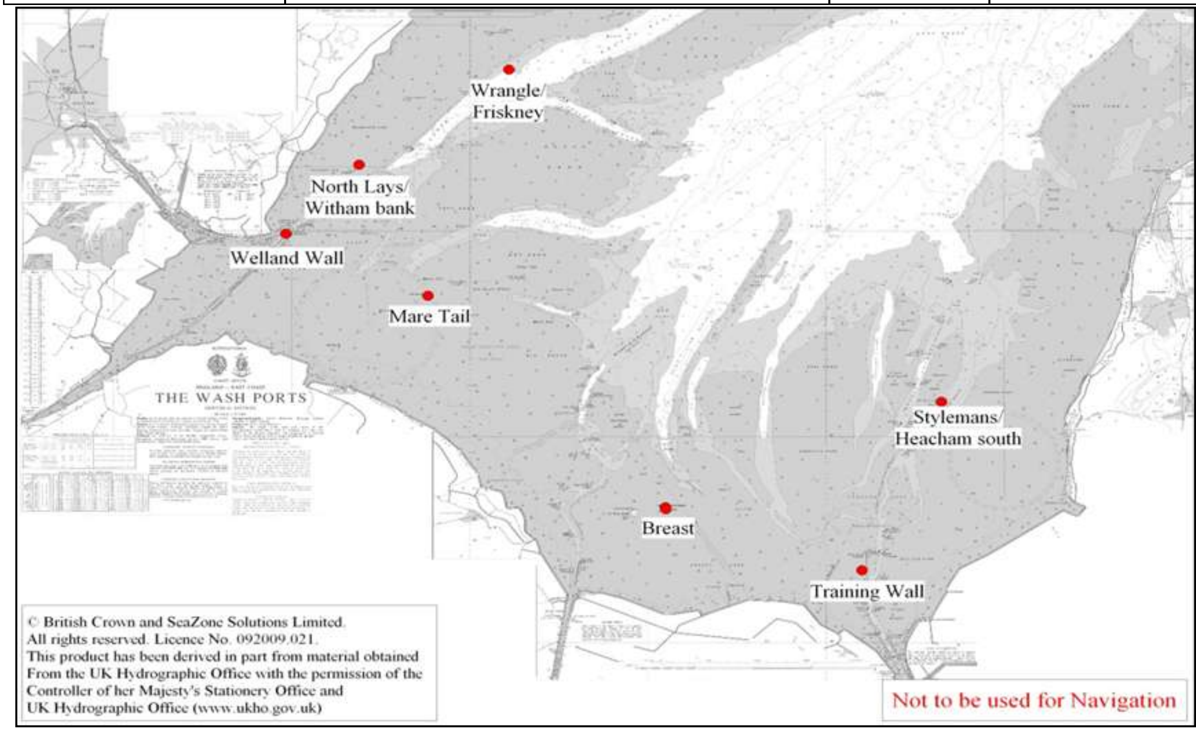


Figure 10.4. Bacteriological, Biotoxin and water sampling sites in the Wash for 2013.

10.5 Results and Discussion

The full list of classifications given for 1 September 2013 to 31 August 2014 for shellfish production areas in England and Wales can be found at:

http://www.food.gov.uk/enforcement/monitoring/shellfish/shellharvestareas/shellfishharvestingclassengwales/shellclassew201314#.Uxm5Js5ezTo

For microbiological results for individual harvesting beds in England and Wales (*E.coli* numbers in detail) and maps including maps of zones see (Cefas website):
http://www.cefas.defra.gov.uk/our-science/animal-health-and-food-safety/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/shellfish-monitoring-results.aspx

For recent biotoxin (ASP, DSP and PSP) and phytoplankton monitoring results see:
http://www.food.gov.uk/enforcement/monitoring/shellfish/ewbiotoxin/

Table 10.12 reports the classification results of bivalve production areas in the EIFCA district during 2014. Classifications are effective from the 1st of September until 31st of August of the following year. Sea zone maps for the individual species can be found in Figure 10.5 and Figure 10.6.

The latest classifications (2013-14) for those sites in which EIFCA collect samples are all of a B-grade, meaning that any shellfish gathered from within the EIFCA district are required to undergo depuration or other suitable treatment by producers prior to consumption (Table 10.9). The majority of the areas have achieved a long-term status, in that they have 5 years of compliance data with 90% or better compliance with 4600 *E.coli*/100g. 2013 saw an upgrade of site status, with the Welland Wall site being upgraded from C to B grade. These bed classification results are generally good, but the aim would be to achieve waters with an A-grade classification for all production areas within the EIFCA district. There have been no incidences of meat or water biotoxin samples containing toxic algae species above what is regarded as safe throughout 2013.

There are many factors which can influence the levels of microbiological contamination in mollusc flesh including environmental conditions, time of year and the quality and quantity of faecal contamination discharged into local coastal area. Sources of contamination include human and animal sources of pollution that can occur as point source inputs (e.g. discharges, outfalls and cracked pipes) or more generally as diffuse pollution (e.g. agricultural run-off). Although there have been many improvements in recent years, the identification and prevention of contamination from such sources is clearly difficult and represents an on-going challenge.

Table 10.12. Designated bivalve mollusc production areas in the Eastern-IFCA district. Effective from the 1st September 2013 (Food Standards Agency. 2014).

Production Area	**Zone**	**Bed Name**	**Species**	**Class**
The Wash - Boston	Zone 1 North	Butterwick Wrangle Friskney	*C. edule*	B
	Zone 1 South	Witham Bank/ North Lays	*Mytilus spp.*	B – LT
	Zone 2 East	Maretail Tofts Ridge Tofts South Gat Sand Toft Lays Herring Hill Black Buoy Holbeach	*C. edule* *Mytilus spp.*	B - LT
		Welland Wall	*Mytilus spp.*	B
The Wash – King's Lynn	Zone 3	Thief Breast Sand Inner West Mark Knock Daseleys	*C. edule*	B – LT
		Scotsman's Sled Thief Breast Sand Daseleys	*Mytilus spp.*	B - LT
	Zone 4 North	Heacham	*C. edule*	B – LT
		Hunstanton	*Mytilus spp.*	B - LT
	Zone 4 South	Ferrier Sand Pandora Stylemans South Daseleys	*C. edule* *Mytilus spp.*	B - LT
	Zone 5	Training Wall	*Mytilus spp.*	B - LT
Brancaster		Brancaster	*C. edule* *Mytilus spp.* *C. gigas*	B - LT
		Thornham	*C. gigas*	B - LT

Blakeney		Simpool	*Mytilus spp.*	B – LT
		South Side	*C. gigas*	B – LT
		Wells – The Pool	*Mytilus spp.*	B
River Alde		Home Reach	*C. gigas*	B – LT
Butley		Creek	*C. gigas*	B – LT
Deben		Girlings Hard Spinny Marsh Girlings Hard Stonner Point Shottisham Creek	*C. gigas* *Mytilus spp.* *C. gigas* *O.edulis* *Mytilus spp.(1)* *C. gigas* *C. gigas*	B

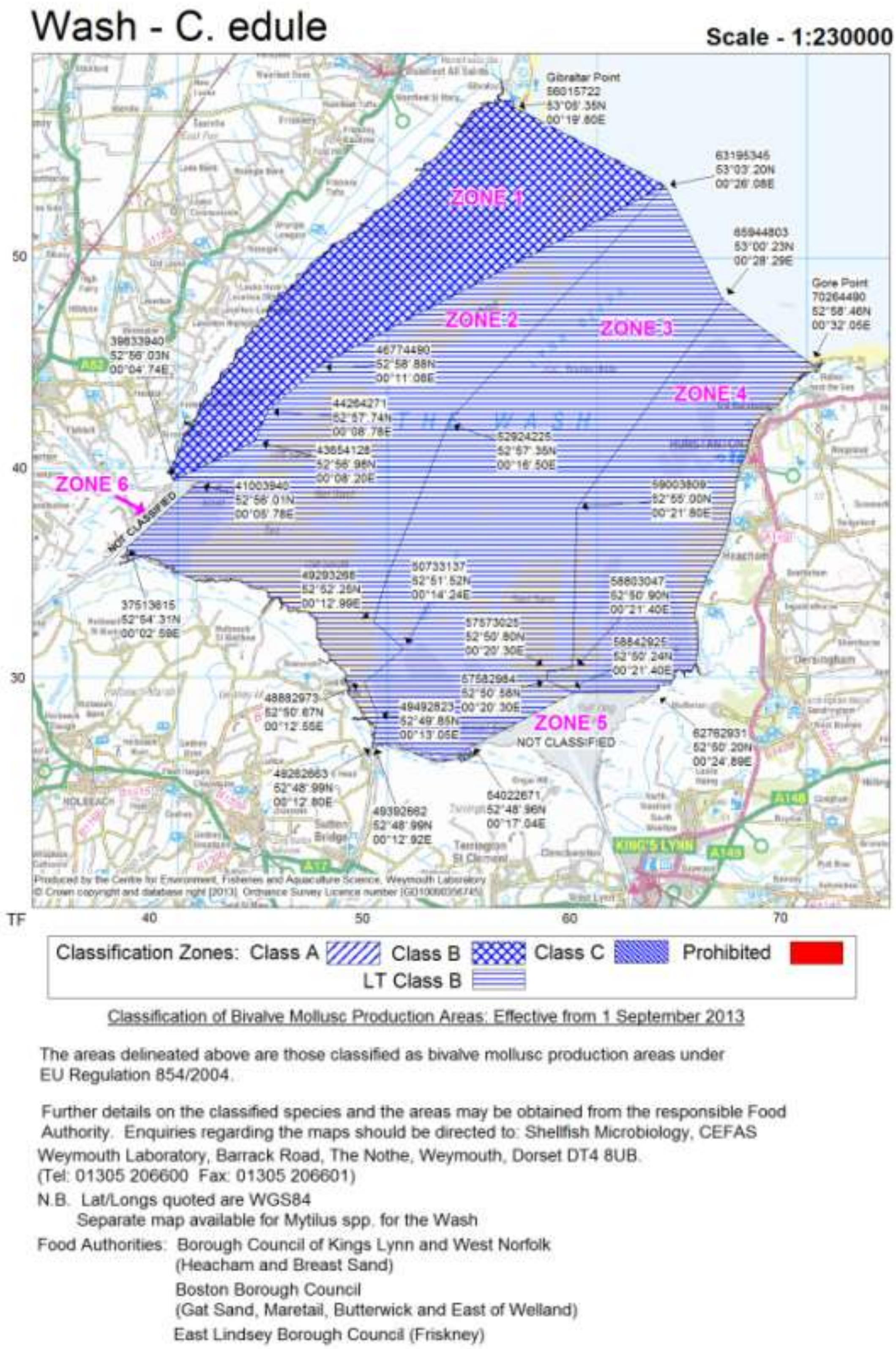


Figure 10.5. Classification of Bivalve Mollusc Production Areas. The Wash - *C.edule*. Effective from 1st September 2013 (Cefas, 2014).

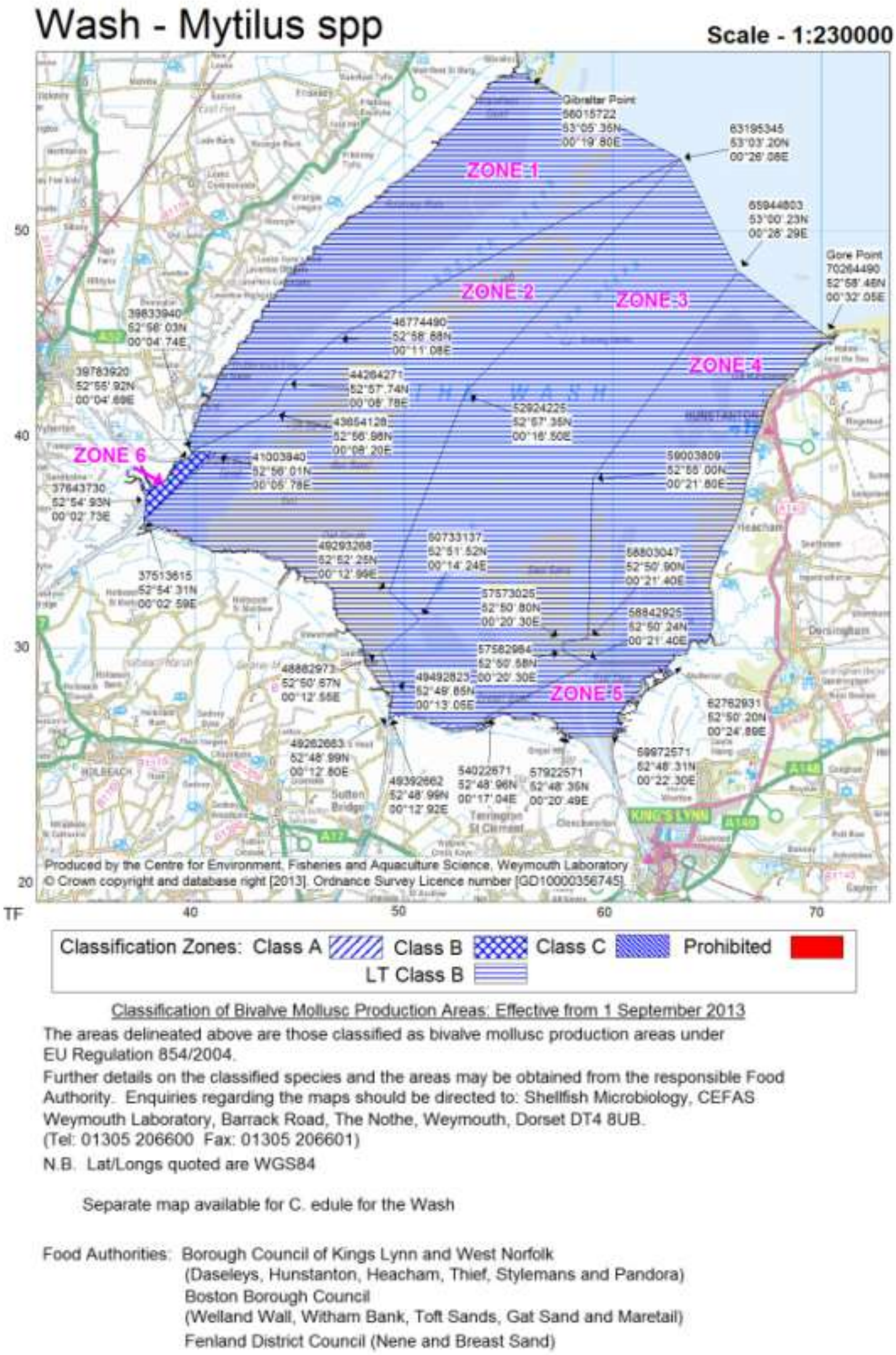


Figure 10.6. Classification of Bivalve Mollusc Production Areas. The Wash - *Mytilus* spp. Effective from 1st September 2013 (Cefas, 2014).

11.0 ACKNOWLEDGEMENTS

The research team of Eastern IFCA would like to thank the following people for their help and contributions to the 2013 research programme and the production of this report:

- The Masters and crews of the Authority's vessels and the shore based officers for their invaluable assistance in the collection of data.
- Temporary research assistant, Laura Rutland, for her contribution towards the field work and data entry during a transition period.
- Marine Environment/Data Officer, Luke Godwin, for his support in developing data bases, field work and facilitating MEDIN compliance of our data.
- All at Eastern IFCA office, in particular Dawn Reeve and Jodi Hammond for their efforts in printing and final production of this report.
- Kent and Essex-IFCA, for the use of their research vessel, Tamesis for the Holbrook Bay oyster survey
- Dave Sivyer, Veronique Creach and Katy Owen from Cefas for their continued help with the SWEEP project
- Koen Vanstaen, Suzanne Ware, David Limpenny, Nigel Lyman, Ken May and Bill Meadows from Cefas for their training and support with the side scan acoustic surveys
- Ewen Bell, Matthew Parker-Humphries, Derek Eaton and Colin Bannister (retired) from Cefas for their advice and support with the assessment of crustacean stocks.
- Michael Gubbins and his team at Cefas for their continued advice and support monitoring pathogens in our shellfish stocks.
- The Environment Agency for their Water Framework Directive fish survey data.
- Daniel Steadman, for his support in updating the MSAR database.
- Conor Donnelly and Emma Thorpe from Natural England, for their conservation advice and support.
- Fishermen throughout the District for their continued support and advice with projects.

12.0 REFERENCES

Addison, J.L. & Lovewell, S.R.J., (1991) Size composition and pot selectivity in the lobster (Homarus gammarus (L.)) and crab (Cancer pagarus L.) fisheries on the east coast of England. *ICES Journal of Marine Science* vol **48** (1): pp79-90.

Belyanina, T., (1969) Synopsis of biological data on Smelt., FAO Fisheries Synopsis No. 78

Bennett, D.B., (1995). Factors in the life history of the edible crab (*Cancer pagurus* L.) that influence modelling and management. *ICES Marine Science Symposia*, **199**, 89-98

Blanchard, M., (1997). *Spread of the slipper limpet Crepidula fornicata (L.1758) in Europe*. Current state and consequences. *Scientia Marina*, 61, Supplement 9, 109-118.

Centre for Environment, Fisheries and Aquaculture Sciences. (2013). *Classification and microbiological monitoring.* [Online](Updated 14 January 2014). Available at http://www.cefas.defra.gov.uk/our-science/animal-health-and-food-safety/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/shellfish-monitoring-results.aspx [accessed 26th March 2014].

Centre for Environment, Fisheries and Aquaculture Sciences, (2013). Classification Zone Maps- Wash-C.edule. [Online] (Updated 15 January 2013). Available at: http://www.cefas.defra.gov.uk/SHSWebModule/Wash%20C%20edule.jpg [accessed 26 March 2014].

Centre for Environment, Fisheries and Aquaculture Sciences, (2013). Classification Zone Maps- Wash-Mytilus spp. [Online] (Updated 15 January 2013). Available at: http://www.cefas.defra.gov.uk/SHSWebModule/Wash%20Mytilus%20spp.jpg [accessed 26 March 2014].

Colclough, S. & Coates, S., (2013) A Review of the status of Smelt *Osmerus eperlanus* (L.) in England and Wales

Department for Environment, Food and Rural Affairs,. 2012. *Marine Conservation Zones: Consultation on proposals for designation in 2013* [Online] London: DEFRA. Available at: http://www.defra.gov.uk/consult/files/mcz-condoc-121213.pdf [Accessed on 11 January 2013]

Eaton, D.R; Brown, J; Addison, J.T.; Milligan, S.P.; Fernand, L.J (2003) Edible crab (Cancer pagurus) larvae surveys off the east coast of England: implications for stock structure. *Fisheries Research*, **65**, 191-199.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J., (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56 pp.

Eno, N.C., Clark, R.A. & Sanderson, W.G,. (1997). *Non-native marine species in British waters: a review and directory.* Peterborough: Joint Nature Conservation Committee.

Food Standards Agency. (2013). *Official control biotoxin monitoring (live bivalve molluscs) programme (England and Wales).* [Online] (Updated 17th March 2014). Available at: http://www.food.gov.uk/enforcement/monitoring/shellfish/ewbiotoxin/ [accessed 26th March 2014].

Food standards Agency, (2014). *Shellfish Harvesting Classifications England and Wales: 2013-2014* [Online] (Updated January 2014). Available at: http://www.food.gov.uk/enforcement/monitoring/shellfish/shellharvestareas/shellfishharvestingclassengwales/shellclassew201314#.Uxm5Js5ezTo [accessed 26th March 2014].

Food standards Agency, (2012). *Designated Bivalve Mollusc Production Areas in England and Wales.* [Online] (Updated 20 December 2012). Available at: http://www.food.gov.uk/multimedia/pdfs/shc13.pdf [accessed 23 January 2013].

Food Standards Agency, (2012). *Animal testing for shellfish monitoring phased out.* [Online] (Updated 17 May 2012). Available at: http://www.food.gov.uk/news-updates/news/2012/may/shellfishtest [accessed 23 January 2013].

Graham, M., (1949) A note on the theory of a dwarf race of lobsters on the Norfolk coast. *Journal of the Marine Biological Association* vol. **28** pp481-487.

Grütjen, F., Lang, T., Feist, S., Bruno, D., Noguera, P., Wosniok W., (2013) Hyperpigmentation in North Sea dab *Limanda limanda*. I. - Spatial and temporal patterns and host effects DISEASES OF AQUATIC ORGANISMS Dis Aquat Org Vol. 103: 9-24,

Howard, A.E., (1980) Substrate controls on the size composition of lobster (*Homarus Gammarus*) populations. *ICES Journal of Marine Science* vol **39** (2): pp 30-133.

Howard, A.E., (1982) The distribution and behaviour of ovigerous edible crabs (*Cancer pagurus*) and consequent sampling bias. *Journal du Conseil.* **40**, 259-261.

ICES Bass Advice (2013) (accessible via {http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/bss-47.pdf})

ICES Dab Advice (2013) (accessible via { http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/dab-nsea.pdf})

ICES Flounder Advice (2013) (accessible via{ http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/2013/fle-nsea.pdf })

Jennings, S. & Pawson, M.G., (1992) The origin & recruitment of Bass *Dicentrarchus labrax* larvae to nursery areas. Journal of the Marine Biological Association of the United Kingdom, 72, pp 199-212.

Jessop, R.W., Akesson, O., & Smith, L.M., (2012). Eastern Inshore Fisheries and Conservation Authority Annual Research Report 2012. Eastern Inshore Fisheries and Conservation Authority, King's Lynn

Jessop, R.W. & Lowry, M., Graves, K.M., (2003). *Eastern Sea Fisheries Joint Committee Research Report 2003*. ESFJC, King's Lynn.

Jessop, R.W. & Graves, K.M., (2005) *Eastern Sea Fisheries Joint Committee Research Report 2005*. ESFJC, King's Lynn.

Jessop RW, Harwood AJP & Woo JR,. (2009). Eastern Sea Fisheries District Research Report 2009. Eastern Inshore Fisheries Joint Committee. Kings Lynn

Jessop, R. W. & Maxwell, E. (2012) Eastern Inshore Fisheries and Conservation Authority Annual Research Report 2011. Eastern Inshore Fisheries and Conservation Authority, King's Lynn

Linnane, A., Ball, B., Mercer, J.P., Browne, R., Van der Meeren, G., Ringvold, H., Bannister, C., Mazzoni, D., Munday, B., (2001) Searching for the early benthic phase (EBP) of the European lobster: a trans-European study of cobble fauna. *Hydrobiologia*. **465**: 63-72.

MAFF (1966) The Norfolk crab fishery. *Laboratory leaflet No. 12, Fisheries Laboratory, Burnham on Crouch*. 23pp.

MAFF Bass nursery areas and other conservation measures, (accessible via {http://www.cefas.defra.gov.uk/publications/techrep/Bass.pdf})

Pawson, M.G., Kelly, D.F., & Pickett, G.D., (1987) The distribution and migrations of bass , *Dicentrarchus labrax* in waters around England & Wales as shown by tagging. Journal of the Marine Biological Association of the United Kingdom, 67, 183-217

"Project Inshore", (accessible via {http://www.seafish.org/media/publications/Project_Inshore_Stage_1_report_SP.pdf})

Regulation (EC) No 852/2004 of the European Parliament and of the Council on the hygiene of foodstuffs, 2004. (c.1-11). Brussels: The European Parliament and the Council of the European Union.

Regulation (EC) No 853/2004 of the European Parliament and of the Council. laying down specific hygiene rules for on the hygiene of foodstuffs, 2004. C.1-4) Brussels: The European Parliament and the Council of the European Union.

Regulation (EC) No 854/2004 of the European Parliament and of the Council. Laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, 2004. (c.2). Brussels: The European Parliament and the Council of the European Union.

Rijnsdorp, A.D., Vethaak A.D., van Leeuwen, P.I., (1992) Population biology of dab *Limanda limanda* in the southeastern North Sea" MARINE ECOLOGY PROGRESS SERIES Mar. Ecol. Prog. Ser. Vol 91: 19-35

"Sea Angling 2012" (accessible via {http://www.marinemanagement.org.uk/seaangling/finalreport.htm})

Seafish Research and Development Species Guide – Grey Mullet, 2010 (Accessible via{http://www.seafish.org/media/379565/seafishspeciesguide_greymullet_201012.pdf}

Seafish "Responsible Sourcing Guide – Sole" Accesible via { http://www.seafish.org/media/Publications/SeafishSummaryofICESAdvice_JuneandOct2013_201311.pdf}

Skerrit, D.J., (2010) Literature review produced for Eastern JSFC "*A review of the European flounder Platichthys flesus - Biology, Life History and Trends in Population*"

van der Veer, H.W., Bergman, M.J.N., Rob Dapper, Johannes, R.D., Whitte, I.J., (1991) Population dynamics of an intertidal 0-group flounder *Platichthys flesus* population in the western Dutch Wadden Sea. MARINE ECOLOGY PROGRESS SERIES Mar. Ecol. Prog. Ser. 73: 141-148

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). MarinX-report 2004.41.1

Williams, W.D., (1986) Conductivity and salinity of Australian salt lakes. Australian Journal of Marine and Freshwater Research 37(2) 177-182