# Brown Crab Stock Assessment

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| Version | Date | Changes | Officer |
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| 1.0 | 27/07/2020 | Removal of LCCC models and YPR curves | TB |
| 2.0 | 22/09/2020 | Edits following internal review | TB |
| 3.0 | 05/11/2020 | Final edits following internal review | TB |

**2019 BROWN CRAB STOCK ASSESSMENT**

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## *Executive summary*

This report utilises data collected between 2012 and 2019 through MSARs and biometric sampling to assess the current stock status of the brown crab fishery within the Eastern Inshore Fisheries and Conservation Authority (EIFCA) district. The volume of landings in the district highlights the local economic importance of this fishery. District-wide Landings Per Unit Effort (LPUE) values for the data reporting period are either rising or are at a plateau, suggesting local brown crab stocks across the district as a whole, are stable and recruitment is sufficient to replace annual depletion from fishing. ICES statistical rectangle 34F1, in which Cromer Shoal Chalk Beds MCZ is located, is the most important fishing ground for brown crab within the district where >48% of reported landings from MSARs are fished. In contrast to the rising trend in district wide LPUE values, those from 34F1 have started to show a slight declining trend since 2016. This suggests the amount of effort taking place in this area may be putting the stocks under pressure and be reducing their density on the ground.

This report indicates that from a purely population sustainability perspective the brown crab fishery in the EIFCA district is currently not under immediate threat. Some management may be needed to ensure localised stock sustainability, but possible measures introduced through the Cromer Shoal Chalk Beds MCZ commercial fisheries assessment and the Fisheries Improvement Plan (FIP) will potentially satisfy sustainability drivers.

MSAR reporting forms are currently being replaced by an electronic reporting system which may result in a temporary absence in data available to EIFCA, impacting our ability to analyse and assess the fishery for a period of up to years. Replacement of MSARs has come at a critical point in management of the brown crab fishery with the potential to impact the assessment of the effects of any management introduced. This may also have implications when assessing progress of the Fisheries Improvement Plan (FIP), the potting assessment in Cromer Shoal Chalk Beds MCZ and any economic impacts of management.

### *Introduction*

Eastern IFCA initiated the current Crustacean stock assessment project in 2013, focusing on brown crab *(Cancer pagurus)* and European lobster (*Homarus gammarus*) stocks with the aim of developing the techniques necessary to conduct stock assessments at a localised level, building on the current understanding of potting fisheries operating within the district. Long term monitoring, coupled with input from the fishermen, enables a better understanding of impacts on the stock through fishing and ultimately informs management decisions in the fishery.

Historically, Eastern IFCA's brown crab and European lobster stock assessments have been reported together, but this year are reported separately. As such, this report focuses exclusively on the brown crab stock assessment.

### *Background to the fishery*

As a mixed fishery, both crabs and lobsters are important species for the fishing industry operating within the Eastern IFCA district, from Saltfleet in Lincolnshire, through Norfolk and down to the southern limits of the District in Harwich. The main fishing season for brown crab commences in March, peaks over the summer months and then drops off through to late October/November. European lobster is also an important target species for these fishers, with the main season generally following closely behind that for brown crab; starting around May and dropping off in October. Although potting activity occurs throughout the district, it is particularly prevalent along the North Norfolk coast; an area with long standing historical and cultural traditions of fishing for these species.

Historically, the fishery was an inshore mixed species creel fishery operating within 2nm of the coastline (MAFF, 1975), primarily due to limitations of the vessels and equipment. The introduction of larger vessels and the capability to store and transport live animals in subsequent years has increased the range in which potters operate, enabling fishing grounds further afield to be utilised (Turner et al. 2009), ultimately leading to the development of an offshore fishery for brown crab. During this period, the introduction of hydraulic pot haulers has improved the efficiency and speed at which pots can be deployed and hauled from a vessel. Coupled with the development of new markets for brown crab, allowing greater sales opportunities, these technological changes have resulted in a substantial increase in landings and effort as expressed by number of pots deployed in the fishery over the past 50 years. Due to these changes, the fleet is comprised of vessels with a range of varying capabilities, and a significant number still fish in close proximity to the shore on the historic fishing grounds around Cromer Shoal. While many of the fishers have replaced their traditional open-decked cobles and skiffs with larger boats, the majority of vessels targeting this fishery within the EIFCA District are still categorised as <10m. The small beach-launched cobles and skiffs that have been retained predominantly target inshore grounds, while the larger vessels, some of which are still beach-launched, have the capability to access stocks further offshore.

Potting fisheries use static gear consisting of strings, or *shanks*, of 20-30 baited pots which are typically left to soak for 24-48 hours before being hauled. Pots have changed in size and efficiency as fishing practices have developed. Creels were historically used, however the mid-20th century saw the introduction of larger parlour pots increasing the yield per pot (figure 1). Catch is sorted at sea, with any undersize or poor-quality individuals returned immediately, whilst the remainder is sold to processors, restaurant outlets and local fishmongers once landed. Static gear use has low mortality rates of incidental bycatch in pot fisheries compared to other fishing gear and survival rates are high amongst discards (Rodrigues et al. 2015), allowing them to grow to a size where they will recruit to the fishery.

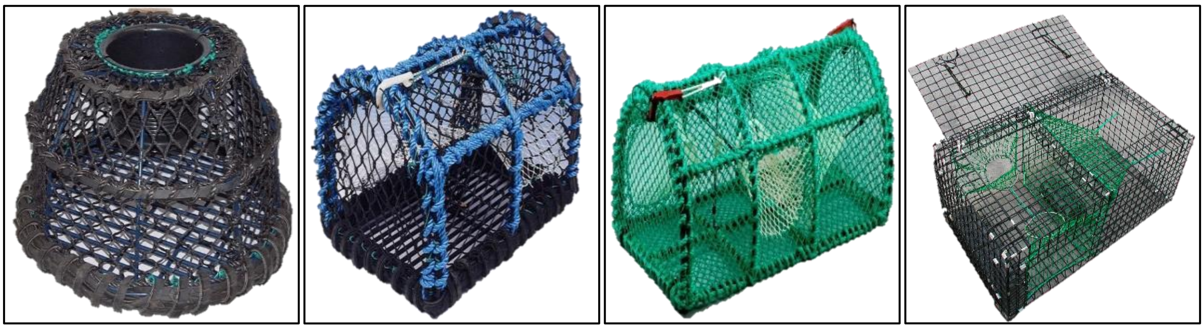

*Figure 1. Various pot designs from traditional inkwell and creels to modern parlour and PVC coated wire.*

*Brown crab – Biology and Ecology*

*Figure 2. Brown crab (C.pagurus).*

While sharing a similar geographic range as European lobster, brown crab is found on a wider range of habitats, including rocky reefs, soft mud and sand. The species can be found from Scandinavia to Portugal, but stock boundaries for brown crab remain poorly understood. Both sexes are known to migrate widely at times, with females in particular having been shown to travel large distances associated with spawning activity. Bennett (1995) identified a smaller size structure in brown crab populations in North Norfolk when compared to adjacent areas; a feature also seen in European lobster populations. Unlike European lobster, however, where size structure is largely constrained by habitat requirements, the smaller size structure in brown crab has been attributed in part to habitat constraints but also as a consequence of migration and recruitment (Addison and Bennett, 1992). Due to this smaller average size of brown crab within the District, there is a dispensation from the national MLS of 130mm carapace width for this species, allowing individuals of 115mm to be landed. Mating activity peaks in the summer when the female has moulted, with spawning occurring in the late autumn or winter. Egg carrying females are largely inactive over the winter brooding period until the eggs hatch in the spring and summer. After approximately five weeks in the plankton, the crab larvae settle on the seabed. Growth is dependent on the frequency of moulting as well as the increase in size on each moulting occasion and it typically takes about four or five years for a juvenile crab to grow to commercial size (Cefas, 2017).

Understanding stock structure requires long term data on where adults spawn and release larvae, the path of larval transport and settlement and the pathway of subsequent recruitment to the fishable stock. Migration data from tagging and analysis of genetic differences between stocks helps strengthen this understanding. Studies conducted by Cefas spanning decades have identified that, as with many UK shellfisheries, brown crab data are far from complete. However, they do imply that, unlike lobster, brown crab stock structure is regional rather than contiguous. Cefas conducted three surveys off the Humber in 1976, 1993 and 1999, in which aggregations of brown crab larvae were identified in each, corresponding with the distribution of emerging fisheries for mature hen crab that developed 70km off the Humber in the 1980s, and subsequently in the Race Bank area further south in the 1990s. There is limited information describing where these larvae recruit to and how they relate to the fishery further south off Norfolk, where crabs that are caught inshore are of an average smaller size than elsewhere (Addison and Bennett, 1992).

Eaton et al. (2013), when conducting brown crab larvae surveys off the east coast of England to identify implications for stock structure, surmised that transport of crab larvae from the north extends southwards along the north-east coast of England, as far as Flamborough Head, before turning offshore towards the Dogger Bank, with very little exchange across the frontal system. South of the Dogger Bank circulation is weak with only a slow eastward residual flow, effectively isolating the north from the south during the period of crab spawning activity, thus challenging a widely accepted belief that the crab fishery in the south is reliant on the spawning areas to the north. The crab population south of the Dogger Bank is now thought to be a separate, self-sustaining stock which provides recruitment of mature hens to the northern fisheries. Cefas conducted research using tagging and genetic differentiation methods to better understand migration patterns in brown crab, and although there are still appreciable knowledge gaps within this aspect of brown crab fisheries, results have shown that stocks are regionally separated, revealing no migratory exchange between North Sea stocks and stocks of the Channel or Celtic Sea. Tagging studies identified both local and distance migrations when observed within regions. Males and immature females were nomadic over relatively short distances of 20+ nautical miles, while recaptures of adult females usually identified more substantial distances travelled, for example northward along the east coast of England from Norfolk to Yorkshire and Northumberland (Bannister, *pers. comms,* 2020).

### *Current fisheries management*

The EIFCA district extends from the River Humber in the north to Harwich in the south, and 6nm out to sea. Within this area, the brown crab fishery is subject to local management in the form of EIFCA byelaws, as well as national and European legislation (table 1).

The crab fishery is currently managed nationally through Marine Management Organisation (MMO) licensing and regionally by IFCA byelaw. International EU regulations set limits on minimum landing size (MLS). EU minimum landing size restrictions for crab are reflected in UK law by statutory instrument, however there is a smaller MLS in the EIFCA district than outside due to a dispensation for smaller crab to be fished. (Undersized Edible Crabs Order 2000 (2000 No 2029)). The 115 mm carapace width for brown crab was also the national limit until 1986; revisions in that year and 1990 raised the MLS to between 130-160mm in other districts. The area falling within EIFCA jurisdictional boundary was given derogation to retain the smaller MLS based on research that identified individuals of the Norfolk population to mature, on average, at a smaller size than in other areas (Addison and Bennett, 1992). In the Eastern IFCA District vessels fishing for brown crab and lobster must have a licence with a shellfish entitlement issued by the MMO. The quantities that are permitted to be landed are not restricted. Owners of vessels that are 10m and under with a shellfish entitlement are required to complete Monthly Shellfish Activity Returns (MSARs) for all landings of crab and lobster and submit them on a monthly basis to the Marine Management Organisation (MMO). Vessels over 10m in length are exempted from MSAR recording but their fishing activities must be recorded in an EU logbook and submitted to the MMO. The crab and lobster fishery is not subject to EU TAC regulations or national quotas. Details of the regulations relevant to the fishery are outlined below in table 1.

*Table 1. Regulations relevant to trap fisheries targeting crustaceans in the Eastern IFCA district*

| Regulation | Effect | Intent |
|---|---|---|
| MMO Vessel Licencing shellfish permit | Prohibits the fishing for shellfish without relevant permits | Limits entry into the fishery as no new additional permits are being issued. |
| Council Regulation 850/98 ANNEX XII for the conservation of fishery resources through technical measures for the | Prohibits landing of organisms below minimum legal landing sizes (115mm CW for brown crab, 87mm CL for European lobster) | Prevents removal of organisms from the fishery before reproductive maturity is reached. |

| | | |
|---|---|---|
| protection of juveniles of marine organisms. | | |
| Statutory instrument: Undersized Edible Crabs Order 2000 (2000 No. 2029) | Increases MLS for brown crab (*Cancer pagurus*) to at least 130mm CW in areas outside of the Eastern Sea Fisheries Committee district. | Increases MLS for crab in areas outside of the EIFCA district while maintaining the lower 115mm CW EU MLS for the Norfolk population. |
| Lobster and Crawfish (Prohibition of Fishing and Landing) Order 2000 | Prohibits fishing for, and landing of, lobsters and crawfish bearing a V notch or mutilated in such a manner as to obscure a V notch. | Protects brood stock that has been marked for protection using a V notch cut into the tail of the animal. |
| EIFCA Byelaw 5: - Prohibition on the use of edible crab (*C. pagurus*) for bait. | Prohibits the use of edible crab in any form (cooked or uncooked) as bait. | Prevents animals below MLS or of low value from being removed from the fishery without being landed. |
| EIFCA Byelaw 6: - Berried (egg-bearing) or soft-shelled crab (*C. pagurus*) or lobster (*H. gammarus*) | Prohibits removal from the fishery any edible crab or lobster that is soft-shelled or bearing eggs. | Protection of current and future brood stock and prevention of poor practice in landing low quality catch. |
| EIFCA Byelaw 7: - Parts of shellfish | Prohibits landing of edible crab (*Cancer pagurus*), Velvet crab (*Necora puber*) or lobster (*Homarus gammarus*) or parts thereof which cannot be measured to ensure compliance with MLS. | Closes a loophole where parts of undersized animals could be landed potentially removing immature organisms from the fishery. |
| EIFCA Byelaw 9: - Redeposition of shellfish | Requires that any shellfish, the removal of which is prohibited, be returned to the sea immediately and as near as possible in the place from which they were taken. | Ensures that organisms are returned the habitat from which they were taken, thus ensuring a greater chance of their survival on return to the sea. |
| EIFCA Byelaw 10: Whitefooted edible crab | Prohibits the landing of 'whitefooted' crab (*Cancer pagurus*) between the 1st of November and the 30th of June. | Further prevents the landing of poor-quality catch by prohibiting 'whitefooted' crabs which have not fully hardened after moulting |

The Authority's Strategic Assessment identified management of the District's crustacean fishery as a high priority based on limited regulation to address effort, gear or catch control combined with low confidence in activity data. This prompted the consideration of management needs driven by the following points:

- Assessments indicating that stocks are approaching or exceeding exploitation rates that would be required to achieve Maximum Sustainable Yield (MSY).
- Requests from the industry to consider revised management.
- Obligations under the Marine and Coastal Access Act 2009 (MaCAA) to manage the exploitation of sea fisheries resources in its district
- Duties under Section 153 of the Marine and Coastal Access Act (2009) to ensure the sustainable exploitation of sea fisheries resources and;
- Achieving good environmental status in all EU marine waters by 2020 set by the Marine Strategy Framework Directive (2008).
- Descriptor 3: Commercial Fish and Shellfish, as described in the Marine Strategy Framework Directive (MSFD), implies that stocks should be:
  1. exploited sustainably consistent with high long-term yields
  2. have full reproductive capacity in order to maintain stock biomass and;
  3. the proportion of older and larger fish/shellfish should be maintained (or increased) being an indicator of a healthy stock

Furthermore, the EIFCA Strategic Assessment 2019 outlines assessing the impact of fishing activities on the Cromer Shoal Chalk Beds (MCZ) and delivering management measures (if required) as a high priority, providing a concurrent driver to establish management measures for the fishery.

Commercially exploited stocks should be in a healthy state and exploitation should be sustainable, yielding the Maximum Sustainable Yield (MSY). This increases the pressure to ensure that management measures are in place to support the sustainability of commercially exploited stocks. Based on this, and in line with duties under MaCAA and MSFD, requirement for the introduction of technical measures[1] may be necessary to address issues identified within the fishery.

The benefits of introducing technical measures include (depending on the technical measure used) some or all of the following:

- increasing population size
- affording protection to a higher proportion of mature individuals
- reducing incidental mortality on immature individuals in the stock and;
- improve spawning and subsequent recruitment within the stock.

Some potential impacts of introducing technical measures include:

- Increases in MLS will result in a reduction in retention for some time
- Associated costs of gear changes needed

[1] Fisheries technical measures are rules that determine the way fishermen are allowed to fish e.g. mesh size, minimum landing size and gear size.

### *Assessment Areas*

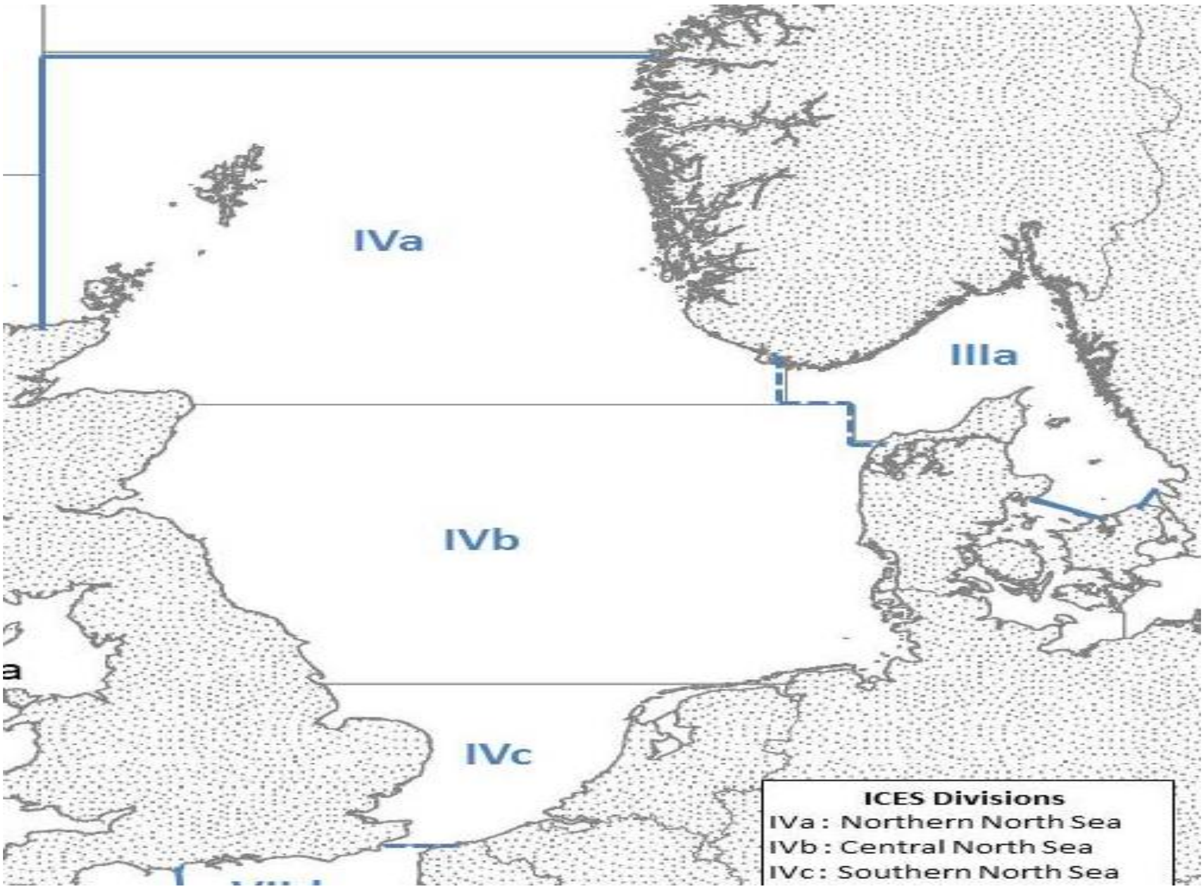


*Figure 3. ICES subdivisions of the North Sea including IVc, classed as the Southern North Sea in which the Eastern IFCA district is located.*

To facilitate the analysis and assessment of fished stocks in the North Sea, the International Council for the Exploration of the Sea (ICES) divide the North Sea into 3 broad areas; IVa, classed as the Northern North Sea, IVb classed as the Central North Sea and IVc classed as the Southern North Sea; the latter inclusive of the area for which EIFCA is the relevant Authority. These are further divided into gridded Statistical Rectangles providing greater resolution. Statistical Rectangles are used to define boundaries of grounds fished by operators in the district, enabling analysis on a site by site basis (figures 3-8).

Assessment of the fisheries is supported by the requirement of fishers to submit either MSAR forms or EU logbooks, clearly stating which ICES Statistical Rectangle has been fished in. Effort and catch are unevenly distributed throughout the fishing grounds within EIFCA's jurisdictional boundary (heavier black line) and are concentrated in certain areas, corresponding closely with the position of major ports associated with the fishery and key production areas located off the North Norfolk coast.

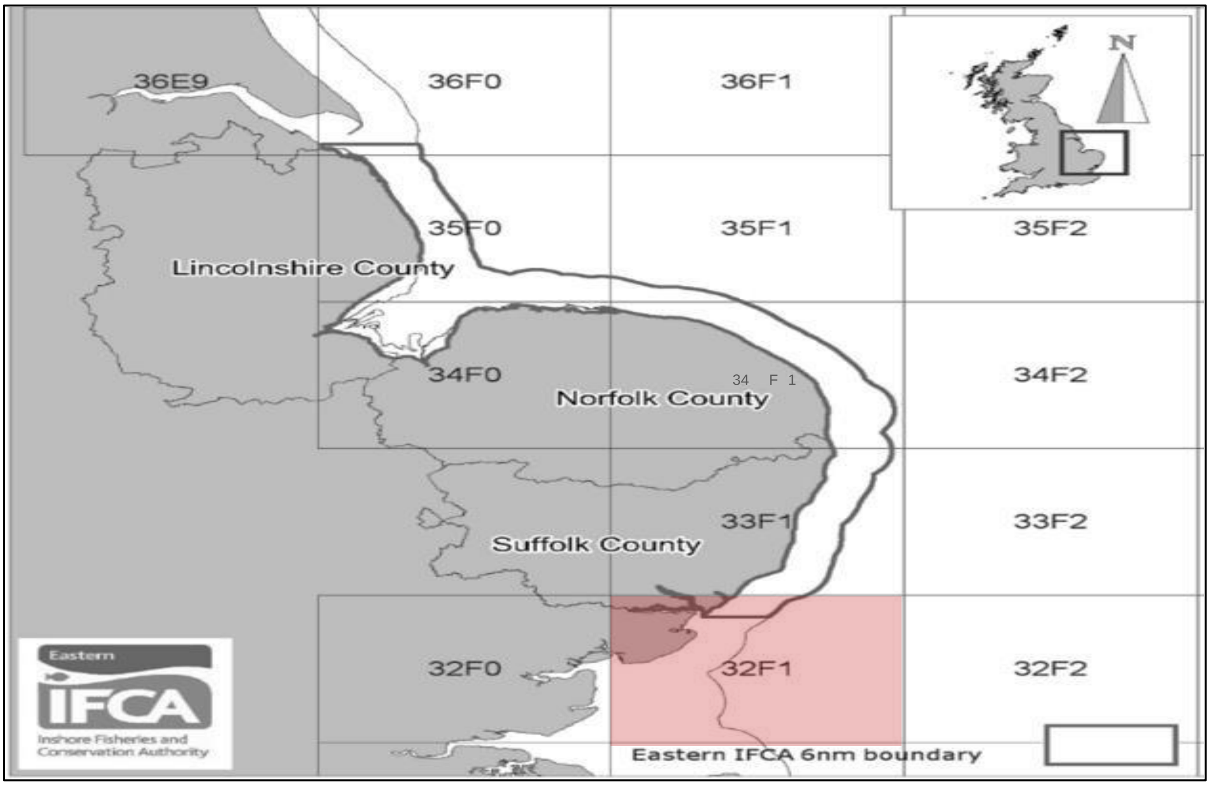


*Figure 5. ICES Rectangle 32F1, located at the southern extremity of the district, overlaps with Kent and Essex IFCA and is fished by a small number of vessels from the EIFCA district, reflected by relatively low levels of reported effort and landings.*

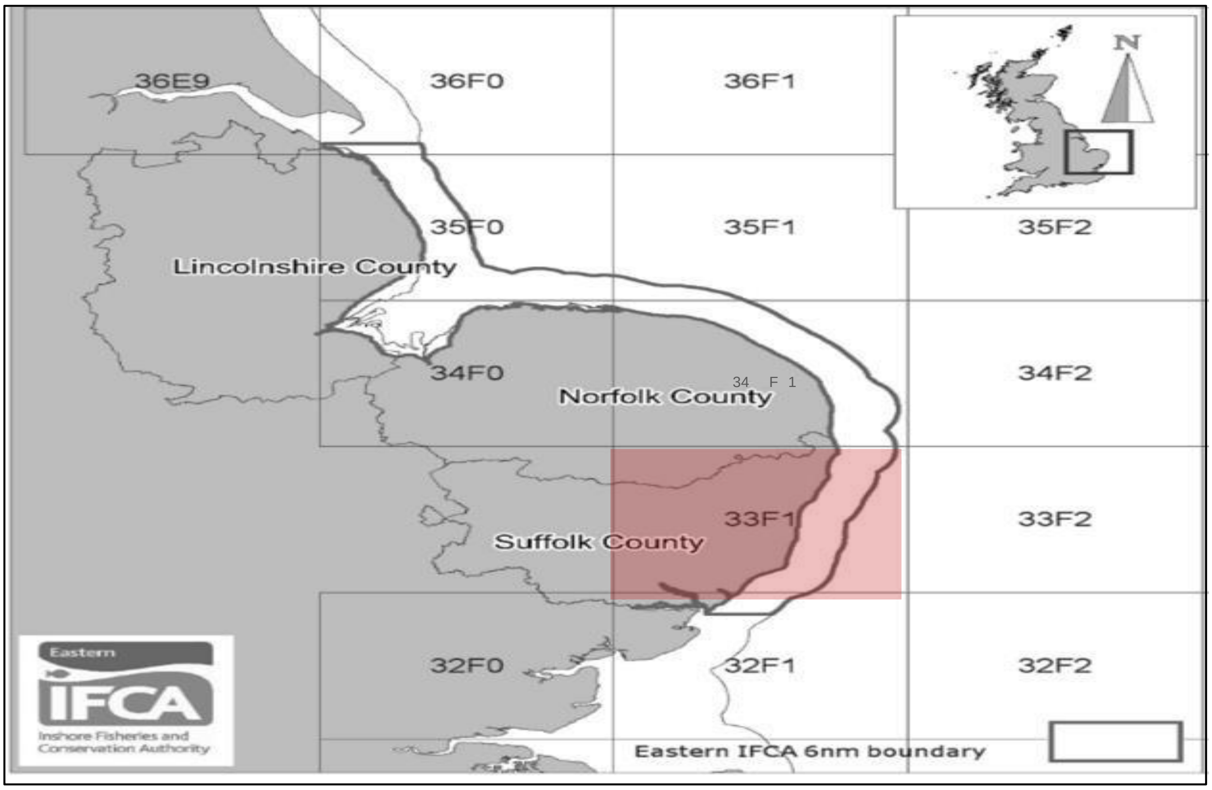


*Figure 4. ICES Rectangle 33F1, situated off the Suffolk coast, covers an area between the Orford and Lowestoft. A comparatively small number of vessels fish this area, reflected in the relatively low landings and effort compared to the Norfolk coast.*

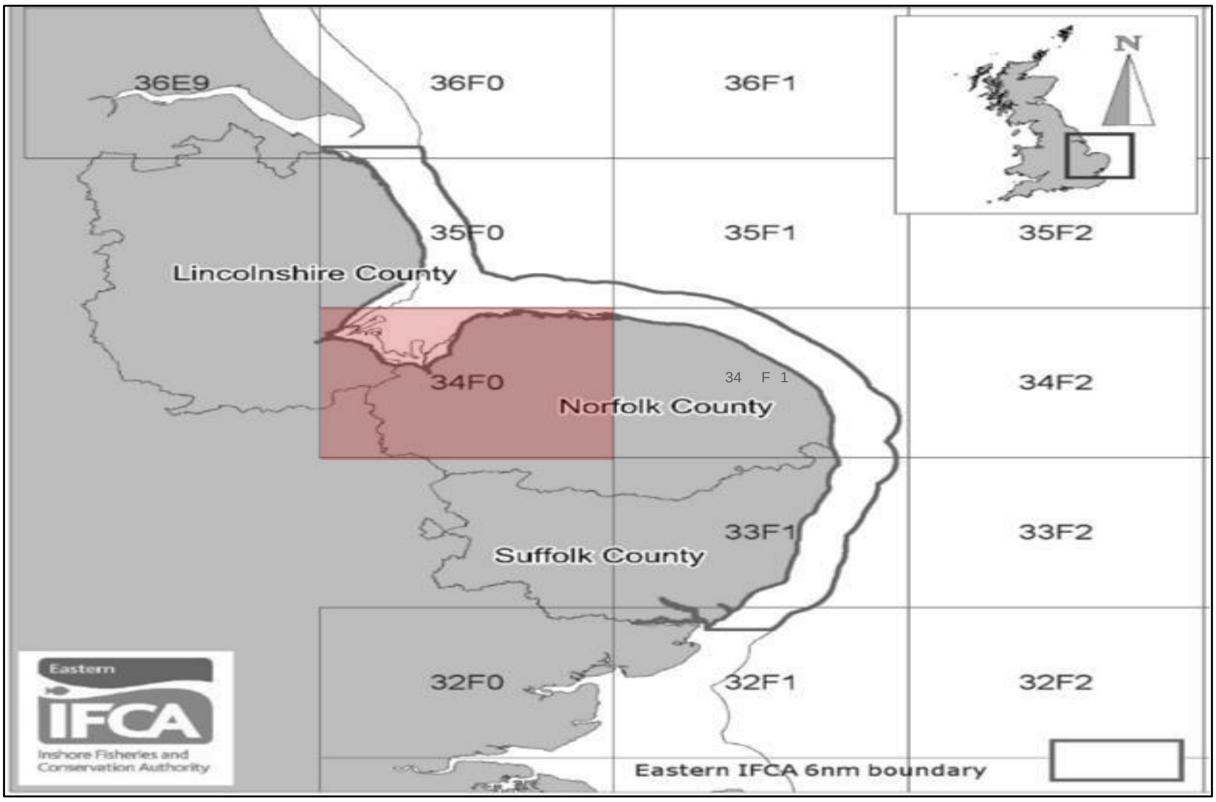


*Figure 6. ICES Rectangle 34F0 straddles the Norfolk/Lincolnshire border, including the Wash and a partial section of the North Norfolk Coast. Relatively low effort is currently dedicated to crab and lobster fishing in the area.*

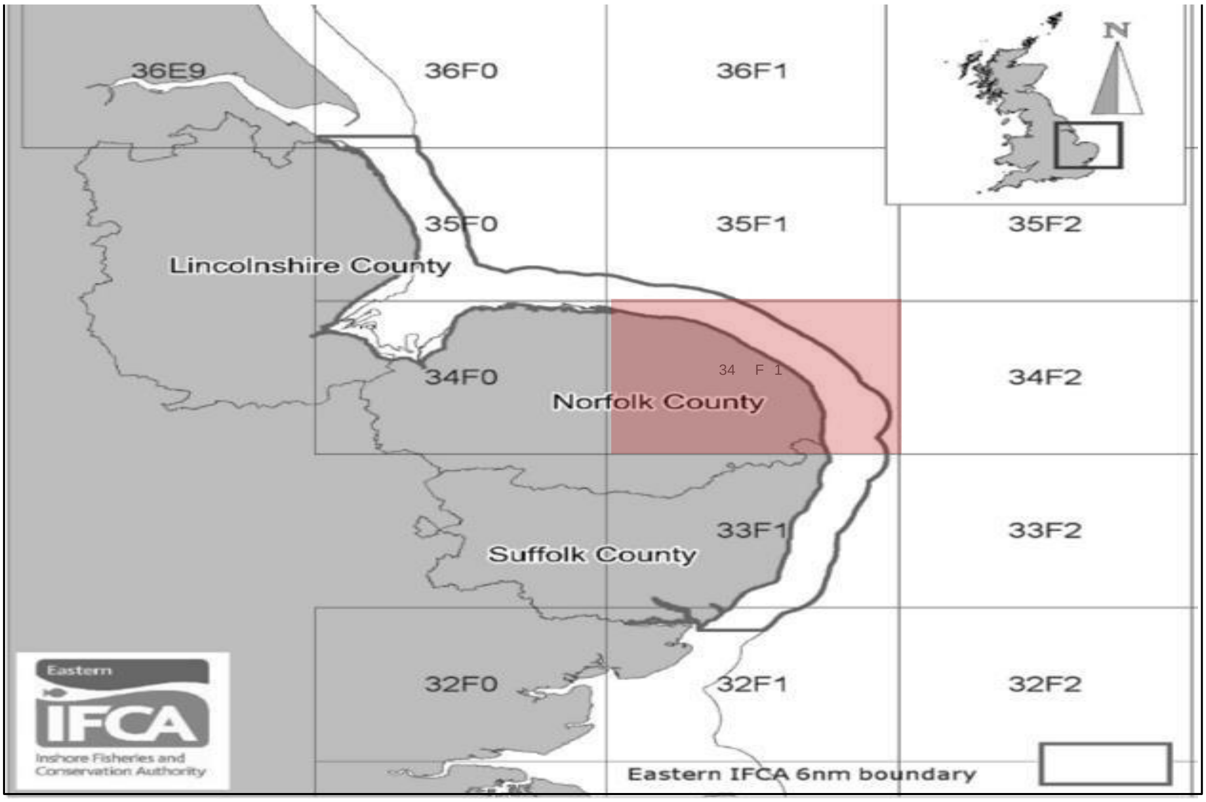


*Figure 7. ICES Rectangle 34F1 contains the primary fishing grounds for vessels operating out of Cromer and is fished by many vessels from ports along the North Norfolk coast.*

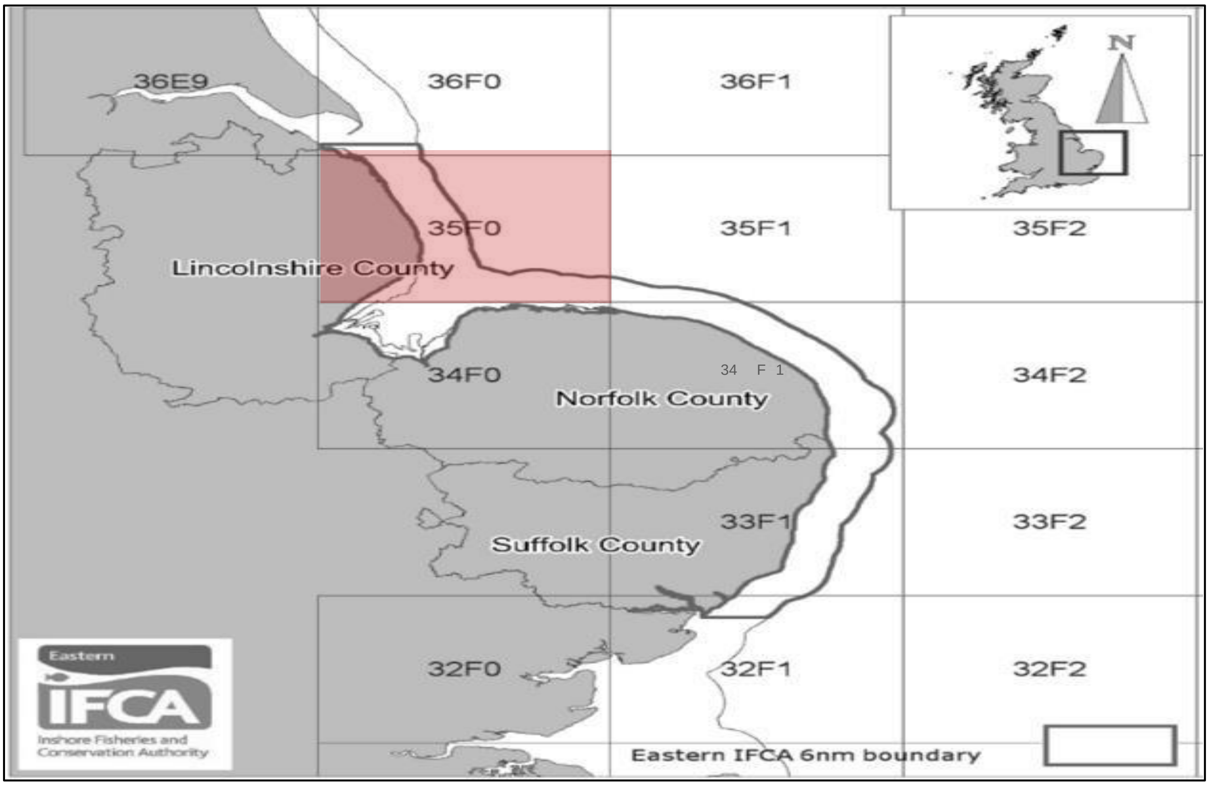


*Figure 8. ICES Rectangle 35F0 is the main offshore potting ground fished by vessels operating out of Wells and Lincolnshire.*

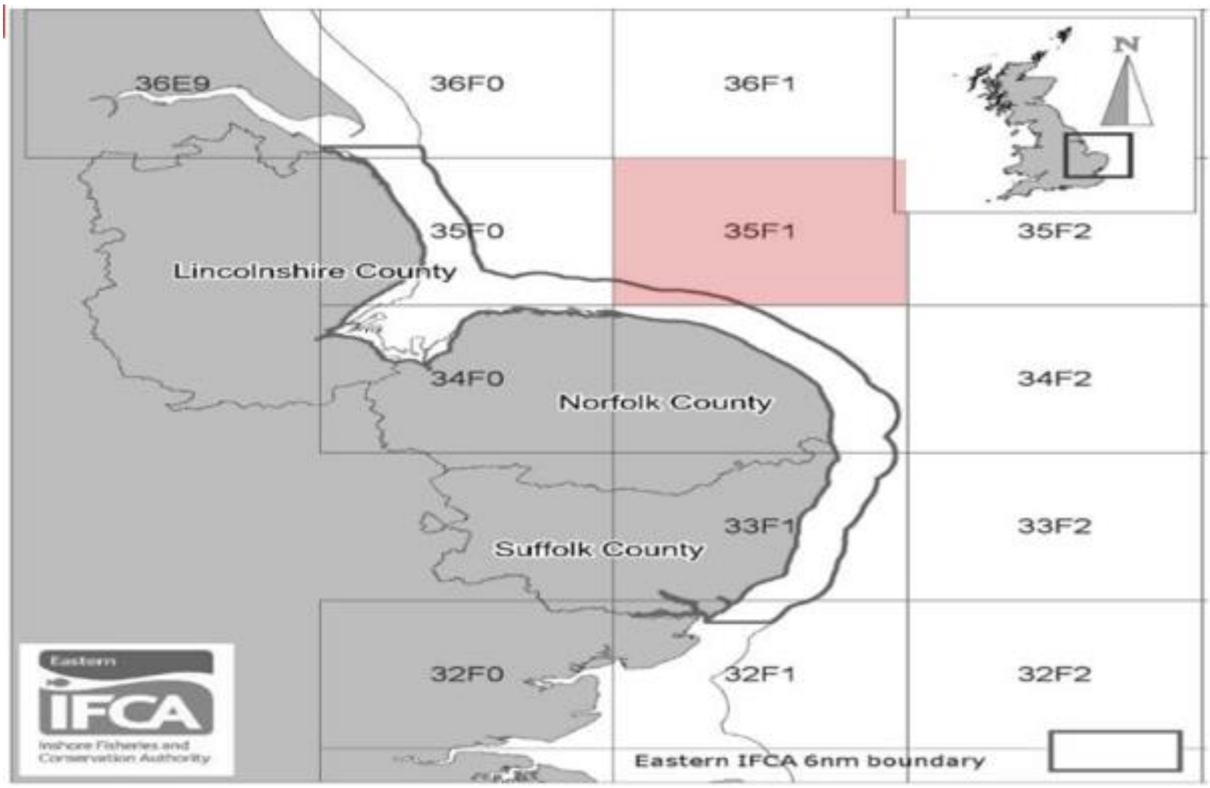


*Figure 9. ICES Rectangle 35F0 is the main offshore potting ground fished by vessels operating out of Wells and Lincolnshire.*

### ***Data sources utilised for assessing stock metrics***

*Landings and Effort Data – Monthly Shellfish Activity Returns (MSARs)*

Monthly Shellfish Activity Returns (MSARs) are standardised forms in which fishers report their catch to the Marine Management Organisation, with a copy going to Eastern IFCA. They form a foundation dataset which arrives primarily in paper format. These data are entered into a bespoke Access database, which can be queried to extract particular components. Submission of MSARs has been obligatory for shellfish entitlement holders operating vessels <10m since 2006, providing daily records of fishing activity including; areas fished (by ICES Statistical Rectangle), landings (Kg), effort (number of pots hauled) and port of landing. MSAR data are used to generate statistics on landings and effort annually, monthly or daily; by port, area fished or vessel. This information provides an overview of the fishery; highlighting productive grounds, relative port activity and concentrations of fishing activity. Landings and effort data can be further utilised to determine LPUE by ICES rectangle. LPUE can be used conservatively as a proxy for stock abundance, potentially highlighting areas with higher LPUE as having higher population densities (Welby 2016).

The Marine Management Organisation (MMO) has now launched the catch recording (e-reporting) service for the under 10m fleet. The service was implemented across all under 10m vessels in a phased approach between November 2019 and January 2020 and will replace the current paper MSAR method, enabling more accurate digital records for all under 10m vessels and will be a future licence condition. Importantly, the data gathered will also benefit the industry and be critical in providing better science to inform stock assessments and support future sustainable management. At the time of writing (August 2020), Eastern IFCA currently doesn't have access to the data from the catch reporting service, therefore, these data have not been included in the overall landings and effort reported below.

*MMO UK fisheries statistics*

UK fisheries statistics, published annually by the government, provide data on annual landings figures by fishery for the 10m and under and the over 10m vessel categories. However, they do not provide information on fishing effort in terms of pot hauls from which LPUE calculations can be calculated. Figure 10 highlights that landings figures are very different when comparing MSAR and MMO landings statistics data for the under 10m fleet. This is primarily due to the method used to capture the data within each database. It is compulsory for all under 10m vessels to submit details of their catches in MSAR forms, so in theory, the MSAR database should contain details of all catches made by this sector of the fleet (albeit, landings weights are estimated by the fishermen). By contrast, the MMO landings data are derived from sales notes generated when fishermen sell their catch to a registered buyer or seller. Critically, sales notes are not required to be submitted when catch is sold directly to the public, or for individual sales smaller than 25kg. Because of the nature of this fishery, where much of the catch is sold in small quantities and/or direct to the public, possibly via their own shops, these landings are not captured by the MMO database. Landings figures from these two data sources are, therefore, non-comparable, but it is important to understand these differences when looking at landings figures for the fishery as a whole.

In addition to under 10m landings data gleaned from both MSARs and MMO landings data, the MMO landings data, based on sales notes, also provides data for vessels over 10m. Figure 11 highlights the total annual landings attributable to the over 10m fleet when compared with landings gleaned from the MSAR data for the under 10m fleet. This provides an overview of the total landings by vessels of both categories within the district. Because effort data, in terms of pot hauls, is not included within the MMO landings data, however, these additional landings data are not comparable with the LPUE calculation made in this report based on pot haul data obtained from MSAR data. It should always be remembered, however, when viewing trends in LPUE derived from MSAR data alone, that they do not incorporate data from the entire fleet.

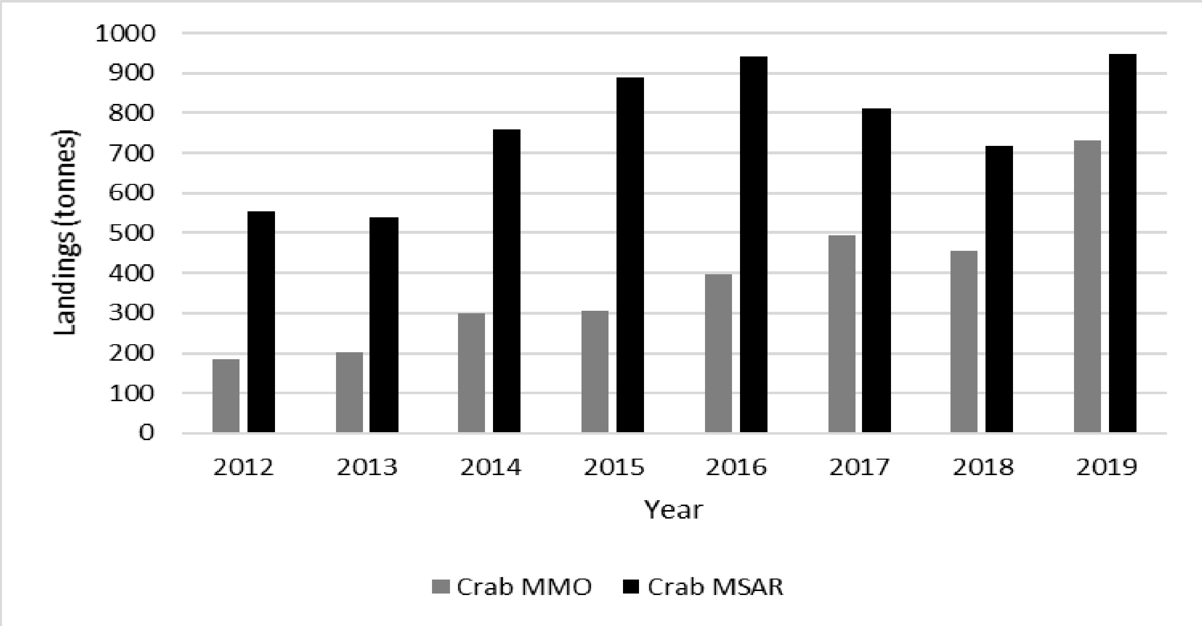


*Figure 10. Comparison of landings (kg) for the 10m and under vessels from the MSAR returns and the MMO UK fisheries landings statistics.*

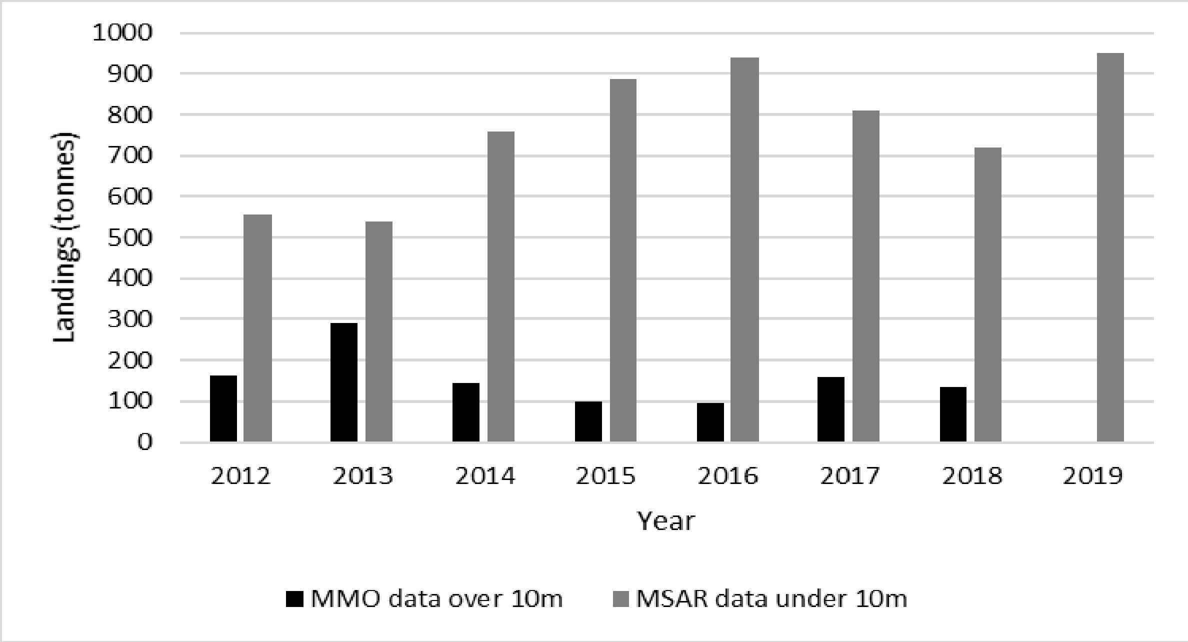


*Figure 11. Additional over 10m vessel brown crab landings data for the district from the MMO UK fisheries landings statistics.*

### *Analytical tools for assessing crustacean stocks*

Catch Per Unit Effort (CPUE) and Landings Per Unit Effort (LPUE) are measures that are both commonly used to assess the abundance of stock by looking at the size of catch or landings in relation to the amount of effort (in this case, pot hauls) that was used to catch them. There are known issues with these metrics, however, as they both assume the catches seen within pots (for CPUE) or landed (for LPUE) are representative of those species on the ground. However, in reality, several mechanisms may influence catchability, reducing the linkage between these metrics and the stock on the ground. These include the biological and behavioural aspects of the crab, for example females not feeding when brooding and therefore not being caught. Changes to the efficiency of fishing vessels and gear, and the experience and knowledge of the crew when deploying gear in the fishing grounds generally result in greater efficiency, resulting in improved CPUE and LPUE values that could mask an overall decline in stock. Seasonal variability in the behaviour of the target species during breeding and spawning times that affects their vulnerability to be captured will also have seasonal impacts on CPUE and LPUE. There are also inter-specific and intra-specific behaviours that can affect the number of animals that are likely to enter a pot. CPUE is invariably calculated without reference to the targeting behaviour of the fishing fleet or the behaviour of individual animals in and around the pots, and with limited understanding of the selectivity and sampling efficiency of baited pots. Baited pots selectively sample portions of target species and although some of this selectivity is intentional, for example through the use of escape gaps, crustacean mobility and behavioural interactions that contribute to catchability is not. Therefore, numbers and distributions of individuals within pots may not be representative of relative abundance and distribution of the larger population leading to complex and interchangeable relationships between CPUE and abundance (Skerritt et al. 2020).

Skerritt et al. 2020, in a study to improve understanding the interactions associated with the simultaneous capture of European lobster and brown crab found that the proportions and quantities of the species fished within a mixed-species fishery varies seasonally, diurnally, spatially and with vessel targeting behaviours, noting that competitive interactions between individuals of the same species (intra-specific) and different species (inter-specific) is likely to affect the observed catch. When looking at the impacts of inter- and intra-specific interactions on CPUE and LPUE values affecting crustacean trap fisheries and their implications for management, they identified that the accurate measurement of CPUE based on catch and effort data collected from a mixed-species potting fishery, is influenced by underlying species interactions.

In addition to factors that influence both CPUE and LPUE, there are further ones specific to LPUE. While LPUE is commonly used as a proxy for CPUE because it is much easier to measure landings than the catch at sea, LPUE can only quantify the landed component of the catch and does not account for the unknown fraction that may have been discarded at sea. Provided discard rates remain relatively consistent over time, LPUE is a reasonable proxy for CPUE. However, that assumption cannot be guaranteed, particularly as changing market demands may affect how much of a catch is landed, possibly resulting in more or less discards. There are also compounding issues that arise from mixed fisheries if any seasonal, temporal or biological variables that impact either species cause the fishers to redirect the usual focus of their target species.

While it is important that the implications of all of the above factors are understood when utilising CPUE or LPUE to assess a stock, it is nevertheless difficult to quantify them. While they make CPUE and LPUE unusable as tools for calculating the actual size of a stock at any given time, if the assumption is taken that these limitations will remain roughly stable from year to year, they can provide insight into how stable the fishery is over time. A steadily declining LPUE over successive years would be cause for concern that the stocks were declining, while a stable trend in LPUE would indicate the fishery was either operating sustainably or had reached equilibrium at a sub-optimal plateau. For all their limitations, CPUE and LPUE are still among the most commonly tools for assessing crustacean stocks. LPUE has been used in this assessment due to the availability of landings and effort data provided by the MSAR forms.

### *Assessing LPUE from MSAR data*

Some fishers use MSAR forms to record other species than crustacea. It is important, therefore, when analysing the data that such records are removed as failure to remove effort targeting other species (e.g. whelk) would inflate the apparent effort with no respective gain in landings. During the data-cleaning process, outliers were also sought that indicated errors had either been made on the original recording form or while being entered into a digital format. These included instances in which crustacea landings were recorded but had zero associated effort, or effort was recorded but had no landings data. Other data were removed where the resultant LPUE appeared impossibly high for that weight of crabs to be present in a pot. Care also needed to be taken to clean more subtle threats, where for instance, crab had been recorded, but appeared from the data to be a small bycatch from another target fishery. While such data were retained for calculating the overall landings of crabs within the district, they were removed for the purpose of calculating the LPUE. This process involved removing data in which the reported biomass of other species was greater than that of crab, and also instances when the weight of other species exceeded 100kg and accounted for more than 25% of the total catch. In some cases, high numbers of crab and whelk were recorded for the same trip, indicating fishers were probably targeting both fisheries the same day with different pots. As it could not be discerned from the forms, however, what proportion of the effort had been targeted at each species, these records were also removed from the LPUE calculations. Because the crab and lobster fishery is a mixed fishery, many reports contained landings of both species. In most cases the volume of crab compared to lobster indicated that crab was the main target species, but in a small number of cases, it appeared lobster may have been the primary target. As these reports tended to be low in number, however, were fairly consistent year to year and accounted for very low overall effort and landings, their impact on LPUE trends was determined to be negligible. As such, these data were retained in the crab LPUE calculations on the off-chance crab had been the target species and such reports were an indication of poor catch rates.

The data-cleaning process also raised a question of whether the apparent selectivity process used by fishers who differentiated between reported catches of male and female crabs would have an impact on the LPUE. When recording landings on the MSAR forms, fishermen can either record the catch by sex or as mixed brown crab. The majority of fishermen do not differentiate, with 98.9% of catch by weight being recorded as mixed. However, in a small proportion of brown crab records, crab sex has been differentiated, with 0.4% of the total landings being recorded as male and 0.7% as female. It is uncertain from the data, however, whether this means in the majority of cases the fishers are not being selective towards a particular sex, or whether they are just not reporting those details. Further, it is unclear whether those who do report differentiated sexes are actually being selective or are just estimating the proportion of each.

If some fishers do sort the catch by sex, it would be time consuming. That being so, they might not be landing many crabs and may also be selective in other ways, such as size and carapace condition. Such selectivity would lower their LPUE and subsequently lower overall LPUE in the fishery should they be included alongside the mixed catch landings. An ANOVA test conducted on the LPUEs of mixed and selective catches found the differences between mixed/male/female catch to be significant with a p value of 0. Combined male and female average landings and LPUEs are considerably lower than figures for mixed sexes suggesting that those reporting selective sexes are returning smaller landings, thus reducing overall LPUEs.

The purpose of separating and testing these different groups for significance was to evaluate whether the selective catch landings should be included with mixed landings when calculating LPUE, or whether they would significantly bias the results. As these selective landings accounted for just 1.1% of total crab landings reported in the MSARs, and most showed the catch included both males and females, it was determined that the inclusion of these data would have a negligible effect on the results. Further, as the selective differentiation of sexes reported in the forms has remained relatively consistent across years, their inclusion would have barely any impact when looking at changes to LPUE over time. As such, these data were retained when calculating LPUE for the fishery.

For the analysis of trends in landings and effort, consistent data is available since 2012. Data for the years preceding 2012 are not reliable due to very low numbers of records within EIFCA's digitised database, so have been removed from the following analysis. Based on the MSAR returns for vessels fishing within the Eastern IFCA district, landings of brown crab peaked at 948.7 tonnes in 2019 (figure 12). The number of pot hauls in the EIFCA district over the same time period had fluctuated considerably and in 2019 totalled 713,832 from a peak of 797,513 in 2012 (figure 13). Despite contrasting trends in landings and effort, landings per unit effort (LPUE) has steadily increased throughout this period, baring a dip in 2018, from 0.64 kg/pot haul in 2012 to 1.13 kg/pot haul in 2019 (figure 14). The scale and volume of landings for brown crab within the EIFCA district highlights the importance of this fishery to the local economy.

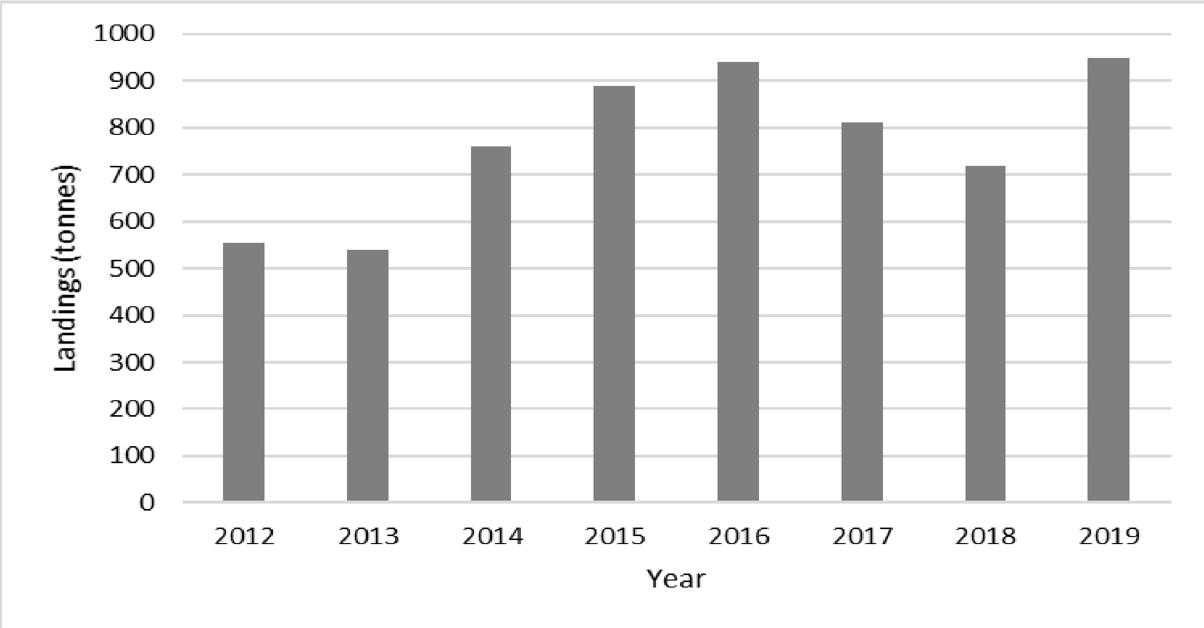


*Figure 12. Annual brown crab landings (tonnes) in the district between 2012 and 2019.*

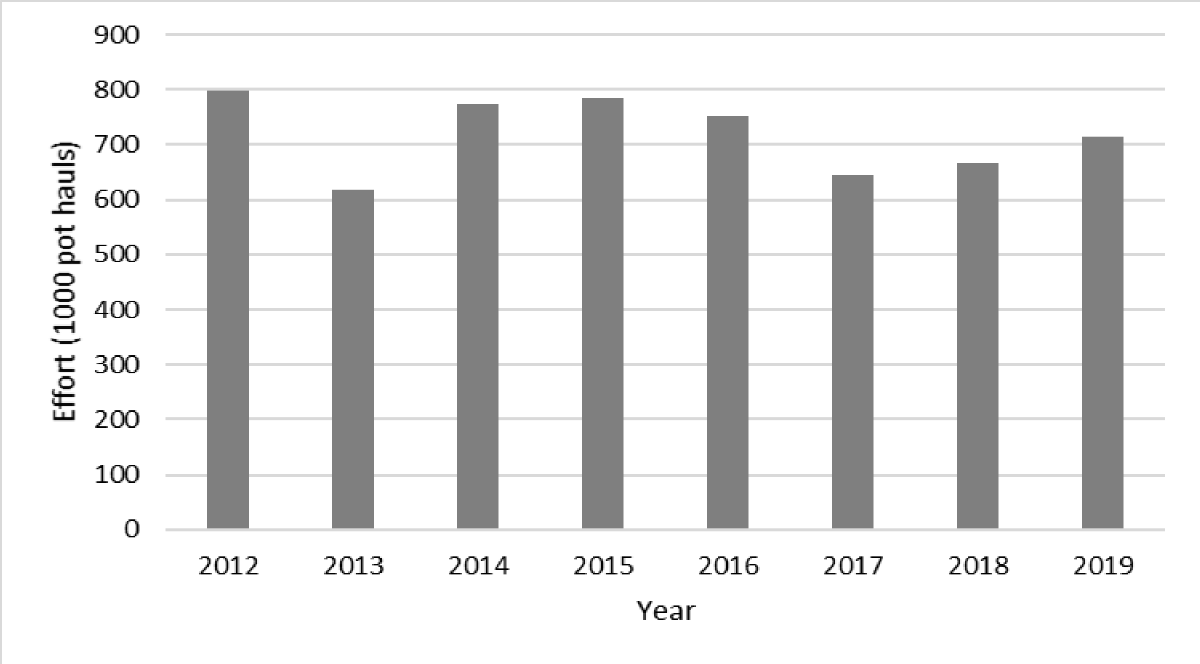


*Figure 13. Annual effort (number of pot hauls) in the district between 2012 and 2019.*

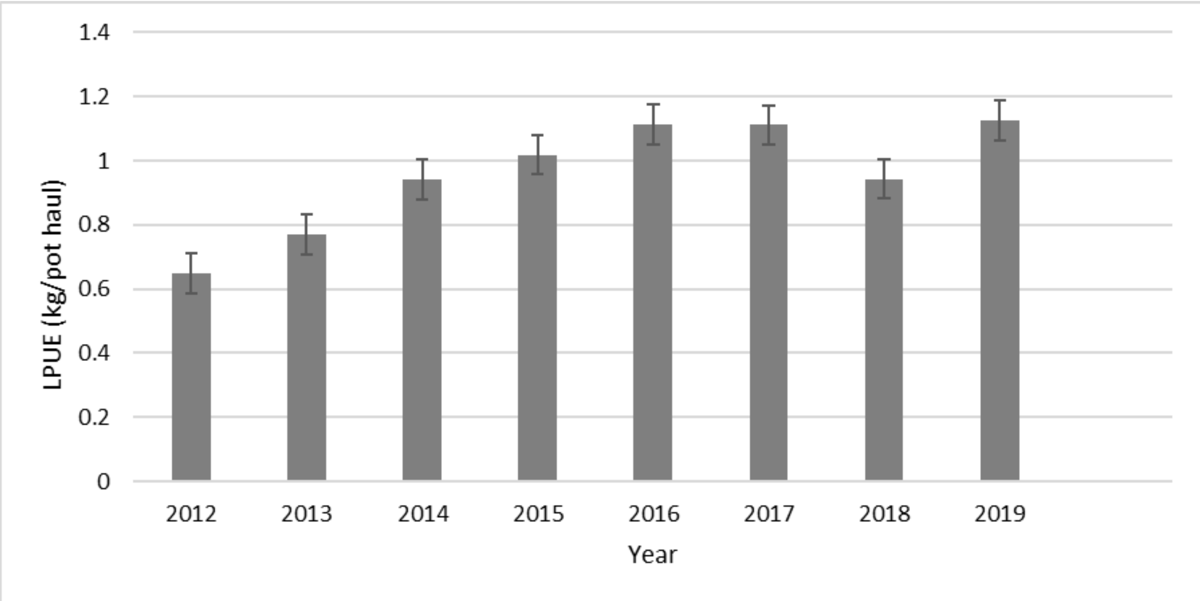


*Figure 14. Annual LPUE including 95% confidence intervals in the district between 2012 and 2019. LPUE has been calculated for each individual MSAR entry and the mean determined from the averaged values combined.*

The 95% confidence intervals (figure 14) indicate a narrow margin of error for 2012 to 2019, the period in which we can confidently report. This is most likely due to the large number of data entries that were averaged to form each year's LPUE calculation. Further analysis of the LPUE data (figures 15-22) at a finer scale indicates that the rising trend in LPUE (figure 14) is likely attributable to increasing levels of stock on the ground as the breakdown of the relative occurrence of different values of LPUE shows a gradual drift upwards of all values, rather than a either a sudden reduction in the proportion of particularly low values, or a sudden increase in the proportion of particularly high values.

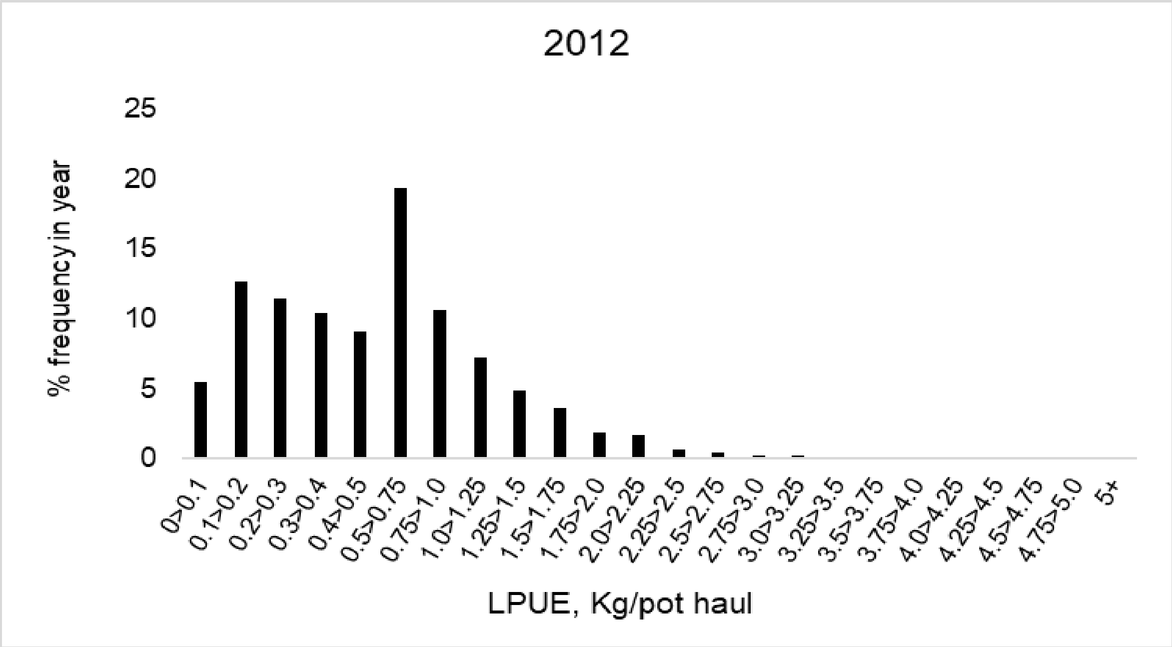


*Figure 15. N= 4561. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2012.*

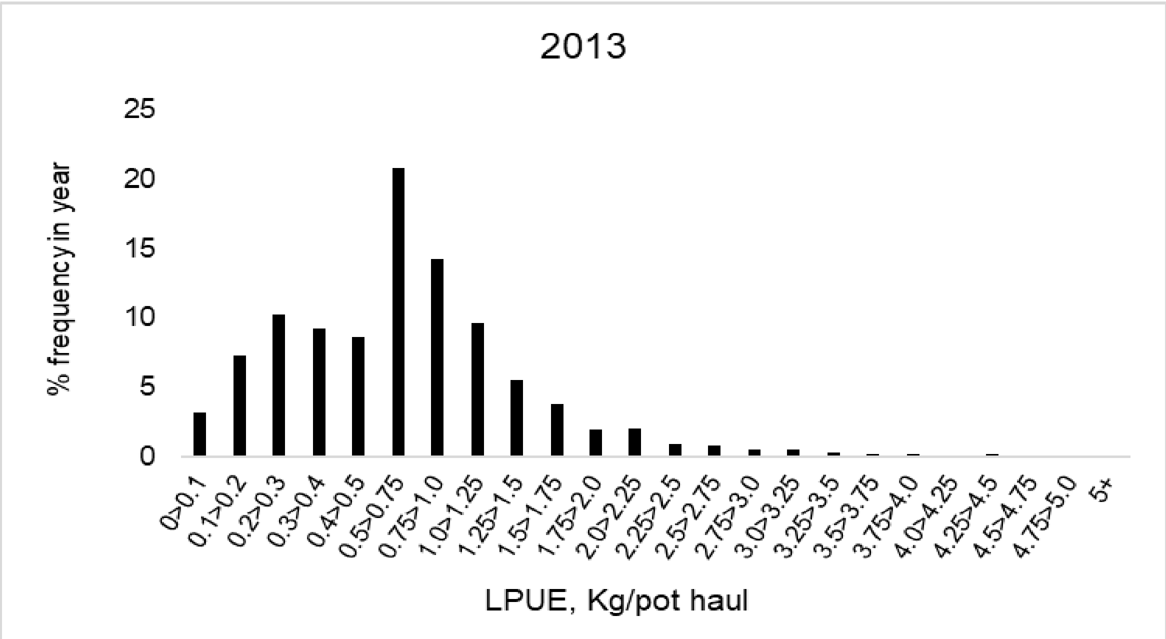


*Figure 16. N= 4021. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2013.*

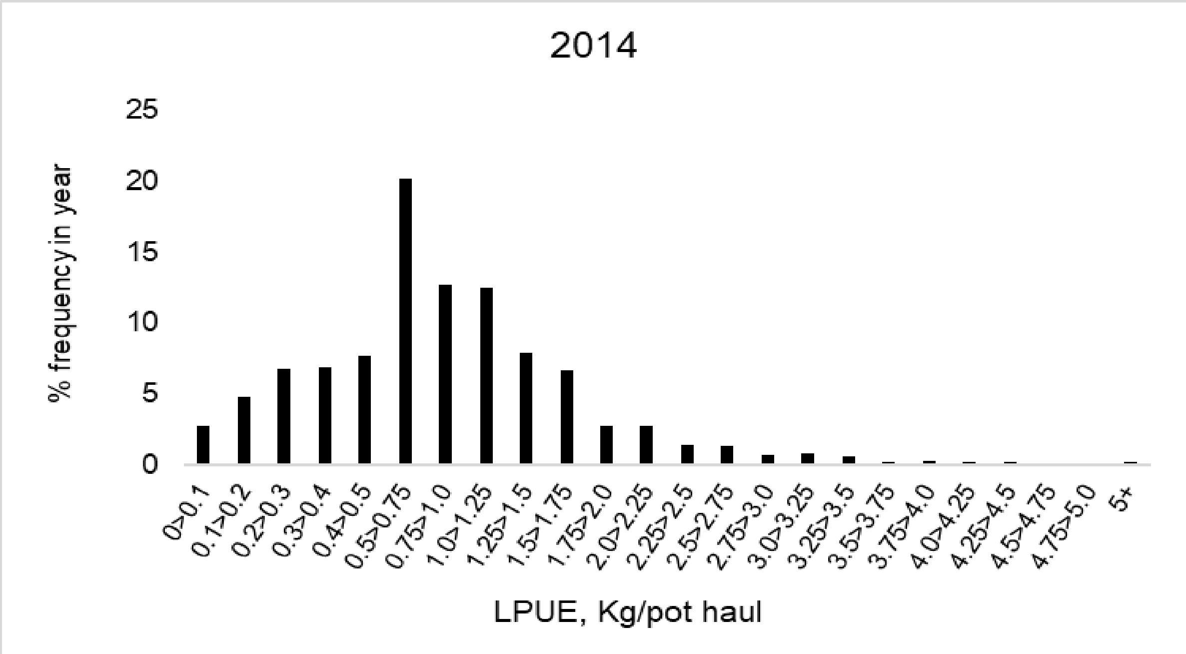


*Figure 17. N= 4699. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2014.*

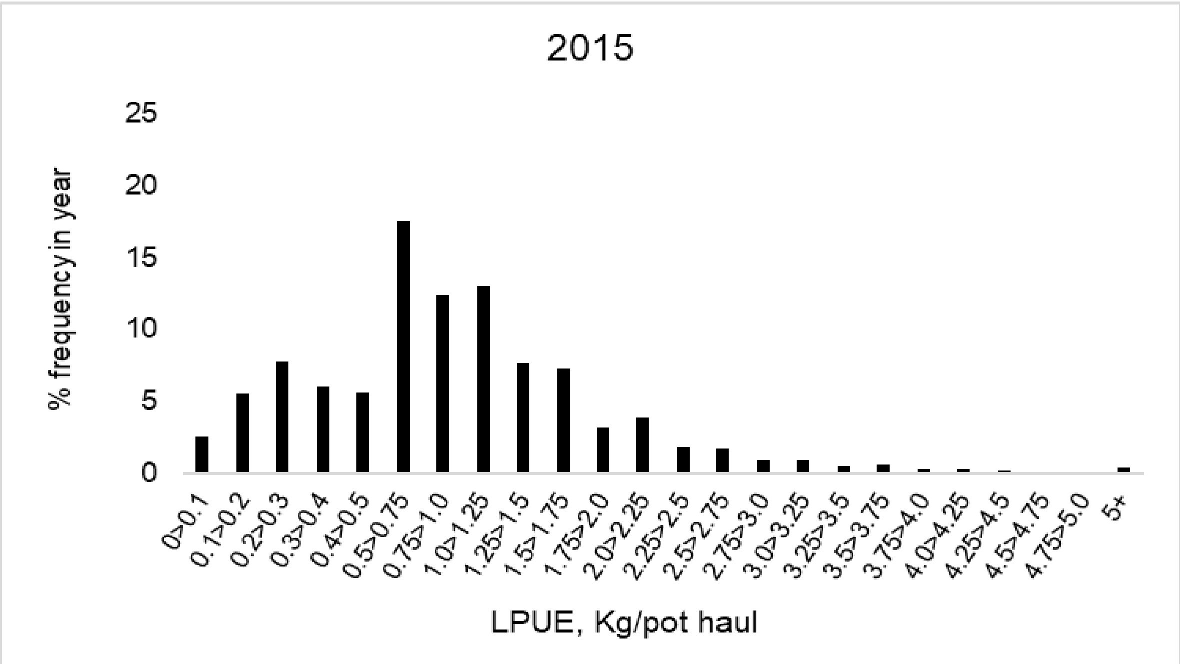


*Figure 18. N= 5162. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2015.*

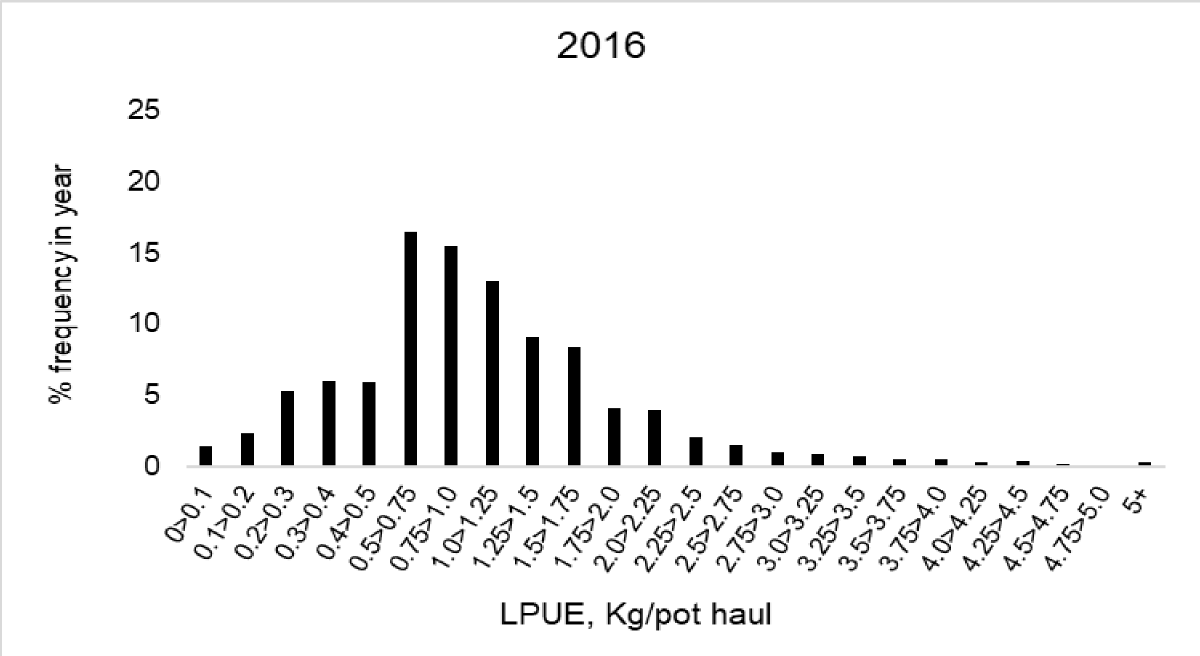


*Figure 19. N= 5087. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2016.*

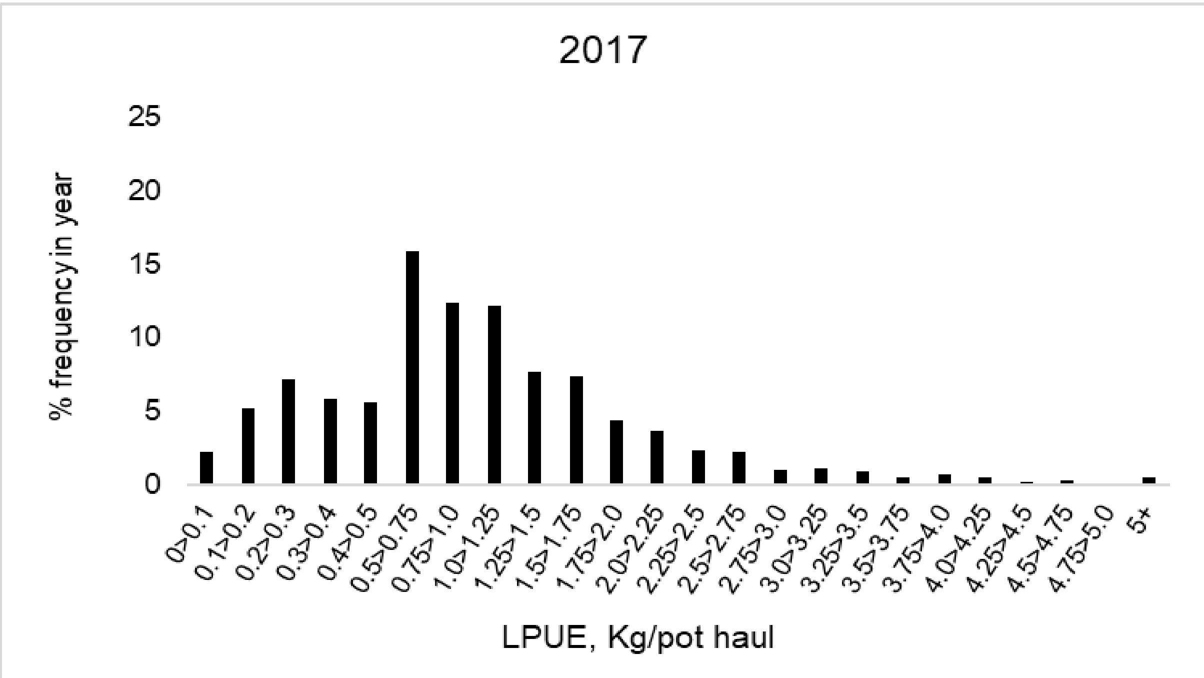


*Figure 20. N= 4420. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2017.*

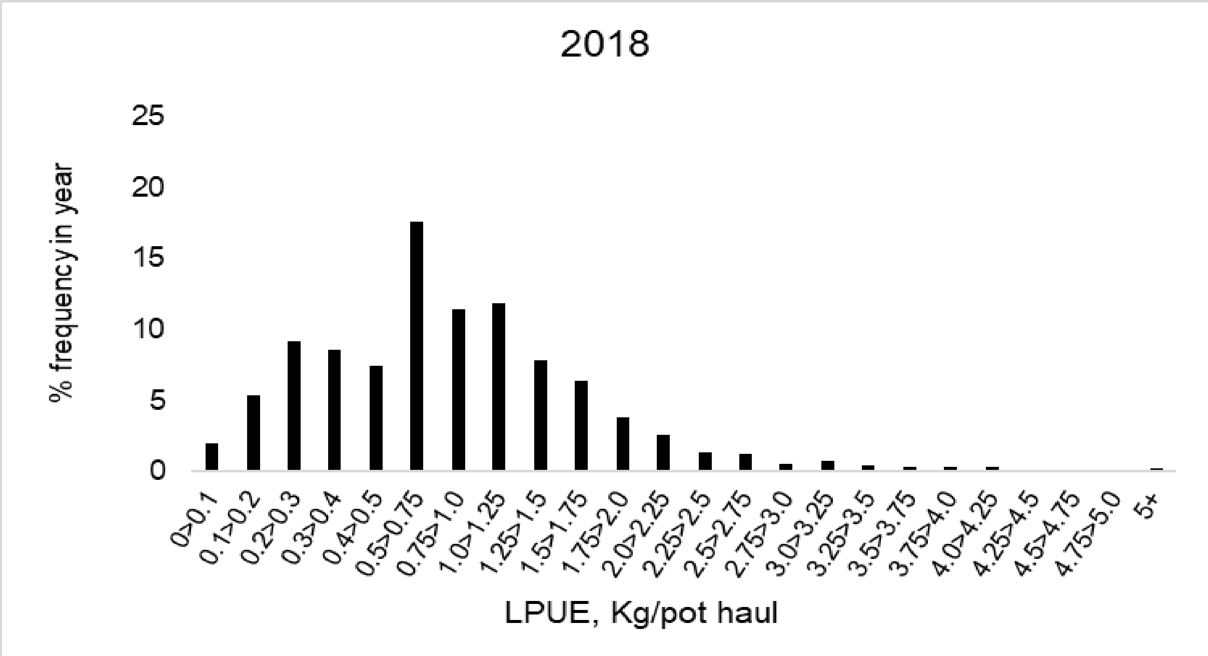


*Figure 21. N= 4750. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2018.*

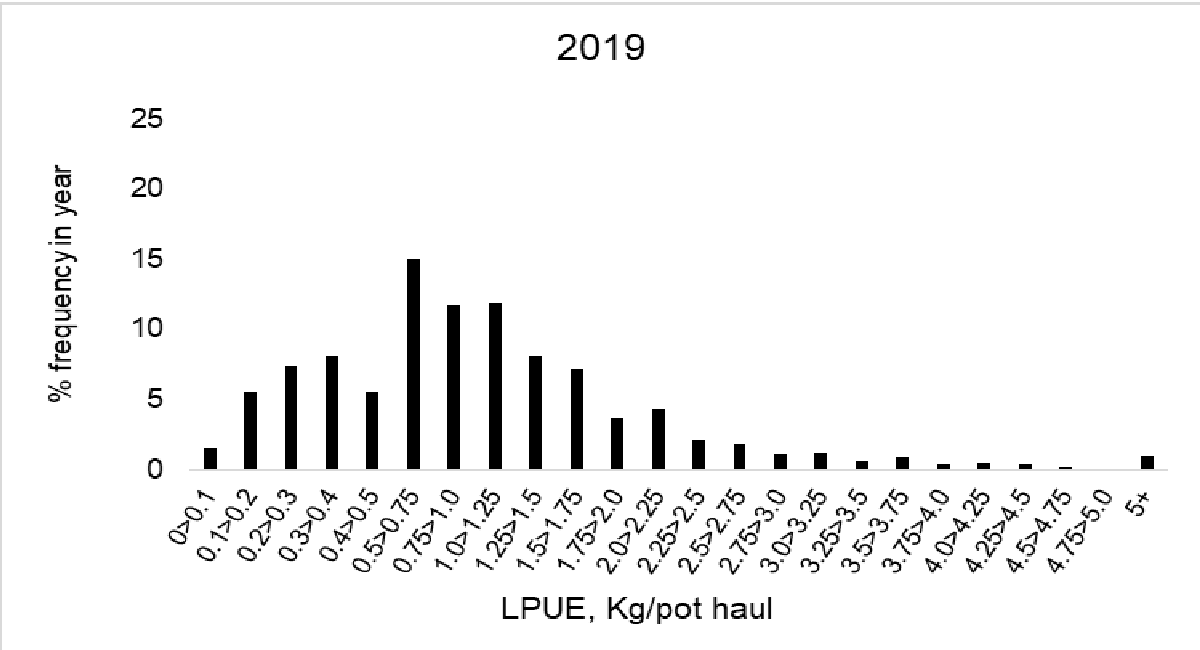


*Figure 22. N= 4803. Landings per unit effort (LPUE) data grouped into bins for the district wide fishery in 2019.*

***Analysis of individual ICES statistical rectangles between 2012 and 2019***

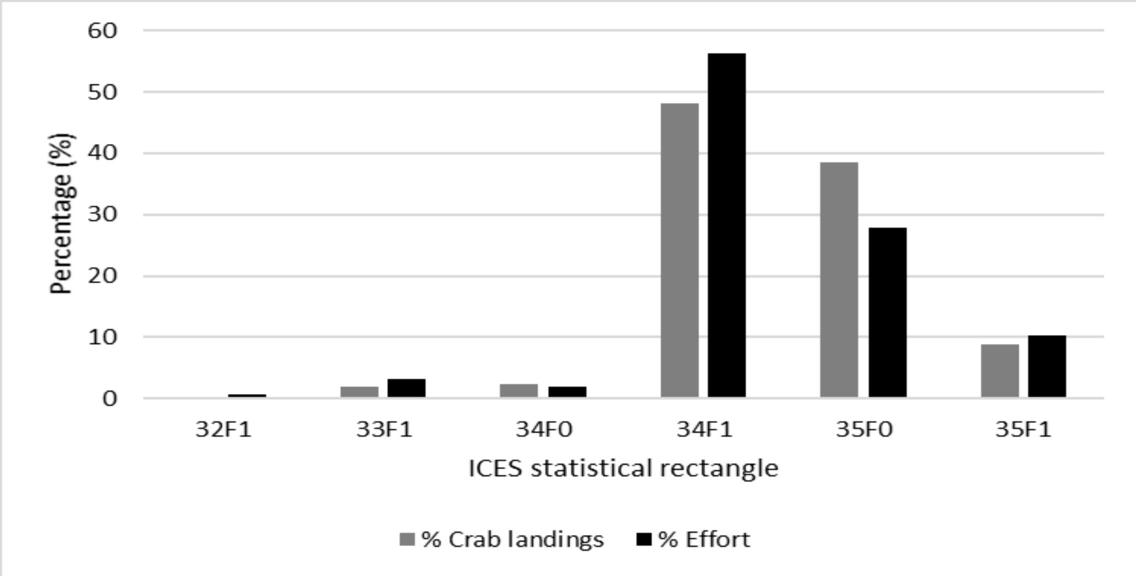


*Figure 23. Percentage of landings and effort attributable to each of the individual ICES statistical rectangles.*

The largest amount of landings and effort are in 34F1 and 35F0, making up 48.2% and 38.6% of total annual landings and 56.2% and 27.8% of total annual effort (pot hauls) respectively. Elsewhere, annual landings and effort in ICES statistical rectangles 32F1, 33F1, 34F0 and 35F1 are appreciably lower. Because of the relatively high levels of effort directed towards 34F1 and 35F0, and the known importance of 35F1 for the larger offshore vessels in the district, these three areas have been explored in more detail below.

## *ICES statistical rectangle 34F1*

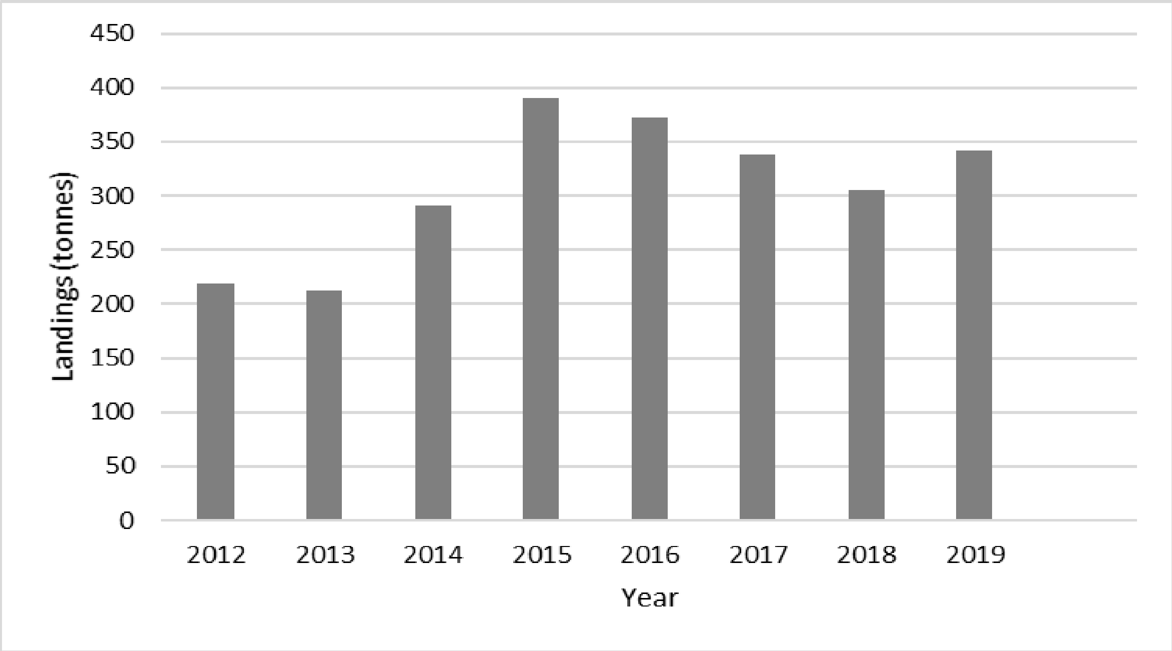


*Figure 24. Annual landings (tonnes) derived from MSARs in ICES statistical rectangle 34F1.*

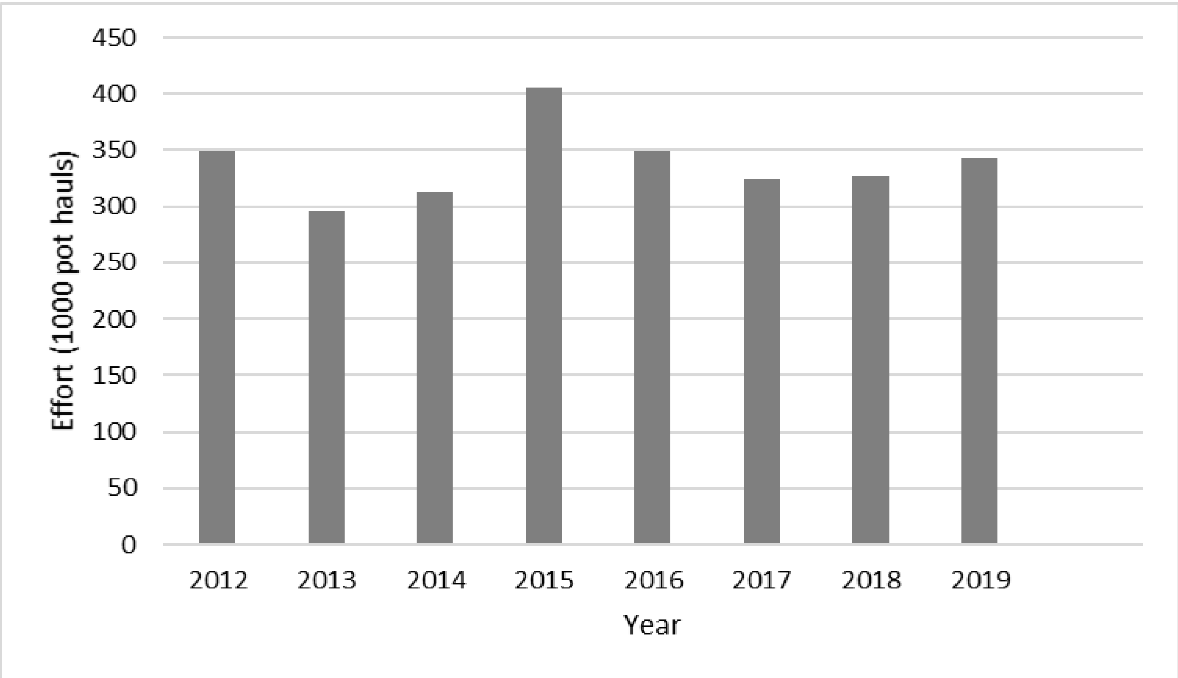


*Figure 25. Annual effort (number of pot hauls) in ICES statistical rectangle 34F1.*

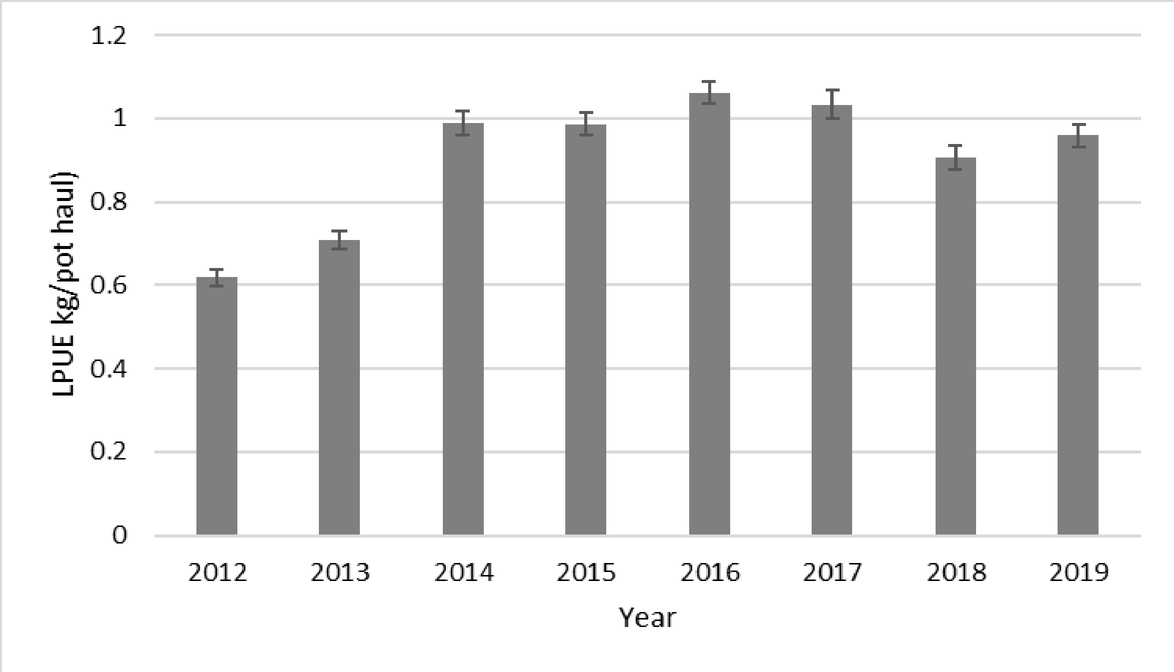


*Figure 26. Annual LPUE including 95% confidence intervals in ICES statistical rectangle 34F1. LPUE has been calculated for each individual MSAR entry and the mean determined from the averaged values combined.*

*Table 2. Summary statistics for ICES statistical rectangle 34F1.*

| Year | Effort (number of pot hauls) | Crab Landings (kg) | LPUE (kg/pot haul) |
|---|---|---|---|
| 2012 | 349,689 | 218,410 | 0.62 |
| 2013 | 296,256 | 211,887 | 0.72 |
| 2014 | 312,458 | 290,373 | 0.93 |
| 2015 | 405,302 | 389,686 | 0.96 |
| 2016 | 349,218 | 371,890 | 1.06 |
| 2017 | 324,626 | 338,321 | 1.04 |
| 2018 | 327,352 | 304,837 | 0.93 |
| 2019 | 343,294 | 341,280 | 0.99 |
| | | | |

ICES statistical rectangle 34F1 is the predominant fishing ground for crab and lobster within the district with >48% of reported landings from MSARs from this rectangle alone. The majority of vessels fishing this area are 10m and under and generally target the inshore coastal area of the rectangle in which the exposed chalk feature of Cromer Shoal Chalk Beds MCZ is situated. Figure 24 shows the landings from this area increased from roughly 215 tonnes in 2012 and 2013 to a peak of 390 tonnes in 2015.

Following this peak, they declined steadily each year to 305 tonnes in 2018 but increased again in 2019 to 341 tonnes. The effort figures show less annual fluctuation than the landings figures, but also peaked in 2015. Figure 26 shows the LPUE has increased each year from a dataset low of 0.41 kg/pot haul in 2011 to a peak of 1.06 kg/pot haul in 2016. The absence of overlaps between the 95% confidence limits associated with these LPUE values indicate the increase in LPUE during this period is likely to be real and not an artefact caused by variability in the data. The mean LPUE declined slightly in 2017 but an overlap with the 95% confidence limit from 2016 indicated this was not statistically significant. There was a significant decline in 2018, however, which recovered slightly in 2019. These trends differ to the figures for district-wide LPUE values, which show an increasing trend between 2012 and 2019, with a dip in 2018, While the average LPUE during the reporting period of 0.88 kg/pot is only slightly lower than the average for the whole district of 0.96 kg/pot, the recent decline in 34F1 could suggest the density of the stocks on the ground within 34F1 may be under pressure from the amount of effort taking place in this area.

## ICES statistical rectangle 35F0

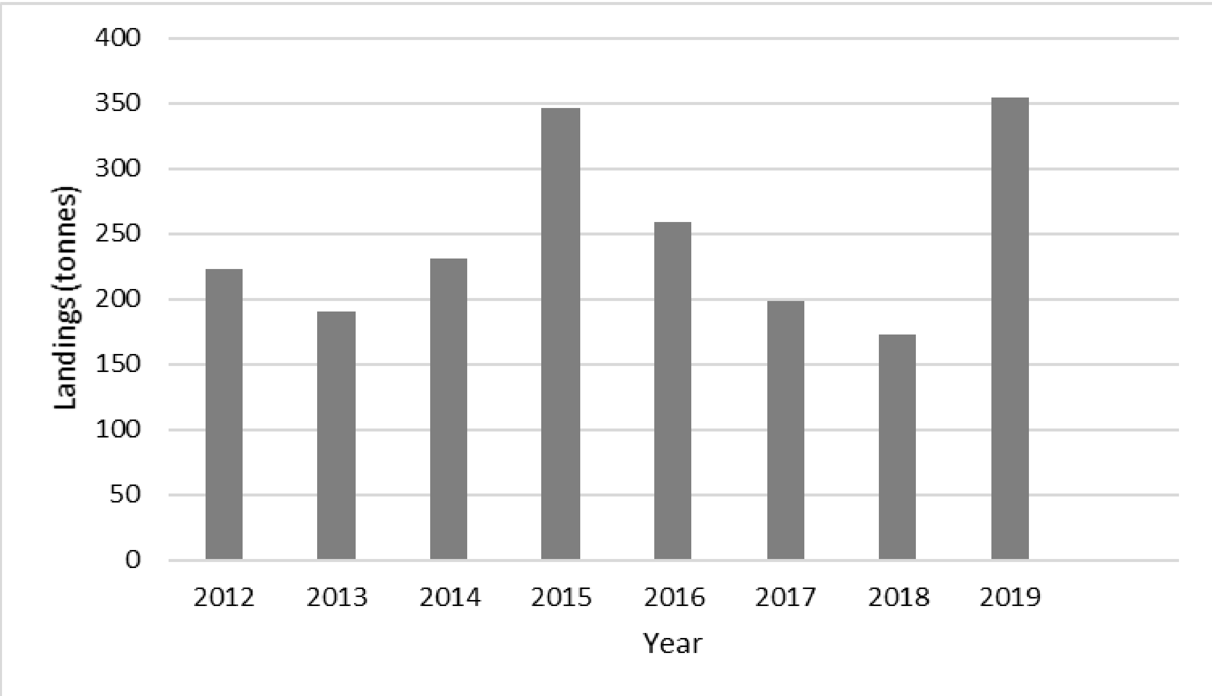


*Figure 27. Annual landings (tonnes) derived from MSARs in ICES statistical rectangle 35F0.*

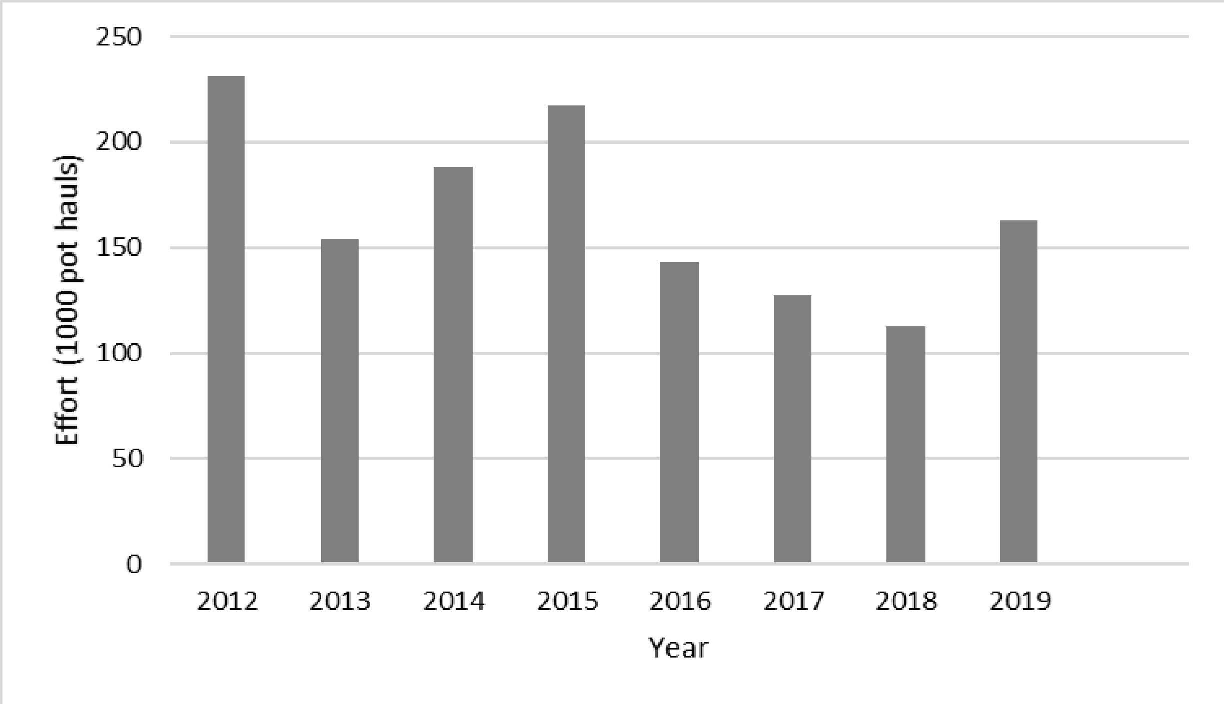


*Figure 28. Annual effort (number of pot hauls) in ICES statistical rectangle 35F0.*

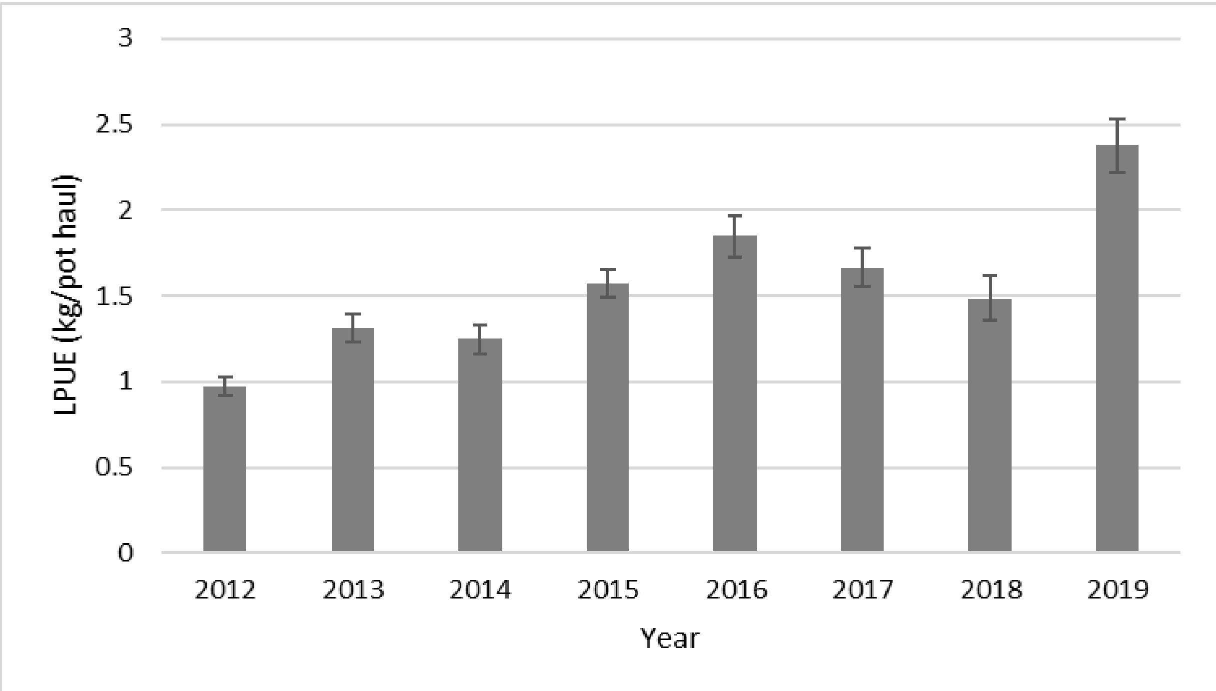


*Figure 29. Annual LPUE including 95% confidence intervals in ICES statistical rectangle 35F0. LPUE has been calculated for each individual MSAR entry and the mean determined from the averaged values combined.*

*Table 3. Summary statistics for ICES statistical rectangle 35F0.*

| Year | Effort (number of pot hauls) | Crab Landings (kg) | LPUE (kg/pot haul) |
|---|---|---|---|
| 2012 | 230,984 | 223,260 | 0.97 |
| 2013 | 154,140 | 189,884 | 1.23 |
| 2014 | 188,190 | 231,334 | 1.23 |
| 2015 | 217,602 | 345,760 | 1.59 |
| 2016 | 143,405 | 258,786 | 1.8 |
| 2017 | 127,221 | 198,342 | 1.56 |
| 2018 | 113,055 | 172,606 | 1.53 |
| 2019 | 162,684 | 354,462 | 2.18 |

Situated off the Lincolnshire coast, ICES statistical rectangle 35F0 is the second most fished area for crab and lobster landed into the district with >38% of reported landed weight in crab from this rectangle. While the data shows this area only attracts about half as much effort as takes place in 34F1, the figures for the weight of crab landed are much closer. This is reflected in the average LPUE for the area, which at 1.52 kg/pot haul is appreciably higher than the average of 0.92 kg/pot haul from 34F1. The annual LPUE seen in figure 32 shows a similar annual increase to that seen in 34F1, peaking in in 2016 and then declining again. In this area, however, there was a large increase in both landings and LPUE in 2019, making 2019 the highest year for both during this data-series.

<u>ICES statistical rectangle 35F1</u>

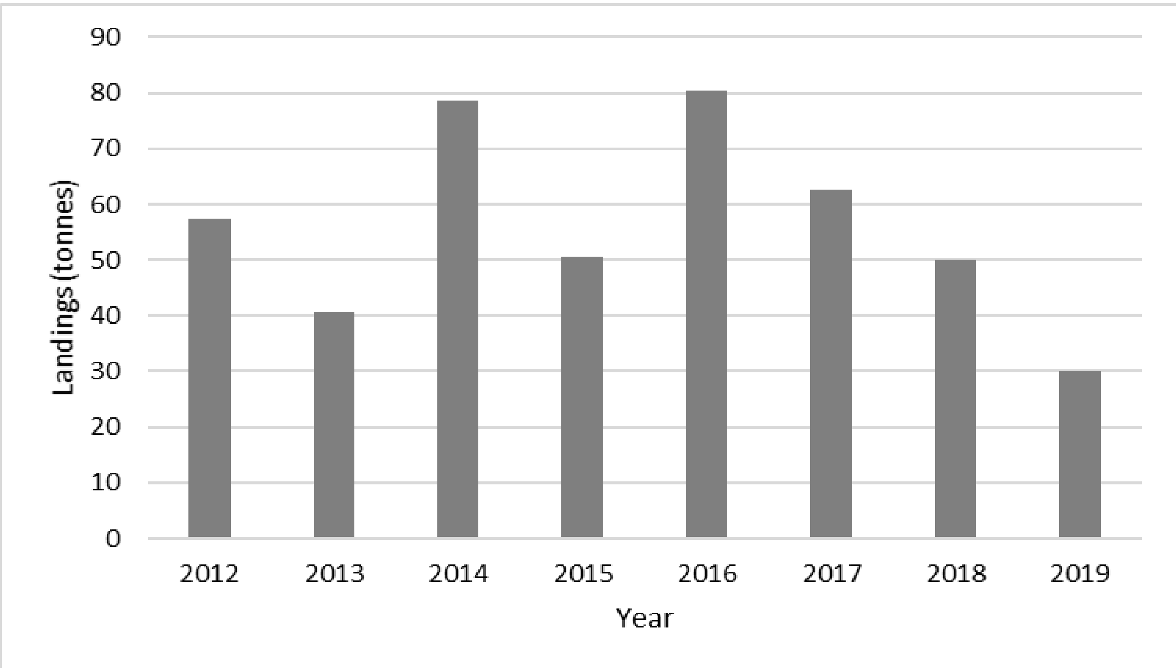


*Figure 30. Annual landings (tonnes) derived from MSARs in ICES statistical rectangle 35F1.*

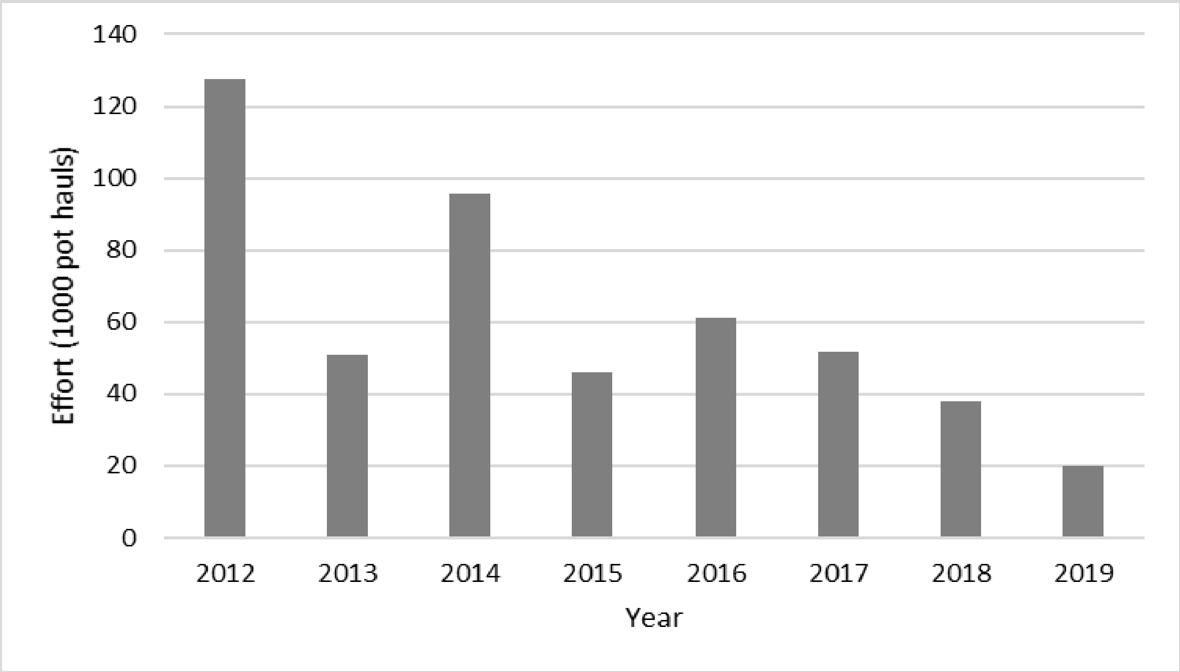


*Figure 31. Annual effort (number of pot hauls) in ICES statistical rectangle 35F1.*

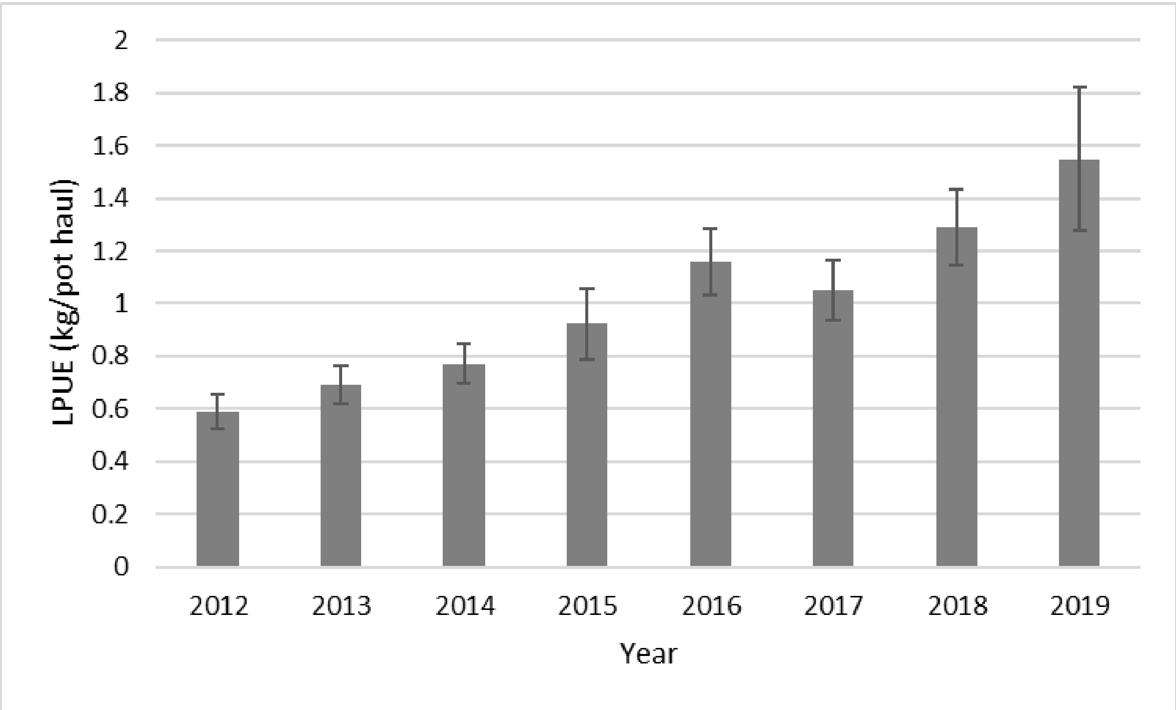


*Figure 32. Annual landings per unit effort (LPUE) including 95% confidence intervals in ICES statistical rectangle 35F1. LPUE has been calculated for each individual MSAR entry and the mean determined from the averaged values combined.*

*Table 4. Summary statistics for ICES statistical rectangle 35F1.*

| Year | Effort (number of pot hauls) | Crab Landings (kg) | LPUE (kg/pot haul) |
|---|---|---|---|
| 2012 | 127,598 | 57,476 | 0.58 |
| 2013 | 50,810 | 40,458 | 0.69 |
| 2014 | 95,745 | 78,531 | 0.77 |
| 2015 | 45,860 | 50,054 | 0.92 |
| 2016 | 60,980 | 80,538 | 1.15 |
| 2017 | 51,705 | 62,401 | 1.05 |
| 2018 | 37,890 | 49,977 | 1.28 |
| 2019 | 19,980 | 29,717 | 1.54 |

In terms of MSAR data, ICES statistical rectangle 35F1 represents only 8.8% of total landed weight for brown crab in the district; a relatively small contribution to overall annual landings when compared with the more heavily fished ICES rectangles 34F1 and 35F0. ICES rectangle 35F1 is further offshore, beyond the inshore fishery of ICES rectangle 34F1 and is targeted mainly by larger vessels with the capacity to reach the offshore fishing grounds. Although much of this data won't be captured in the MSARs, the data we do have for vessels under 10m that target the area indicates that LPUE is currently at a dataset high for the fishery, increasing from 0.58kg/pot haul in 2012 to 1.54kg/pot haul in 2019, with a minor drop in 2017 but continuing to rise thereafter despite both landings and effort showing a decreasing trend in recent years.

### ***Population biometrics***

*Biological Data – Bio-sampling at ports and processors*

In addition to analysing MSAR data, crab length-frequency data were collected by Eastern IFCA officers from processors and ports within the district as part of its biometric sampling programme (bio-sampling). Sampling effort is currently targeted at ports and processors on a proportion of catch from selected vessels at the point of landing or once catch has been distributed to local processors. Carapace width (CW) is measured across the widest part of the body and recorded with sex, area fished (ICES statistical rectangle), number of pots hauled, weight sampled and total vessel landing weight.

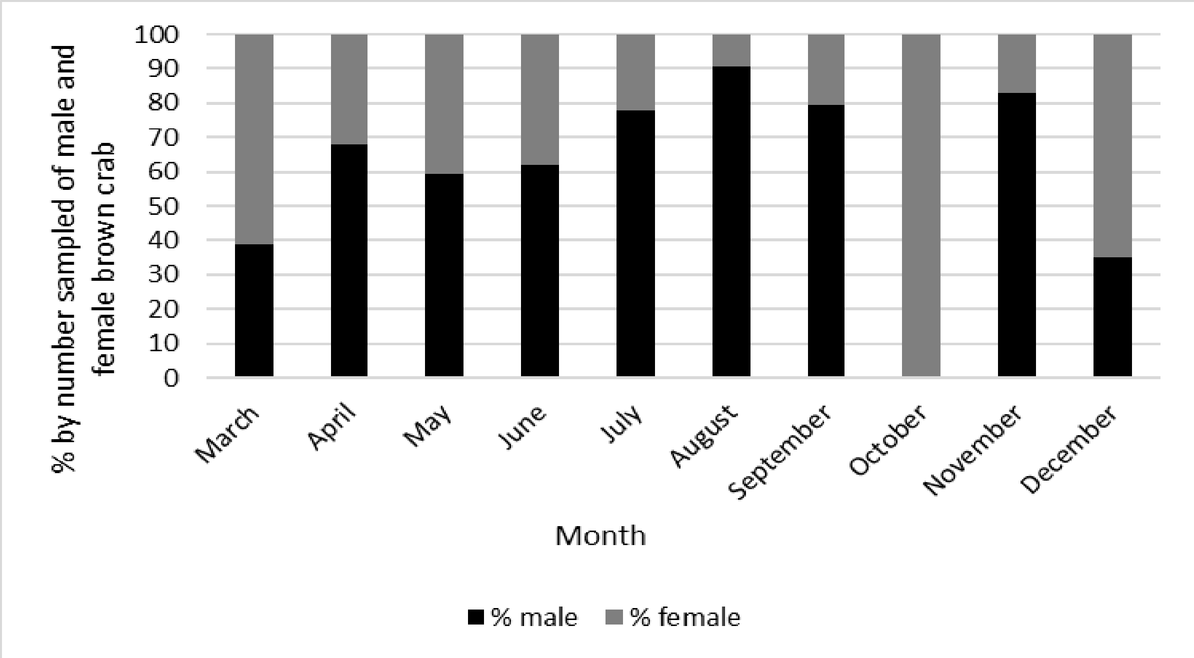


*Figure 33. Percentage by number of male and female brown crab fished per month in 2019 from biometric data sampling.*

Through biometric sampling a better understanding of the current population status of brown crab within the EIFCA district was established. However, this was confined to only the landed catch; from the minimum landing size of 115mm upwards. Average male animal size was 131.5mm, with females averaging 135mm throughout the year. There was a high degree of variation in animal sizes for both male and female individuals, varying from 115-195mm for males and 115-186mm for females (figure 34 and 35). Overall, males and females comprised 65% and 35% of sampled individuals respectively. However, there was significant temporal variation between months (figure 33) with male abundance peaking at 92% in August and dropping to 0.5% in October. Female abundance was lowest at 8% in August, peaking in October to 99.5% of total catch for the month.

Figures 34 and 35 present the population structure for brown crab, based on all individuals sampled during the biometric sampling program in 2019 from vessels known to fish inshore and offshore, as determined by the ICES statistical rectangle in which the catch was recorded.

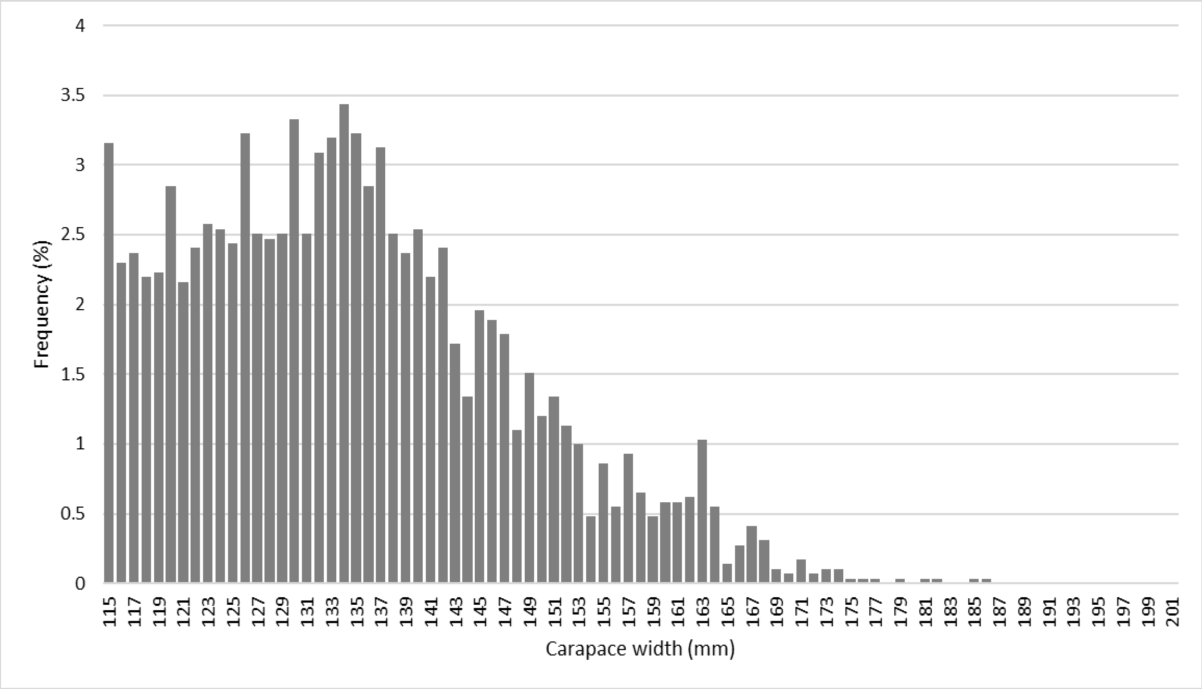


*Figure 34. Population histogram for female brown crab derived from the whole biometric sampling dataset.*

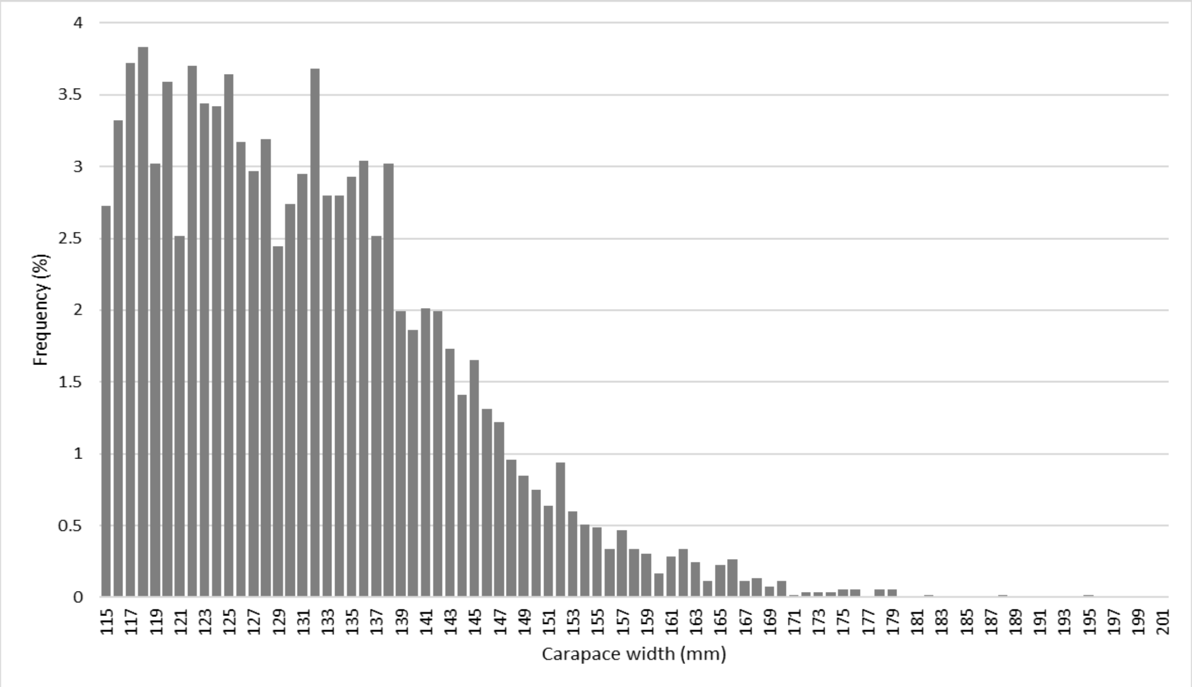


*Figure 35. Population histogram for male brown crab derived from the whole biometric sampling dataset.*

Figures 36 and 37 present the population structure for brown crab, based on all individuals sampled during the biometric sampling program in 2019 from vessels known to fish just inshore, as determined by the ICES statistical rectangle in which the catch was recorded, in this case ICES rectangle 34F1.

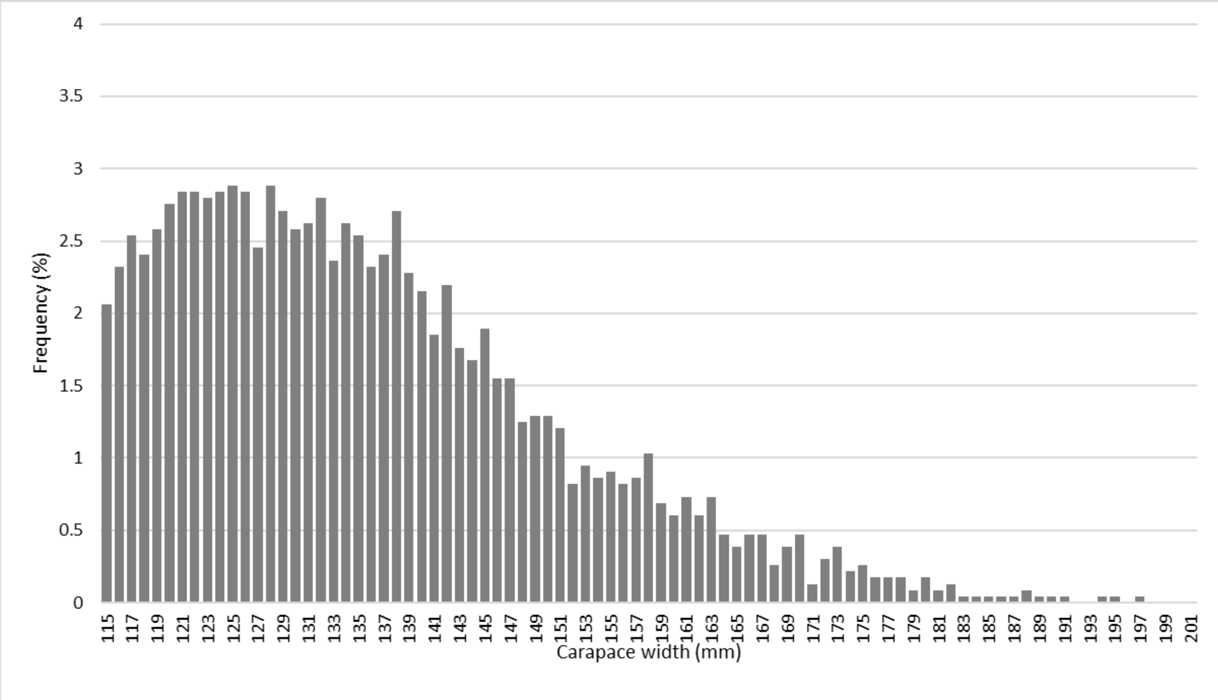


*Figure 36. Population histogram derived from biometric sampling for female brown crab fished by the inshore fleet.*

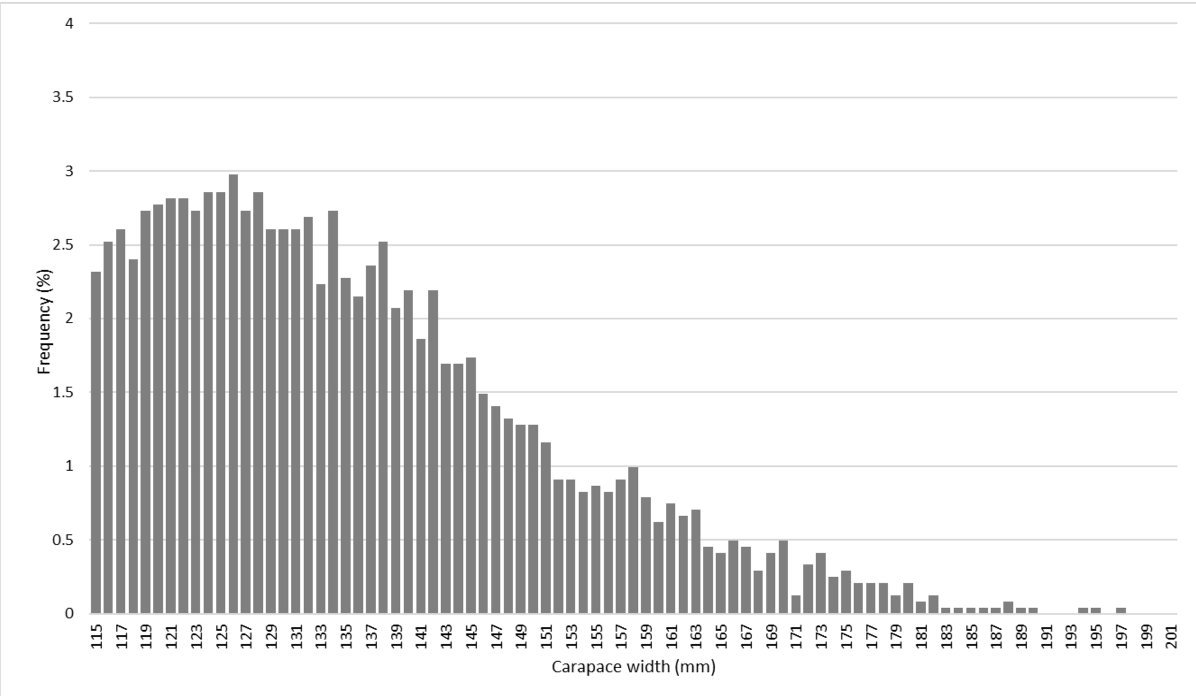


*Figure 37. Population histogram derived from biometric sampling for male brown crab fished by the inshore fleet.*

Figures 38 and 39 present the cumulative percentage of brown crab males and females in landings based on all individuals sampled during the biometric sampling program in 2019. This provides a basis from which to estimate the percentage reduction in retention at different Minimum Landing Size (MLS) reference points.

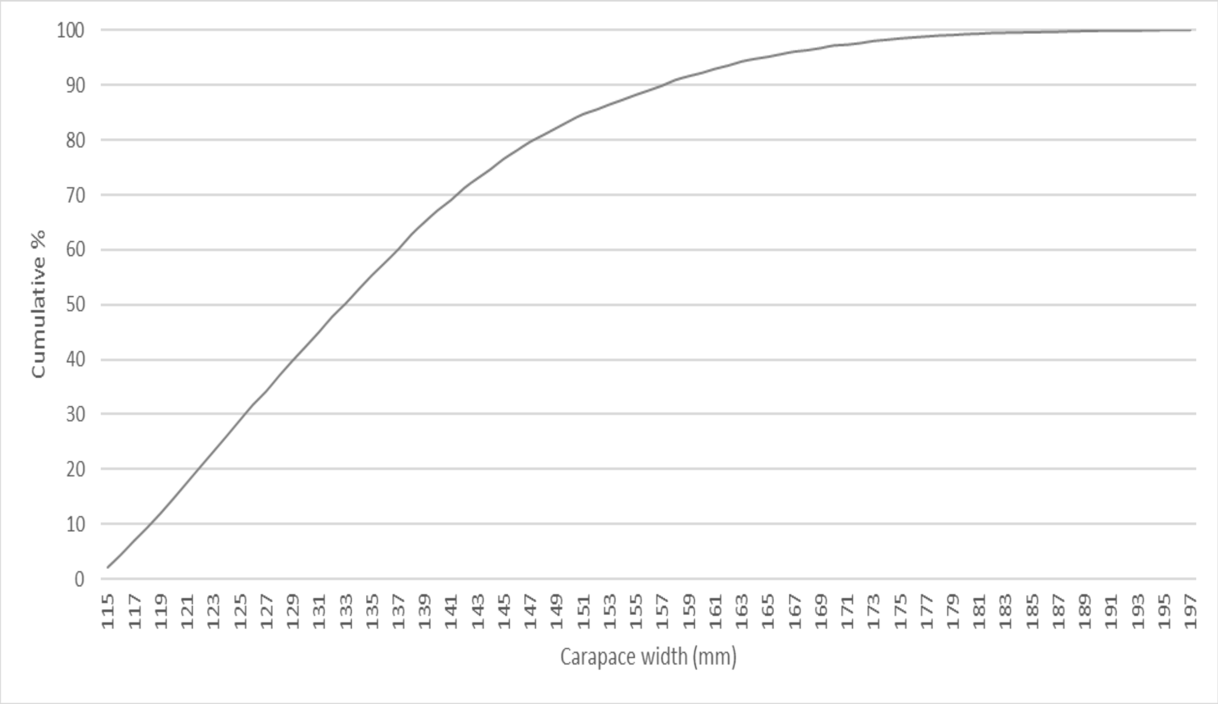


*Figure 38. Cumulative percentage (%) of brown crab females in landings by carapace width.*

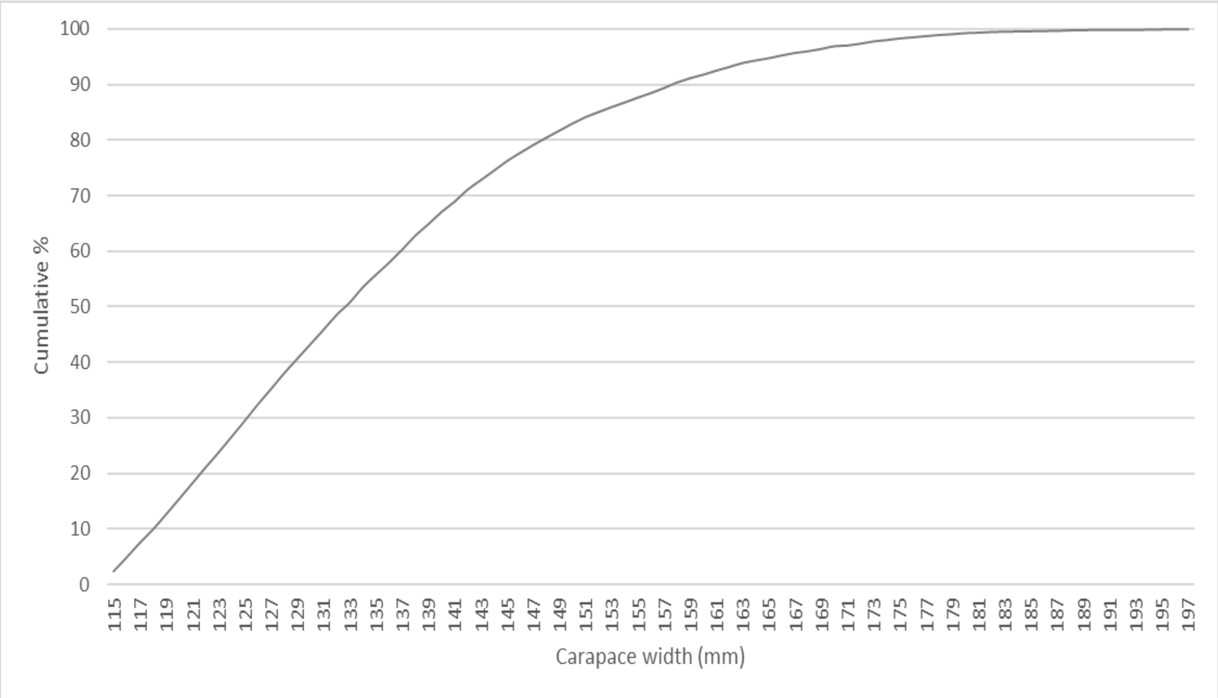


*Figure 39. Cumulative percentage (%) of brown crab males in landings by carapace width.*

## *Discussion*

### *Landings per unit effort (LPUE)*

Although trends in landings and effort for the brown crab fishery fluctuated between 2012 and 2019, LPUE steadily increased through the period. The spatial distribution of the edible crab fishery remains similar to previous years with ICES rectangles 34F1 and 35F0 representing 48.2% and 38.6% of annual landings and 56.2% and 27.8% of annual effort (pot hauls) respectively. ICES rectangle 34F1 is well established, both historically and culturally, as the predominant crab fishing ground within the district. It contains a complex chalk reef ecosystem which acts as both a nursery and habitat for juvenile and older crabs and lobsters. Whereas LPUE has steadily increased when looking at all ICES rectangles in the district combined, LPUE has decreased marginally in 34F1 from a peak of 1.06kg/pot haul in 2016 to 0.99kg/pot haul in 2019. LPUE has increased appreciably in 35F0 whilst landings have increased 2-fold and effort considerably less. Addison and Bennett (1992) suggests that observable trends of increased landings correlate closely to strong recruitment years. Offshore areas such as 35F0 are influenced by recruitment patterns taking place in inshore waters which receives larval recruits from the north as it provides settlement substrate seldom found along the district's coastline. 35F0 is positioned off the Lincolnshire coast and within that area, fishermen generally target species further offshore. Trends in LPUE in individual ICES rectangles represent localised characterisations of the fishery, in terms of effort, individual sizes of crabs and distribution of individuals on the fishing grounds.

LPUE decreased in 2018 through the entire dataset as well as within ICES rectangles 34F1 and 35F0 but showed signs of recovery in 2019 with a marginally higher figure than that seen in 2017. Anecdotal reports of reduced catch from fishermen following the 'Beast from the East' climatic event in 2018 appear to support the appreciable drop in LPUE in the fishery of the same year. Local media (www.northnorfolknews.co.uk, 2018) reported widespread beaching of crustacean and mollusc species, including brown crab and lobster, providing images of a number of locations on the coast within the EIFCA district of stranded individuals nearly 6 inches deep in places and spanning whole beaches. This coupled with anecdotal evidence provided by fishermen from both Cromer and Wells, that crab and lobster appeared to be behaving differently during this event, in terms of catchability and location, and catches at 60% of the 2017 fishery in 2018 following the event meant that landings were much lower in February 2018. The following fishing season was said to be one of the most difficult in a long time. Fishermen reported losing considerably more shanks of pots than usual during the event, some losing up to 200 pots, further impacting their ability to fish and creating an additional financial burden, as well as potential increases in "ghost" fishing. The drop in LPUE may be linked to this event, however there is no firm evidence to support this theory.

The MMO are currently in the process of administrative changes, replacing MSARs with electronic reports. This may result in an absence of data available to EIFCA, impacting on our ability to analyse and assess the fishery for a number of years. A similar trend was seen when MSARs were introduced and it took a number of years to obtain reliable consistent data. This change has come at a critical juncture in management of the fishery and may present problems when assessing the effects of any management measures introduced, including potential impacts on assessing progress of the Fisheries Improvement Plan (FIP), the potting assessment in Cromer Shoal Chalk Beds MCZ and any economic impacts of management.

*Population biometrics*

Increases in sampling effort since 2015, primarily through access to processors has increased the acquisition of bio-sample data, allowing for a greater number of individuals to be measured during each sampling occasion. The data shows male crabs make the largest contribution to landings overall in 2019 (the year when these measurements were taken). There were, however, a number of months in the 2019 fishing season in which considerably more females were landed than males, particularly those months where the females are not egg bearing and sessile. A number of factors affect catchability throughout the season. During courtship the female crab is protected by the male, thus reducing the amount that both will feed. This reduces the likelihood of them being caught in baited pots. Mating takes place post-moult whilst the shell is still soft. Once mating has occurred the male tends to relinquish guardship of the female and foraging behaviours will increase, making them more susceptible to being fished. Fertilised eggs are carried under the females tail for up to 9 months in which time the female will remain relatively sessile, with limited movement to feed when necessary. Once hatched, the pelagic larvae drift with water movements until they settle to the seabed as miniature adults (about 2.5 mm in size) in summer or autumn depending on latitude and water temperature. These factors play a key role in growth rate of individual brown crabs, ultimately determining when they recruit into the fishery and become part of the catchable stock.

Female crabs sampled from vessels that are known to fish offshore grounds are often 10-20mm bigger in carapace width on average than individuals fished within the inshore areas. There is evidence (Addison and Bennett, 1992) to show edible crabs in the inshore areas of the district mature at a smaller size than the national average, hence a lower minimum landing size of 115mm compared to other UK waters. A number of hypotheses have been postulated for this maturation at a smaller size within these fishing grounds. Bannister (*pers. Comms. 2020)* indicates that the inshore waters around the coast act as nursery grounds, and those crabs not fished will migrate offshore to the Race Bank or other areas of the North Sea.

The population structure for the district wide fishery indicates a peak at 133mm for female brown crab and a peak of 118mm for male brown crab, with a secondary peak at 133mm. The population structure for the inshore fishery indicates a peak between 127 and 129mm for female brown crab and a peak of 127mm for male brown crab. Relative abundance then falls with increasing size. This is potentially due to fisheries exploitation and natural mortality. Although these factors are likely to influence the population structure curve to some degree, it is also likely that the selection of particular individuals for market sale will influence the shape of the size distribution curve when compared with natural population curves for the stock still in the sea.

Importantly, this doesn't represent the overall peak in abundance for the whole population, only those that are landed. Data captured during biometric sampling provides the opportunity to measure a broad range of catch without the risk of recapture which may skew the data and not show an accurate representation of the population. However, sampling at sea may risk recapture but provides a better representation of the population as a whole as those individuals usually returned as undersize provide a better understanding of population trends below the 115mm minimum landing size. Sampling at ports is less dependent on external factors such as weather, enabling a consistent dataset to be compiled whereas sampling at sea is very much dependent on availability to join fishermen on trips. A limitation with our approach of heavily bio-sampling at processors is the risk that some of the catch may be sorted at sea before landing and selectively diverted to shops rather than going to the processor, preventing us from measuring the whole catch or a sub sample that accurately reflects the overall component each fisher has in the whole catch. Particularly large or healthy individuals are usually selected from the catch, or a specific sex which has the potential to skew the data towards an increase in the smaller end of the range of catch. Another limitation of the sampling method is the spatial distribution of sampling effort. Surveys are currently conducted at two locations on the north Norfolk coast, where catches tend to have originated from ICES statistical rectangles 34F1 and 35F1. As a consequence, no recent bio-metric data have been collected from crab that have been landed from Lincolnshire or Suffolk, two very different fisheries, targeting different fishing grounds and different size crab.

The population structure of crab stocks in the southern North Sea, and nationally, is not well understood, but edible crab are known to undertake extensive seasonal migrations. Tagging and population genetics studies of brown crab have been conducted in a number of crustacean fisheries and results suggest a linkage between inshore and offshore crab stocks. Population dynamics, including recruitment and migration are widely unknown in the North Norfolk fishery, however, research (Bannister, *pers. Comms*. 2020) has shown that the North Norfolk crab population migrates through the Eastern IFCA district, eventually moving offshore as size increases, suggesting that the inshore and offshore fishery target the same population. This is supported by anecdotal evidence provided by fishermen that crabs migrate from the inshore area once reaching a certain size, into the deeper water of the offshore area thus limiting the size of crab available to be fished by the inshore fishery and increasing the size of crab available to be targeted by the more substantial vessels on the offshore grounds. This has been attributed to a lack of suitable substrate for the larger individuals inshore, particularly when they need shelter while moulting.

Based on the number of brown crabs sampled during biometric sampling, an increase in Minimum Landing Size (MLS) would equate to approximately 15% reduction in retention if MLS were raised to 120mm as has been widely suggested by the industry. An increase of MLS to 130mm in line with the minimum landing size outside of the EIFCA district without the dispensation for landing smaller crabs in place would equate to approximately 43% reduction in retention. It was recently suggested at a brown crab meeting at Fishmonger Hall, where there was agreement that in order to safeguard crab populations the minimum landing size everywhere should be increased nationally to at least 140mm, a standardisation of minimum landing sizes across UK inshore and offshore waters. This would equate to an approximate reduction in retention of 65% based on the biometric sampling data.

### *Data gap analysis*

The current stock assessment has identified a need to examine our approach to crab and lobster sampling in terms of the data collected and the location from which it was sampled in order to provide an assessment that is representative of the fishery as a whole. Limited sampling locations and access to catch that has been sorted before reaching the point of sampling mean that the introduction of bias into our sampling method is something that could be influencing results. Prior to the 2019 crab stock assessment, Eastern IFCA trialled a multi-metric approach to crustacean stock assessments including LPUE and Length Converted Catch Curve (LCCC) fisheries models. LCCC is used to assess how the fishery effects stock structure, population dynamics and age (size) classes. Fishing mortality estimates derived from the LCCC model consider the frequency of sizes within a population to estimate the depletion over time of individuals, represented as mortality rate. This is based on the difference between how many small (young) and big (old) individuals are in the population. LCCC models were originally developed to overcome issues with conducting stock assessments on tropical finfish that, like crustacea, do not produce distinctive growth rings in their hard-skeletal structures from which they can be aged. LCCC determines age (pseudo age) from size using known (estimated) growth parameters, but also has the assumption that recruitment and natural mortality occur at steady rates and that there is no emigration from the population. These assumptions, and the fact that crustacea grow in steps rather than at a steady rate, mean the LCCC model is less than ideal for crustacean stock assessment. Nevertheless, while this method is not tailored to the specifics of crustacean biology it is commonly used for estimating fishing mortality for this stock; providing an indication of stock health and a means of monitoring and quantifying any changes resulting from management actions.

The LCCC modelling method is currently under internal review at Eastern IFCA to determine whether local conditions make its continued use appropriate for stock assessments in the district. Its continuation will require improvements being made to improve sampling techniques, to ensure the whole stock is proportionally represented in assessments

*National and regional differences in brown crab stock assessments*

This stock assessment forms part of a group of current projects focussed on potting fisheries in the Eastern IFCA district and the wider southern North Sea. A commercial fisheries assessment is currently under way to assess the impacts of potting fisheries on the designated features of Cromer Shoal Chalk Beds MCZ and an industry led Fisheries Improvement Plan (FIP) with the aim of improving the sustainability of the fishery.

Cefas publish reports describing the status of the brown crab every 2 years. The most recent report (Cefas, 2020) indicates that the exploitation rate for both male and female; the spawning stock biomass as a whole is high for the southern North Sea stock. That said, Cefas recognise that inconsistencies in data inhibit a more refined analysis of stock exploitation driven primarily by a lack of data on population dynamics such as recruitment into and migration out of the fishery.

It is widely recognised that the UK's brown crab populations are data poor with large regional variations. In October 2019, policy and regulatory stakeholders involved in managing brown crab fisheries in England, Wales and Jersey met to discuss the current status of brown crab fisheries, both nationally and regionally, including areas of concern and potential knowledge and regulatory gaps that could be acted on to improve the status of brown crab stocks. The Cornish IFCA for example reported a decrease in landings whilst effort continues to rise. The Sussex IFCA also reported a 50% decrease in landing per unit effort (LPUE) compared to the preceding year and Jersey has experienced a decline in number and size of crabs over recent years. The Eastern, Northumberland, North Western and North Eastern IFCA on the other hand all reported an increase in landings, with Eastern and Northumberland also seeing an increase in LPUE.

It was agreed at the meeting that there are clear regionalised issues that need addressing, however the group did not agree at this stage that there was a national problem with brown crab stocks. It was noted that although the data does not currently indicate a national issue, widespread data gaps and inconsistencies made coming to an accurate consensus difficult.

*Wider knowledge gaps in the science and data for consideration*

It was widely acknowledged that more accurate data surrounding fishing effort will provide a better understanding of how to manage brown crab stocks. The group highlighted that landings data is not equivalent to effort data, and landings data does not provide information on the whole population, including smaller cohorts and thus recruitment. Furthermore, improvements in data collection surrounding number of pots hauled and soak times will enable a better understanding of the relationship between recorded landings and fishing effort. Cornwall IFCA reported that implementation of an alternative reporting requirement with shellfish permits tailored to the needs of a stock assessment provided significantly improved data after MSAR data proved to be poor and incomplete, making it difficult to use for stock monitoring.

The group also agreed that further information on the entire stock was needed including larval movement and adult migration. There was also a desire to better understand stock structure including recruitment levels. The need for better understanding of stock boundaries and spatial structure was also raised in order to facilitate management on a biological stock basis, rather than at the arbitrary spatial division between 0-6 mile and 6-12-mile management zones, which crab populations often span. Improved knowledge of brown crab growth rates was also cited as a gap in existing knowledge given that it proved one of the key factors surrounding uncertainty in stock assessments.

Concerns were raised over the absence of evidence regarding the long-term impacts of offshore developments such as windfarms and associated underwater cabling. There was widespread concern regarding the absence of a requirement to monitor the impacts of these developments after installation, with the general feeling that this was a big “missed opportunity” to gain understanding, to inform future offsetting, planning and/or mitigation. The effect of upwelling from wind turbines and its impact on water temperatures was raised as an area that warranted further investigation. It was highlighted that improving understanding of the long-term impacts of current infrastructure would help to reduce the impact of future, larger developments.

***Conclusions***

LPUE results for the district-wide fishery indicate that populations of brown crab have been increasing over the years for which data is available and/or plateaued at a dataset peak, suggesting that stocks are stable and currently recover from annual depletion with recruits maintaining LPUE. While this indicates that fishing activity is not influencing recruitment to the point of reducing contemporary levels of stock biomass, it does not necessarily mean it is not inhibiting the potential increase the species' abundance through recruitment overfishing. Increasing LPUE may be driven in part by improvements in fishing gear and/or fishing practices, however it is unlikely that these would account for such a large increase in LPUE. Within a limited dataset, a stable LPUE can also be achieved where prior fishing pressure has already reduced the stock to a stable plateau that is below its optimum capacity. We are unable to identify whether this has been the case in the current study, and as the fishery predates associated fishery records, would be difficult to discover without restricting fishing effort and observing the effects on LPUE.

Through much of the district, the crab fishery is a mixed fishery; in which the fishers use the same gear in the same area to concurrently catch lobster as well as crab. Candidate management measures will need to be proportionate. Any measures implemented for one species has the potential to impact on the other, potentially causing unnecessary detrimental effects on the fishery.

### ***Recommendations***

The stock assessment indicates that from a purely population sustainability perspective the crab fishery in the Eastern IFCA district is currently not under immediate threat and only minor management is needed to ensure stock sustainability. Measures introduced through the Cromer Shoal Chalk Beds MCZ commercial fisheries assessment and the Fisheries Improvement Plan (FIP) will likely satisfy management requirements to ensure the stock maintains a good population status.

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