Eastern IFCA

Inshore Fisheries and Conservation Authority

RESEARCH REPORT

2017

Crab and Lobster Stock Assessment

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Contents

Executive Summary

Commercially and culturally important Brown crab (*C. pagurus*) and European lobster (*H. gammarus*) fisheries operate throughout the Eastern Inshore Fisheries and Conservation Authority (EIFCA) district with key production areas located off the North Norfolk and Lincolnshire coasts. The Crustacean Stock Assessment project was initiated in 2013 with aims of developing a robust methodology for assessing this mixed fishery, ultimately providing the necessary conclusions through data acquisition and analysis to inform whether or not management measures are required. As the regulatory Authority, a primary objective of EIFCA is to ensure sustainable exploitation of commercial fish populations in order to fulfil 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).

Following an increasing trend in landings, with a peak in 2016, data acquired from Monthly Shellfish Activity Returns (MSARs) on landings and efforts have identified a general decreasing trend in landings and effort across the district in 2017. This has been largely driven by the number of individuals taken from the fishery in 2016 when combined landed weight equated to over 1000 tonnes. This was an unprecedented landing figure for the fishery, and it is unclear how this boom in crab came about. Increased levels of recruitment to the fishery following strong spawning in the 3-5 years preceding this peak may have been the key driver.

CPUE has decreased in 2017 across the district, with the exception of ICES rectangle 34F1, where CPUE has continued to rise. 34F1 has the highest level of brown crab removal through fishing in the district, reflected by landings figures and this pattern continues into 2017. Effort has continued to drop in this area following the 2016 fishery suggesting there were a great number of mature individuals fished as Kg/haul was high whilst effort was decreasing. Brown crab (*C. pagurus*) dominates landings, a continuing trend from previous years, however due to the value per Kg of each species, annual contributions to the value of the fishery remain relatively even. Landings for effort for European lobster (*H*. *gammarus*) have remained relatively stable across the dataset period with significantly lower landings figures when compared to *C*. *pagurus*.

Fishing mortality estimates using length converted catch curve and biological reference points against which contemporary mortality estimates could be measured using yield per recruit analysis indicated that brown crab is being exploited beyond the maximum recommended reference point however; current estimates are lowest in 3 years suggesting that fishing mortality is moving in a positive direction. Management measures developed through this study will aim to ensure this trend continues for brown crab, ultimately reaching the necessary reference point. Comparatively, analysis for European lobster provided low confidence results, an artefact of low sampling which led to inconclusive results due to insufficient data.

Management recommendations are based on the level of exploitation the fishery is currently experiencing which currently exceeds the maximum recommended reference point to support a sustainable crustacean fishery. Although current fishing mortality

levels are moving in a positive direction, displaying a decreasing trend for both male and female *C*. *pagurus* towards the reference point, considerable work is still needed to achieve 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). It is evident, in both our own reporting and reports from Cefas (2014), that current sampling protocol for H. *gammarus* is providing insufficient data to analyse stocks confidently.

Based on findings within this report, management recommendations would aim to cap effort at current levels in order to address the issue of high fishing mortality. Potential technical and control measures need assessing to understand efficacy in achieving management objectives. Importantly, a revised bio-sampling methodology for *H. gammarus* is required to ensure sufficient data is acquired to model data with confidence to assess current stock levels.

Introduction

Background

Potting fisheries targeting crustaceans operate widely throughout the EIFCA district from Saltfleet in Lincolnshire, through Norfolk and down to the southern limits of the District in Felixstowe. Although potting activity is prevalent throughout the district, it is predominantly focused along the North Norfolk coast; an area with long standing historical and cultural traditions of fishing for Brown crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*). Most vessels operating in the EIFCA district are categorised as <10m, and historically the fishery operated within 2nm of the coastline (MAFF, 1975), primarily due to accessibility restrictions on vessels. Turner et al. (2009) highlighted that advancements in technology have increased the range in which potters can operate, enabling fishing grounds further afield to be utilised. Despite this a significant number of potters still fish in close proximity to the shore, consequently the fleet is represented by a range of vessels with varying capability; smaller vessels target inshore grounds whilst larger vessels accessing less pressured deeper water further offshore target larger fish (Welby, 2016).

Potting fisheries specifically target crab and lobster through the deployment of static gears consisting of a string of 30 baited pots which are typically left to soak for 24-48 hours before being hauled. Vessels will fish several shanks on a rotational basis, hauling between 100-500 pots each trip. Catch is sorted at sea with any undersize or poor-quality individuals returned immediately, whilst the remainder is sold to various outlets ashore. 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, allowing them to grow to a size where they will recruit to the fishery.

Numerous static gear designs are available, highlighted in figure 1. Parlour pots are growing in popularity, helping to improve catch retention, allowing for longer soak times between hauls so that pots do not need to be hauled as frequently. However, inkwell and creel style pots have traditionally been deployed and are still favoured by some of the fleet (Addison and Lovewell, 1991).

Figure 1. Pot designs include traditional inkwell pots and creels, modern parlour pots and aluminium wire pots.

The main season for *C. pagurus* commences around late March/early April with peak landings in May and June, dropping off through to late September/early October. The main season for *H. gammarus* generally follows closely behind, starting around May/early-June, peaking in late-June/July and dropping off in October (Cefas, 2014).

European Lobster (H. gammarus)

European lobster can be found from Scandinavia to North Africa, however they are mainly centred around the British Isles where a large proportion of landings occur (Cefas, 2014). They occupy solitary shelters in rocky substrates and crevices between rocks and boulders and availability of suitable habitat of this type has been postulated as a factor influencing the carrying capacity and size structure of *H. gammarus* populations (Seitz et al. 2014). *H. gammarus* is one of the most commercially exploited shellfish species found in UK waters and has one of the highest value/Kg (*Pers. Comms., 2018*). Moulting occurs in summer approximately once a year for adults, becoming less frequent in older animals, and mating occurs soon after the female has moulted. After the eggs hatch the larvae are in the water for 34 weeks before the first juvenile stages settle on the seabed. Larval distribution depends on local hydrographical conditions and the behaviour of individuals. With such a lengthy time in the plankton, the probability of individual larvae surviving is low and consequently recruitment levels are highly variable. Both sexes are considered fairly sedentary, although some inshore/offshore and longshore migration is known to take place at some locations (Cefas, 2014).

Brown Crab (C. pagurus)

While sharing a similar geographic range as *H. gammarus, C. pagurus* is found on a wider range of habitats, including rocky reefs, soft mud and sand. As with *H. gammarus*, studies have revealed a smaller size structure in *C. pagurus* populations in North Norfolk when compared to adjacent areas. Unlike *H. gammarus* however this has not been associated with habitat requirements but is believed to be a consequence of migration and recruitment (Welby, 2016). This smaller average size is reflected by a lower MLS for *C. pagurus* in the EIFCA district compared to other areas. The species can be found from Scandinavia to Portugal, however stock boundaries for edible crab remain poorly understood and both sexes move quite widely at times; females in particular have been shown to travel large distances in relation to spawning activity. Egg carrying females are largely inactive over the winter brooding period but the eggs hatch in the spring and summer. After around 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. Mating activity peaks in the summer when the female has moulted with spawning occurring in the late autumn or winter (Cefas, 2014).

Figure 2. Brown crab (*C*. *pagurus*) and European Lobster (*H*. *gammarus*).

District Landings and Value

MSAR (Monthly Shellfish Activity Returns) records collated from the <10m fleet between 2006-2017 indicate average annual landings in the district of 749 tonnes (SD±134) for target species combined, however recent years preceding this report have seen landings significantly higher than this average (913 tonnes, 1003 tonnes and 1057 tonnes for 2014, 2015 and 2016 respectively). *C*. *pagurus* accounts for the majority of crustacean landings in the district each year whilst lobster represents less than a quarter of total landings. Values for the fishery have dropped significantly in 2017 to £0.6 million (46%) for Brown crab and £0.7 million (54%) for European lobster. In the 3 years preceding this assessment the Brown crab fishery has been worth significantly more than the European lobster fishery, with values for Brown crab equating to £1.4, £1.8 and £1.9 million in 2014, 2015 and 2016 respectively. The value for 2017 of £0.6 million is an unprecedented low for the fishery, indicating an economic impact sustained by the previously high landings in the preceding years. The value of the European lobster fishery is not significantly different from the preceding 3 years and stability in landings and effort have seen a steady economy for the fishery. The mean value for the dataset period since the introduction of MSARs (2006-2017) equates to £1.3 million (SD±0.3) and £1.0 million (SD±0.2) for the crab and lobster fishery respectively, with total mean worth of the fishery being £2.3 million (SD±0.3). Inter annual value fluctuates around the mean, with £1.9 million and £1.5 million the peak values for crab and lobster respectively. Despite clear differences in landed proportions, both target species contribute more equally to the mean value of the catch due to the higher sale value/Kg of lobster, which fluctuates seasonally between £10-16.50/Kg when crab will attain 0.90p-£1.30/Kg. Although important in monetary terms to a large number of towns and ports within the district, the fishery also provides strong intrinsic cultural and character ties dating back hundreds of years.

Management

The 2016/2017 Strategic Assessment identified fisheries for crab and lobster as a high priority based on the limited regulation in place to manage the fishery including effort, gear or catch control in combination 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 result in Maximum Sustainable Yield (MSY).
• Increasing demand from industry to consider revised management.
• Obligations under the Marine and Coastal Access Act 2009 (MACAA) and the Marine Strategy Framework Directive 2008 (MSFD).

Furthermore, Priority 6 – Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ), as highlighted in the Strategic Assessment provides a concurrent driver to establish management measures for the fishery. The Cromer Shoal Chalk Beds site was designated in January 2016 and management assessments and activities are less advanced than for Special Areas of Conservation (SACs) and Special Protected Areas (SPAs). The site features are closely linked with a major fishery within the EIFCA district, namely crustacean potting, and one which has been identified as a high priority in the 2016/2017 Strategic Assessment.

EIFCA is responsible under Section 153 of the Marine and Coastal Access Act 2009 (MACAA) to ensure the sustainable exploitation of sea fisheries resources. The Marine Strategy Framework Directive 2008 (MSDF) highlights additional objectives to achieve Good Environmental Status (GES) in EU marine waters by 2020. In relation to this, issues identified with the crustacean fishery resonate with descriptor 3, implying that stocks should be, exploited sustainably consistent with high long-term yields, have full reproductive capacity to maintain stock biomass, and that the proportion of older and larger fish/shellfish should be maintained (or increased), as an indicator of a healthy stock. All three attributes must be fulfilled to achieve Good Environmental Status. In fulfilling the criteria, all commercially exploited stocks should be in a healthy state and exploitation should be sustainable, yielding the Maximum Sustainable Yield (MSY). This equates to an increasing pressure to ensure that management measures are in place to support the sustainability of commercially exploited stocks.

The target species 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 which has increased MLS for this species outside of the Authority’s district (Undersized Edible Crabs Order 2000 (2000 No 2029)). Minimum landing sizes are set at 115mm carapace width for *C. pagurus* and 87mm carapace length for lobster within the EIFCA district. These were reflected nationally for *C. pagurus;* however, these were reviewed in 1986 and 1990, raising 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 be, on average, smaller than in other areas (Addison and Bennett, 1992).

Table 1. Regulations relevant to trap fisheries targeting crustaceans in the EIFCA district (Welby, 2016).

Regulation	**Effect**	**Intent**
MMO Vessel Licencing shellfish permit	Prohibits the fishing for shellfish without relevant permits	Limits entry into the fishery as no new permits are being issued.
Council Regulation 850/98 ANNEX XII for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms.	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.
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 (as amended)	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. As amended, prohibition of fishing and landing of berried lobsters and crawfish.	Protects brood stock that has been marked for protection using a V notch cut into the tail of the animal. As amended, protects brood stock from fishing and landing that are bearing eggs.
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 from being landed

Brown crab (C. pagurus) and European lobster (H. gammarus) Assessment

EIFCA initiated the Crustacean stock assessment project in 2013 with the objective of building on current understanding of potting fisheries operating within the district. The aim; to develop the techniques necessary to conduct stock assessments at a localised level including a long-term monitoring strategy that uses analysis of contemporary data to feed into an adaptive management approach, protecting the health of stocks and the viability of the fishery. This assessment uses catch return data and biometric sampling (bio-sampling) to analyse the districts fishing grounds by ICES rectangle, estimating fishing mortality by sex/species using length converted catch curve models.

Data Sources

Monthly Shellfish Activity Returns (MSARs)

Monthly Shellfish Activity Returns (MSARs) are standardised forms on which fisher's record catch reports and send to the Authority, forming a foundation dataset which arrives in paper carbon copy format of the original records. 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 and effort data and port of landing by vessel. Discerning whether activity has occurred inside or outside of the EIFCA boundary is challenging due to the nature of spatial data. Activity is frequently reported in areas that straddle the boundary, however all data is included within the assessment as the determination of overall stock status is the objective, inclusive of those components of the stock inside and outside of EIFCA's jurisdictional boundary. Data is then digitised and captured in a bespoke Access database, providing opportunity to perform queries on elements that form the database. Basic fisheries statistics can then be calculated for fishing grounds within the district by ICES statistical rectangle. Previously, this data has been used to model fishing grounds using surplus production methods, and although useful as indicative tools to describe the current state of the fishery, there is a level of uncertainty associated with the models generated and overall effectiveness in monitoring change in the fishery due to biological factors or management changes (Welby, 2016).

Bio-sampling – Port and processors

Bio-sampling is undertaken at ports and processors throughout the district, providing data to describe population dynamics and model mortality. Sampling is conducted on a proportion of catch from randomly selected vessels at the point of landing or once catch has been distributed to local processors. Size of carapace and sex, area fished (ICES statistical rectangle) and number of pots hauled are recorded, coupled with weight sampled and total vessel landing weight. Data is then used to model mortality, providing an estimation of fishing mortality (F) using length converted catch curve. Biological reference points against which contemporary mortality estimates could be measured using a yield per recruit methodology. Welby (2015) provides a full methodology for conducting this process.

Summary statistics from Monthly Shellfish Activity Returns (MSARs)

To facilitate the analysis and assessment of fished stocks in the North 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 define boundaries of fished grounds by operators in the district, enabling analysis on a site by site basis and this is further supported by the requirement of fishers to submit MSAR forms, clearly stating which ICES Statistical Rectangle has been fished in. Importantly, effort and catch are unevenly distributed throughout all fishing grounds within EIFCA's jurisdictional boundary and is concentrated in certain areas, corresponding closely with the position of major contributing ports, with key production areas located off the North Norfolk coast. Fishing grounds, as defined by ICES, are assessed below.

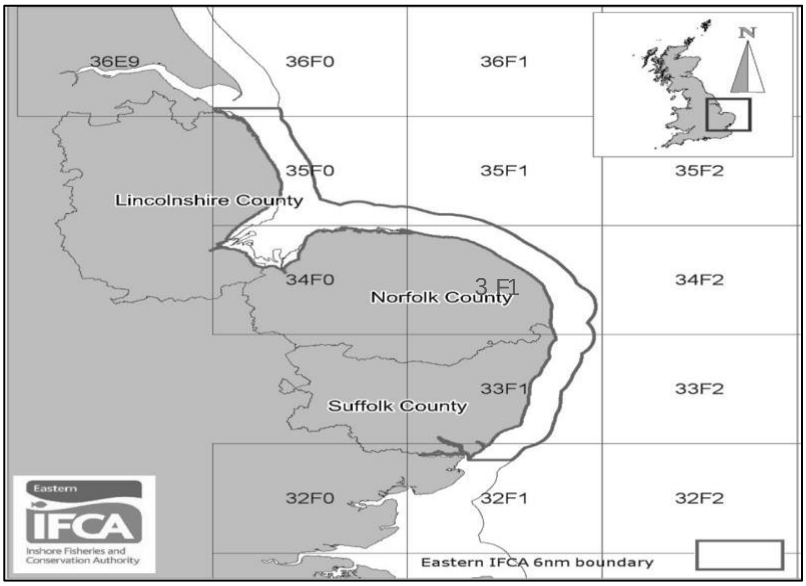


Figure 3. Map of the eastern IFCA district showing ICES Statistical Rectangles and 6nm boundary.

District Overview

Landings and effort data used to compile the 2017 crustacean stock assessment represents all data collected up to the beginning of March 2017 and, as with previous years reporting, MSAR data is continuously sent to the Authority and will continue to come in for the year of reporting throughout the first half of the following year. Importantly, as a caveat of this landings and effort data, the reporting of this data has a cut-off point of March 2018 and following previous trends will likely increase as the final data is collected. Comparatively, landings values calculated for this report are similar to those published by the Marine Management Organisations (MMO) for 2017, therefore significant increases in current landing figures are not expected.

In the three years preceding the 2017 crab/lobster stock assessment an increasing trend was reported in total landings (crab and lobster landings combined) with the highest recorded landings (since the introduction of MSARs in 2006) occurring in 2014, 2015 and 2016 sequentially, exceeding 1000 tonnes in both 2015 and 2016. Combined landings for crab and lobster in 2017 were significantly lower at the data cut off point of March 2018, equating to 645 tonnes. Individually, landings for crab equated to 587 tonnes and landings for lobster equated to 58 tonnes in 2017. Crab represent 46% and lobster 54% of the annual landings. The annual mean for combined landings was 749 tonnes ((SD±134) (crab = 670 tonnes, lobster = 78 tonnes)). Although combined landings for 2017 were lower than the preceding three years to March, they are relatively similar to the annual means, and more representative of the years preceding 2014 where landings began to climb significantly.

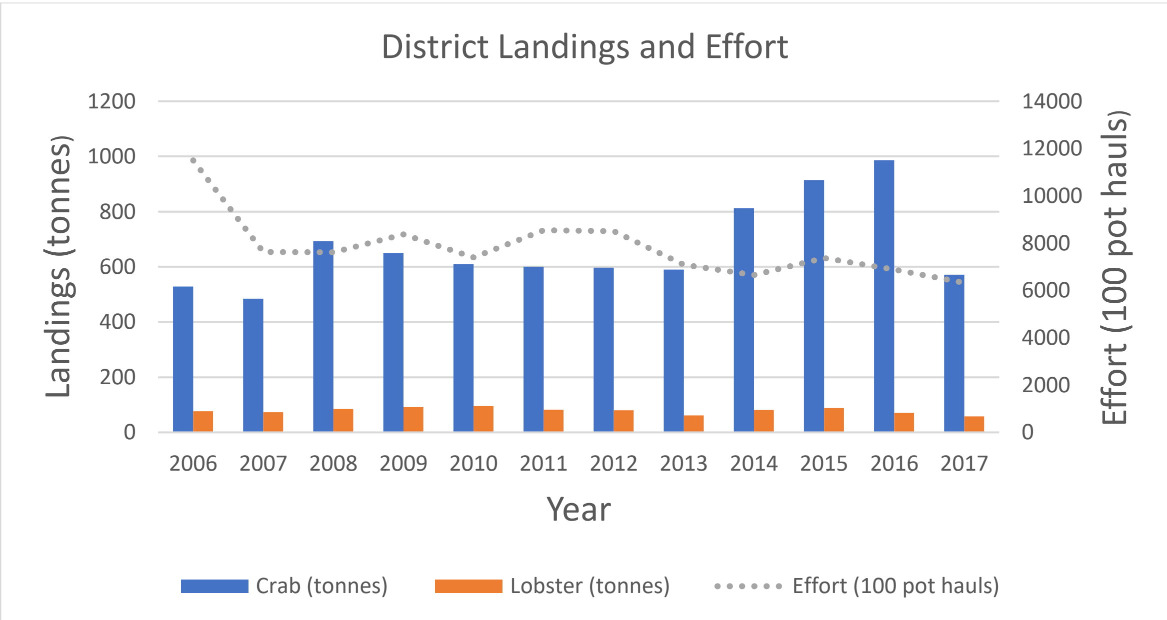


Figure 4. District summary of annual effort (dashed line) and landings by species.

Annual increases had been driven by *C. pagurus* in the three years preceding the 2017 report, growing by more than 200 tonnes between 2013-14, 100 tonnes between 2014-15 and 70 tonnes between 2015-16. Data collected and analysed up to March indicate that landings have decreased between 2016-17 to 587 tonnes, a reduction of 395 tonnes. Landings of crab between 2014-16 (2014 = 813 tonnes, 2015 = 915 tonnes 2016 = 986 tonnes) far exceeded the annual mean of 687 tonnes, however landings of crab for 2017 (587 tonnes) are below the annual average. Landings of *H. gammarus* in 2017 (58 tonnes) falls below the annual mean of 79 tonnes (SD±14). Catch has remained relatively stable, displaying less variability across the dataset period and has not expressed similar increasing trends as *C. pagurus*. Historically, higher market values for *H. gammarus* (£10-16.50/Kg) than *C. pagurus* (0.90p/£1.30/Kg) has offset disparity in landed weight when considering catch value. The difference in landed weight thus far between 2016-17 has seen this pattern continue, with crab and lobster worth £0.6 and £0.7 million respectively, whereas differences in landed weight between the species in 2016, coupled with lower than average landings for *H. gammarus* meant that *C. pagurus* were worth almost twice as much for that year.

Table 2. Annual value of district potting fisheries by species.

Year	*C. pagurus* Value (Millions)	*H. gammarus* Value (Millions)	Total Value (Millions)
2006	£1.1 (55%)	£0.9 (45%)	£1.9
2007	£1.0 (55%)	£0.9 (45%)	£1.9
2008	£1.5 (60%)	£1.0 (40%)	£2.5
2009	£1.3 (54%)	£1.1 (46%)	£2.4
2010	£1.2 (45%)	£1.5 (55%)	£2.7
2011	£1.2 (50%)	£1.2 (50%)	£2.4
2012	£1.2 (53%)	£1.1 (47%)	£2.3
2013	£1.1 (59%)	£0.8 (41%)	£1.9
2014	£1.4 (58%)	£1.0 (42%)	£2.4
2015	£1.8 (61%)	£1.1 (39%)	£2.9
2016	£1.9 (66%)	£0.9 (34%)	£2.8
2017	£0.6 (46%)	£0.7 (54%)	£1.3
Mean	**£1.3** (SD±0.3)	**£1.0** (SD±0.2)	**£2.3**(SD±0.3)

Effort (pot hauls) has remained relatively stable across the dataset besides a peak in 2006, decreasing in 2015, 2016 and continuing in 2017. This effort stability coupled with decreasing landings in 2017 is reflected in landings per unit effort (LPUE) for *C. pagurus* from a peak of 1.3Kg/pot to its current level of 0.9Kg/pot.

LPUE for *H. gammarus* has remained relatively stable throughout the dataset and continues to do so in 2017 (0.09Kg/pot), decreasing marginally from 2016 (0.12Kg/pot), however this is representative of minor fluctuations around the annual mean (0.11Kg/pot).

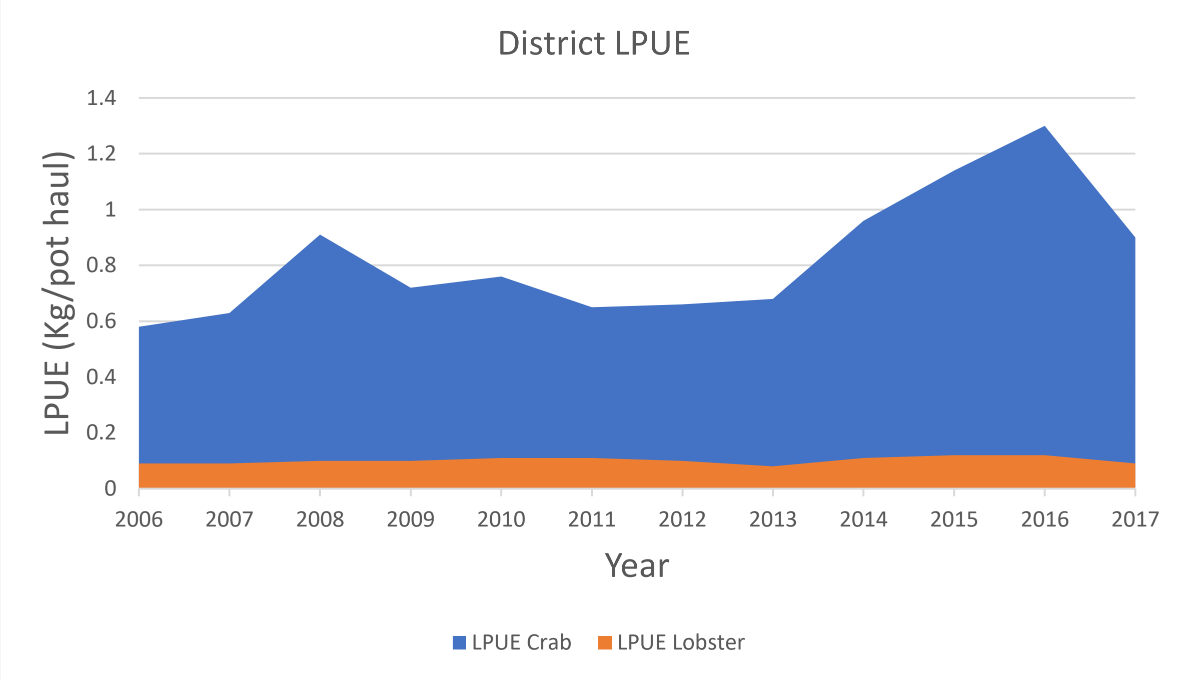
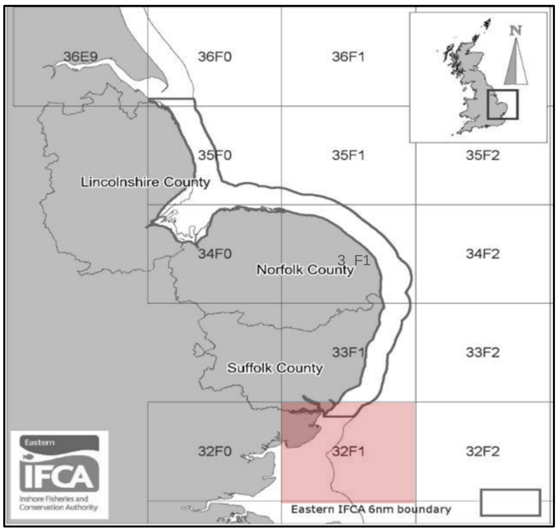


Figure 5. Annual district LPUE *C. pagurus* and *H. gammarus*.

Summary Statistics 32F1



ICES rectangle 32F1, located at the southern extremity of the district, overlaps considerably with Kent and Essex IFCA. The area is fished by a small number of ports and vessels from our district, reflected by relatively low levels of reported effort and landings.

Figure 6. ICES rectangle 32F1.

Table 3. 32F1 Summary of vessels, Ports, Effort (100 pots 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	12	85	2.6	0.6	1.9
2011	1	9	99	2.3	0.6	1.7
2012	1	8	112	2.3	0.4	1.9
2013	2	10	123	2.2	0.6	1.5
2014	2	9	127	2.4	0.7	1.7
2015	2	6	59	1.1	0.6	0.5
2016	5	6	14	0.7	0.5	0.2
2017	5	7	59	1.6	0.9	0.7
Mean	**3**	**9.2**	**112.6**	**3.11**	**1.1**	**2**
SD	**2.5**	**2.5**	**56.1**	**2.4**	**0.8**	**1.5**

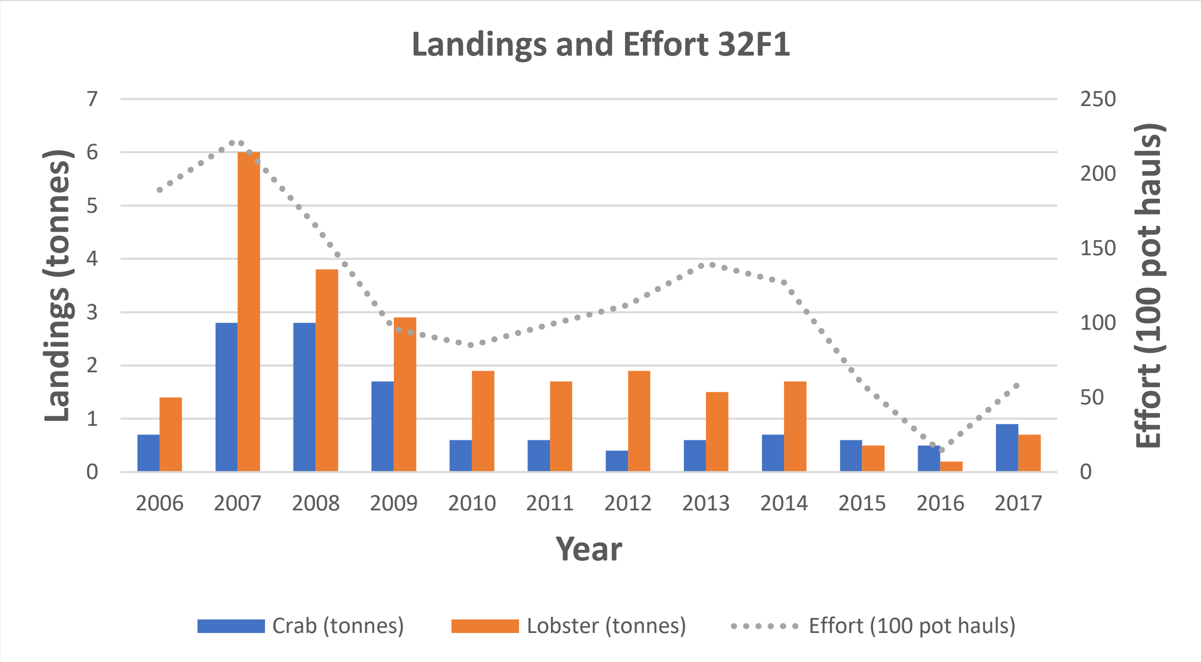


Figure 7. Summary of annual effort (dashed line) and landings by species.

Having reached a peak in effort (pot hauls) in 2007, in line with the highest landings for both species across the dataset, to lows in 2016 of less than half a tonne. Effort dropped significantly until 2010 where it began to rise gradually whilst the general trend in landings for both species fluctuated slightly. A second peak occurred in 2013 however; a decreasing trend in effort occurred again, dropping dramatically low in 2016. Effort has increased again in 2017 somewhat, and this is reflected in increases in landings of both crab and lobster. *H. gammarus* significantly dominated catch in this area between 2006-2014, however 2015-2017 have seen both species reduced to near even catch rates however; C. *pagurus* now dominate landings in the area.

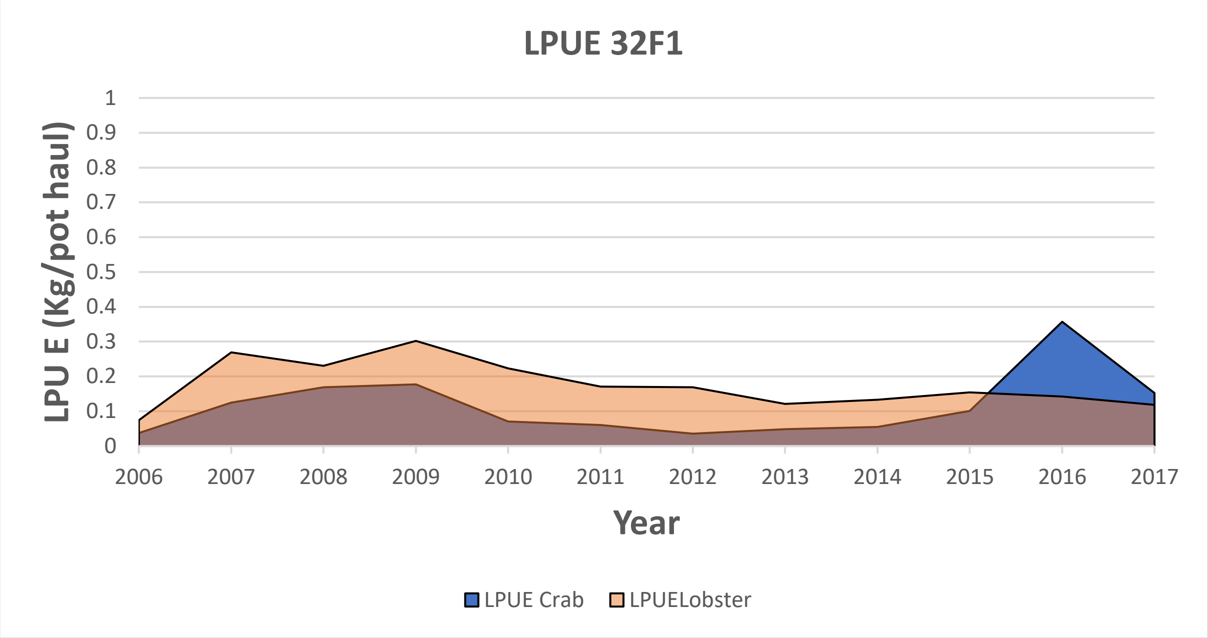
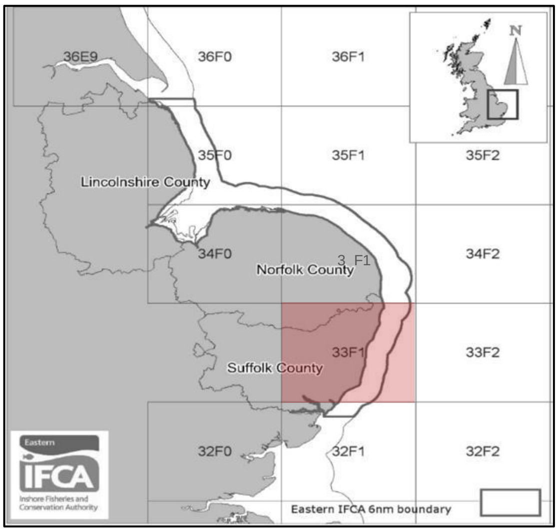


Figure 8. Annual LPUE for ICES statistical rectangle 32F1.

LPUE has remained relatively stable across the dataset for both C. *pagurus* and *H. gammarus* despite minor fluctuations between years. LPUE increased for C. *pagurus* between 2014 and 2016 and is the result of decreased effort throughout these years rather than catch increases. This trend suggests that C. *pagurus* catches are limited by the abundance of crab on the ground rather than effort levels. LPUE decreased in 2017 to levels observed throughout the dataset, asides from the evident peak in 2014-2016, in line with a rise in effort.

LPUE for *H. gammarus* has remained relatively stable throughout the dataset, including the period of declining effort in 2015 and 2016 which has continued into 2017. The results indicate that decline in landings is attributable to a decline in effort.

<u>Summary Statistics 33F1</u>



ICES rectangle 33F1, situated off the Suffolk coast, covers an area between the Orford and Lowestoft. A comparatively small number of ports and vessels fish this area and this is reflected in the relatively low landings and effort compared to the Norfolk coast. Annual fluctuations in landings are seldom significant when compared to the annual mean, until recently.

Figure 9. ICES rectangle 33F1.

Table 4. 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	22	238	17.9	10.4	7.5
2011	6	21	239	18.9	12.2	6.7
2012	8	23	344	18.9	11.6	7.3
2013	8	20	173	11.3	7.4	3.9
2014	6	18	211	16.2	11.1	5.0
2015	8	22	251	17.3	12.7	4.6
2016	8	21	283	25.11	20.21	4.9
2017	7	16	302	12.6	10.0	2.6
Mean	**7.3**	**19.4**	**288**	**16.9**	**11.4**	**5.5**
SD	**0.7**	**2.6**	**124.5**	**3.8**	**3.05**	**1.9**

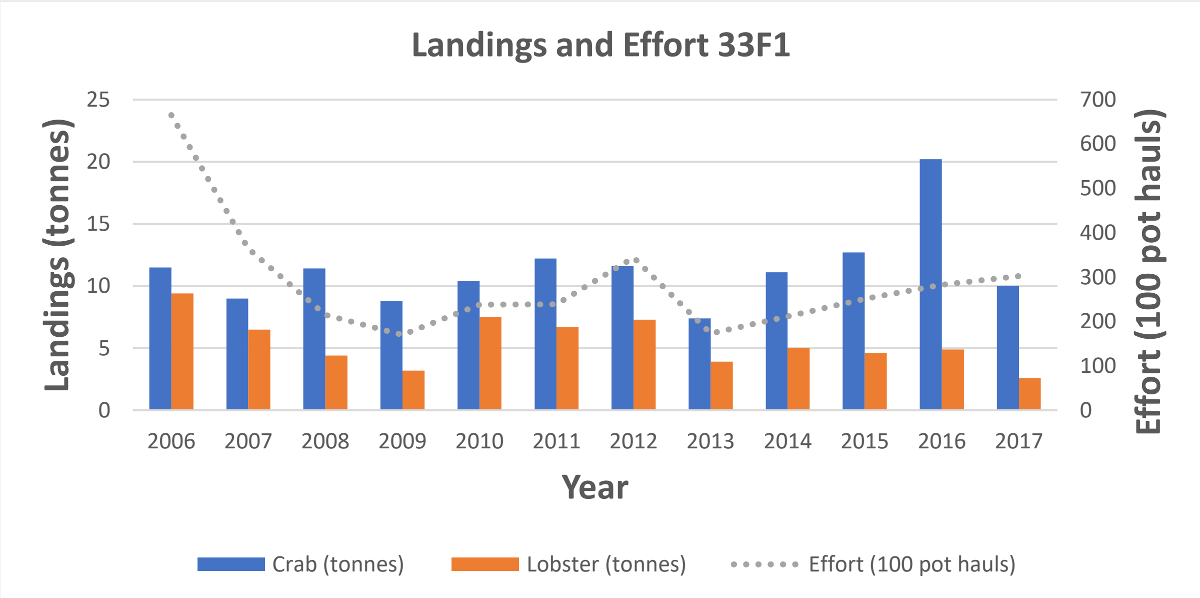


Figure 10. Summary of annual effort (dashed line) and landings by species.

Effort peaked in 2006 before declining rapidly to 2008. Since then effort has fluctuated around the annual mean with a small peak occurring in 2012 before dropping again in 2013. Effort has increased steadily over 2014, 2015 and 2016 and continues to do so in 2017. Landings for *H. gammarus* have remained relatively stable throughout the dataset period, fluctuating around the 5.5 tonne mean. Landings for the species have dropped in 2017, although not significantly. An increasing trend in landings for *C. pagurus* has occurred between 2014-16, varying significantly from the mean of 11.3 tonnes, with a peak in landings in 2016 of just over 20 tonnes. This has dropped to a level more representative of the landings trend for the years preceding the peak in 2016 and closer to the annual mean with current landings reported at 10 tonnes.

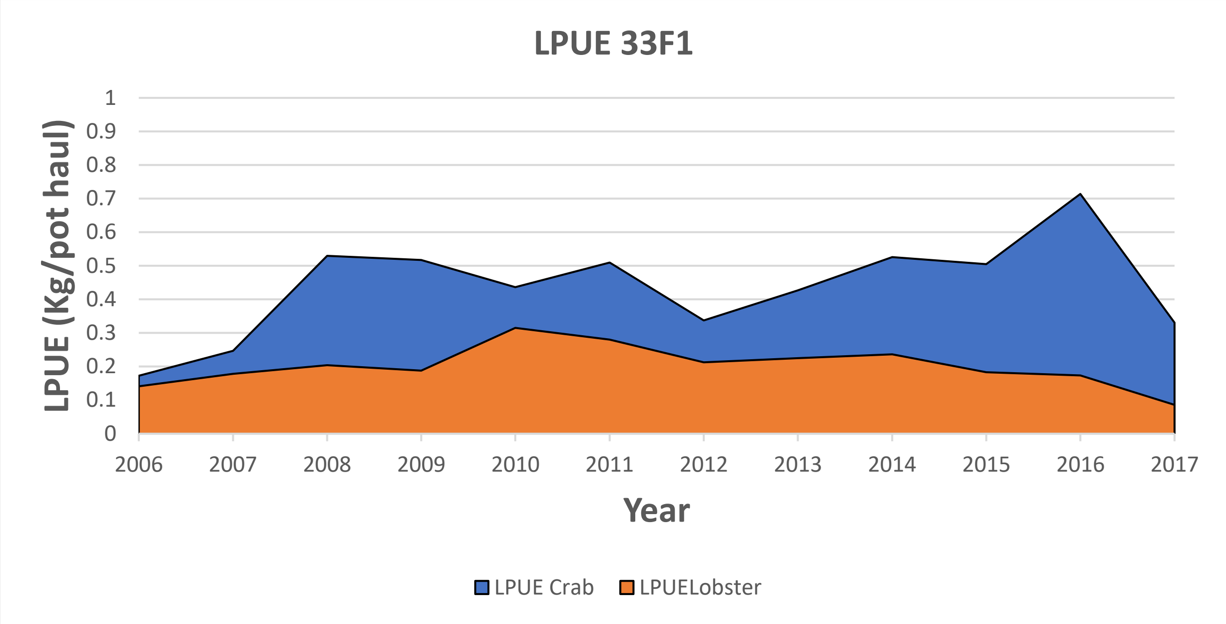
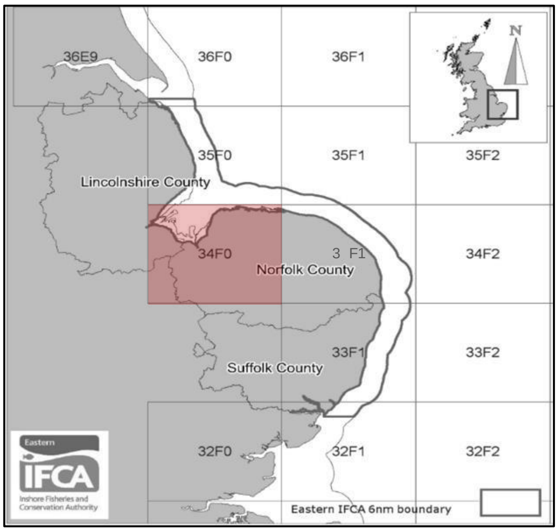


Figure 11. Annual LPUE for ICES statistical rectangle 33F1.

LPUE for *H*. *gammarus* has experienced minor fluctuations throughout the dataset, but has remained relatively stable, however there is greater variability in LPUE for *C*. *pagurus.* LPUE was lowest in 2006 for *C*. *pagurus* when effort was at a peak. This rose swiftly as effort fell approaching 2008. Again, effort increased in 2012 and there was another observable drop in LPUE. Welby (2016) suggests a link between effort and LPUE for *C*. *pagurus* in this area and this is supported by a current drop of LPUE in 2017 as effort has increased.

<u>Summary Statistics 34F0</u>



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, however this appears to be increasing steadily. MSAR data detailing catch and effort were not submitted in both 2007/2008.

Figure 12. ICES rectangle 34F0.

Table 5. 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	0.4	0.0	0.03	0.0
2007	n/a	n/a	n/a	n/a	n/a	n/a
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	155	11.5	6.9	4.6
2012	6	6	30	3.2	3.0	0.3
2013	5	5	60	6.5	6.1	0.3
2014	3	4	129	11.4	10.6	0.7
2015	2	2	159	25.2	24.2	1.0
2016	4	5	213	24.7	23.3	1.3
2017	4	5	66	6.1	5.6	0.5
Mean	**3**	**3.5**	**82.1**	**8.2**	**7.2**	**1.1**
SD	**1.8**	**2.1**	**72.2**	**8.5**	**8.1**	**1.4**

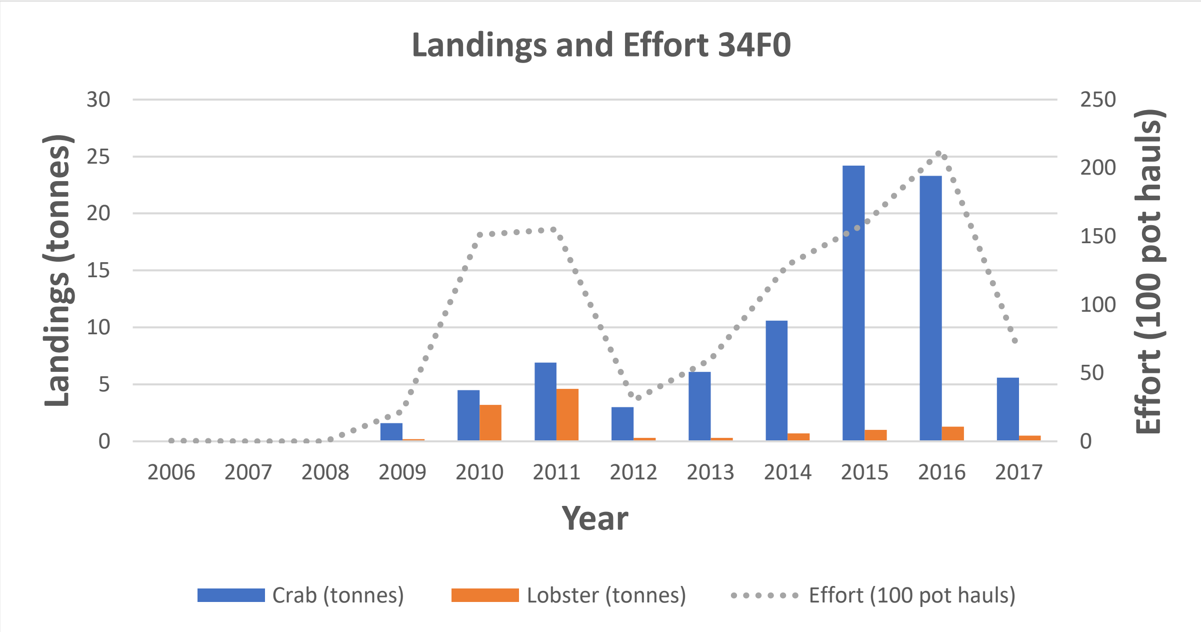


Figure 13. Summary of annual effort (dashed line) and landings by species.

Little or no effort was reported for the first three years since the introduction of MSARs. Following this, effort has been erratic throughout the dataset period, peaking in 2010-2011and dropping dramatically in 2012. Effort has increased gradually year on year through to 2016, however 2017 saw a sharp decline in effort.

Landings have generally followed the trend in effort, rising and dropping concurrently, as witnessed between 2009 and 2012. Similarly, the same trend is apparent between 2012 and 2017. Early reports identified that *C. pagurus* and *H. gammarus* catches were relatively even however; this trend has changed with crab landings dominating catches since 2012 and this trend continues into 2017. Landings of crab were significantly higher than the annual mean for 2015 and 2016, however 2017 has seen landings return to similar levels in years preceding 2014.

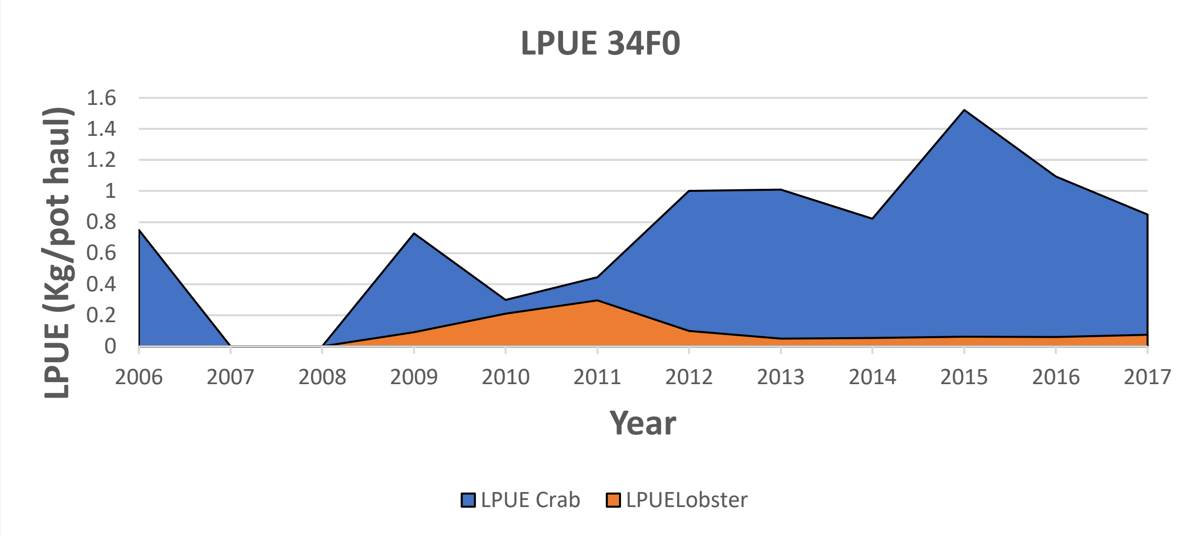
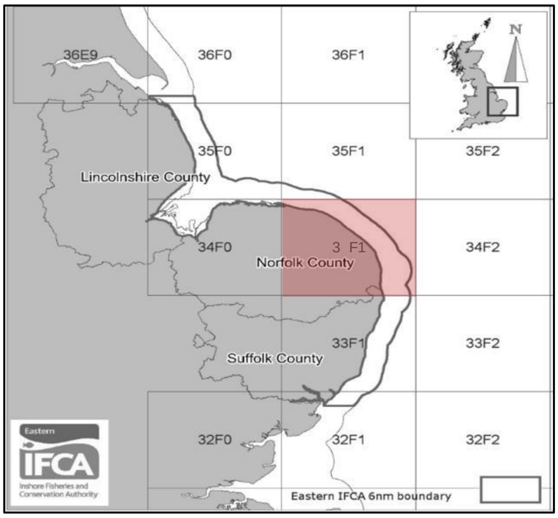


Figure 14. Annual LPUE for ICES statistical rectangle 34F0.

Welby (2016) surmised that this area had only been regularly fished relatively recently due partially to the variability in LPUE across the period of the dataset. Compared to other areas in the district annual LPUE displays an increasing trend leading up to 2015 suggesting that *C. pagurus* was particularly abundant in this area. Following a peak in 2015 LPUE dropped sharply and continues to drop into 2017, suggesting that levels of exploitation are higher than in previous years. LPUE for *H. gammarus* peaked in 2010-11 before dropping to a stable level in 2012 and this trend continues throughout 2017. Populations of lobster may have been more abundant previously, however the LPUE for the species suggests that stocks have since been reduced.

Summary Statistics 34F1



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. Effort and landings figures reflect the high number of vessels fishing this area, making this the most productive potting ground in the district. Crab makes up the majority of catch from this area, and much of the lobster caught in the district is also fished here.

Figure 15. ICES rectangle 34F1.

Table 6. 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	36	3037	167.4	142.6	24.9
2011	12	46	4001	213.1	178.5	34.6
2012	13	50	3777	259.3	228.7	30.6
2013	14	45	3680	244.9	218.1	26.8
2014	12	38	3257	328.9	299.5	29.4
2015	14	44	4152	436.5	394.6	41.9
2016	17	46	3819	457.5	420.6	36.9
2017	13	43	2847	361.0	329.8	31.2
Mean	**13.7**	**42.2**	**3619**	**277.9**	**246.3**	**31.6**
SD	**1.7**	**5.1**	**403**	**93.7**	**89.7**	**4.1**

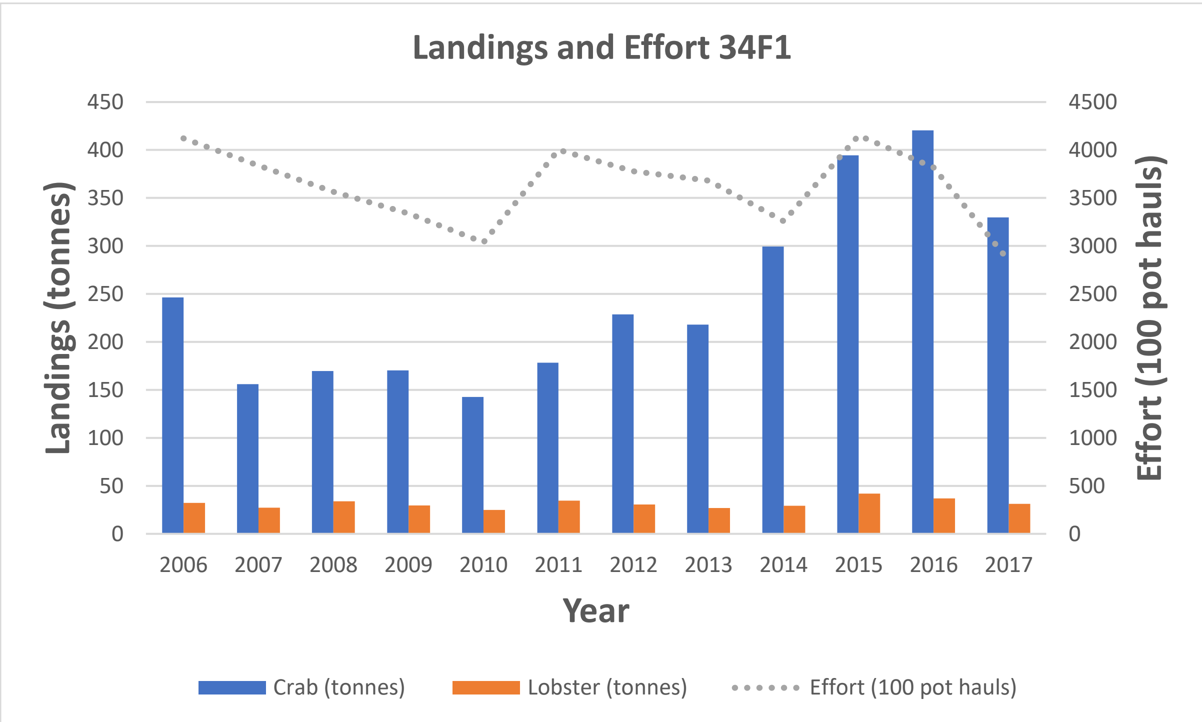


Figure 16. Summary of annual effort (dashed line) and landings by species.

Effort has risen and fell in a cyclical pattern across the period of the dataset, rising to peaks of 400,000 pot hauls/year, then dropping off over 3-4 years to a low of approximately 300,000 pot hauls/year. This pattern appears to be continuing in 2017 although the decline in effort has been markedly steeper between 2016-17. Landings in 34F1 are dominated by *C. pagurus*, representing on average 7 times the landed weight of *H. gammarus,* however up to the cut-off point of data collection landings were approximately 100 tonnes lower than 2016. *H. gammarus* landings have remained relatively stable across the dataset with only minor inter annual fluctuations around the annual mean whereas in comparison, *C. pagurus* landings had been rising steadily by almost 100 tonnes a year between 2013 and 2016.

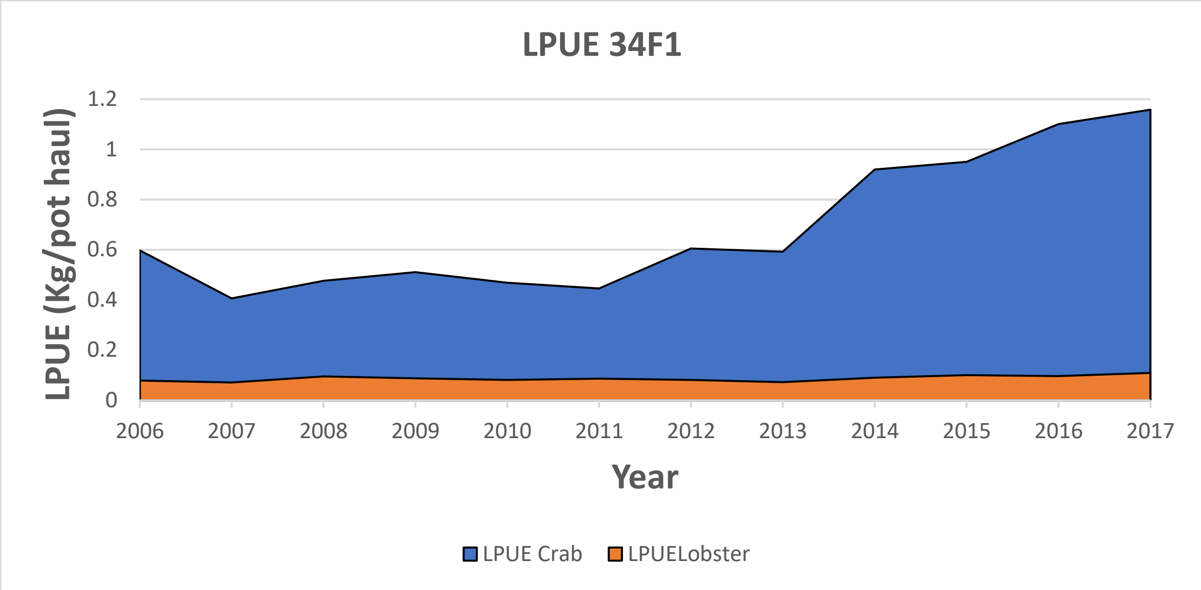
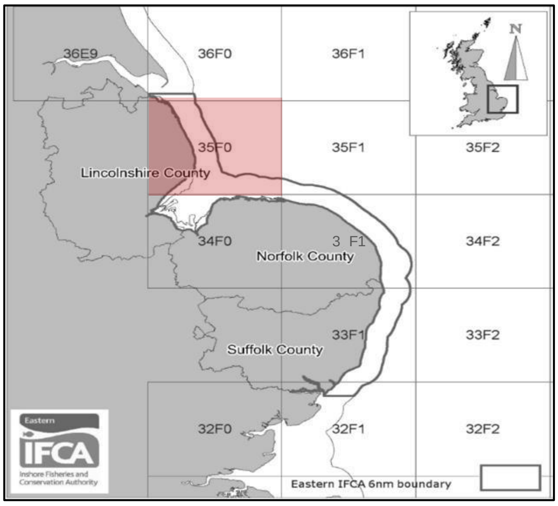


Figure 17. Annual LPUE for ICES statistical rectangle 34F1.

LPUE has steadily increased for *C. pagurus* since 2011 to its current high of 1.15kg/pot haul, following a fairly stable position between 2006 and 2011. LPUE is driving recent year on year increases in landings suggesting either an increase in abundance on the ground or potentially, as suggested by Welby (2016), behavioural changes or modified fishing methods making the species more catchable. In contrast LPUE has remained stable throughout the dataset, with very minor fluctuations. Drivers that are affecting crab population dynamics are not affecting lobster populations, as is evident in LPUE.

<u>Summary Statistics 35F0</u>



ICES rectangle 35F0 is the main offshore potting ground fished by vessels operating out of Wells and Lincolnshire. Although vessels outside of the EIFCA district fish these grounds, only data captured on MSARs originating from vessels landing within the EIFCA district are included in the analysis.

Figure 18. ICES rectangle 35F0.

Table 7. 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	2017	231.4	208.4	23.0
2008	3	14	2089	368.8	340.6	28.2
2009	3	13	2318	281.8	248.2	33.6
2010	3	15	2354	275.3	247.4	27.9
2011	4	15	2350	247.7	218.8	28.9
2012	4	23	2809	282.4	246.4	36.1
2013	4	14	2492	235.4	210.4	25.0
2014	2	11	1884	261.4	237.8	23.6
2015	3	12	2250	389.3	355.0	33.9
2016	3	14	1935	284.3	263.7	20.6
2017	3	11	2350	184.5	167.5	17.0
Mean	**3.3**	**13.9**	**2258**	**273.5**	**246.5**	**27**
SD	**0.6**	**3**	**244.8**	**93.2**	**89.8**	**3.9**

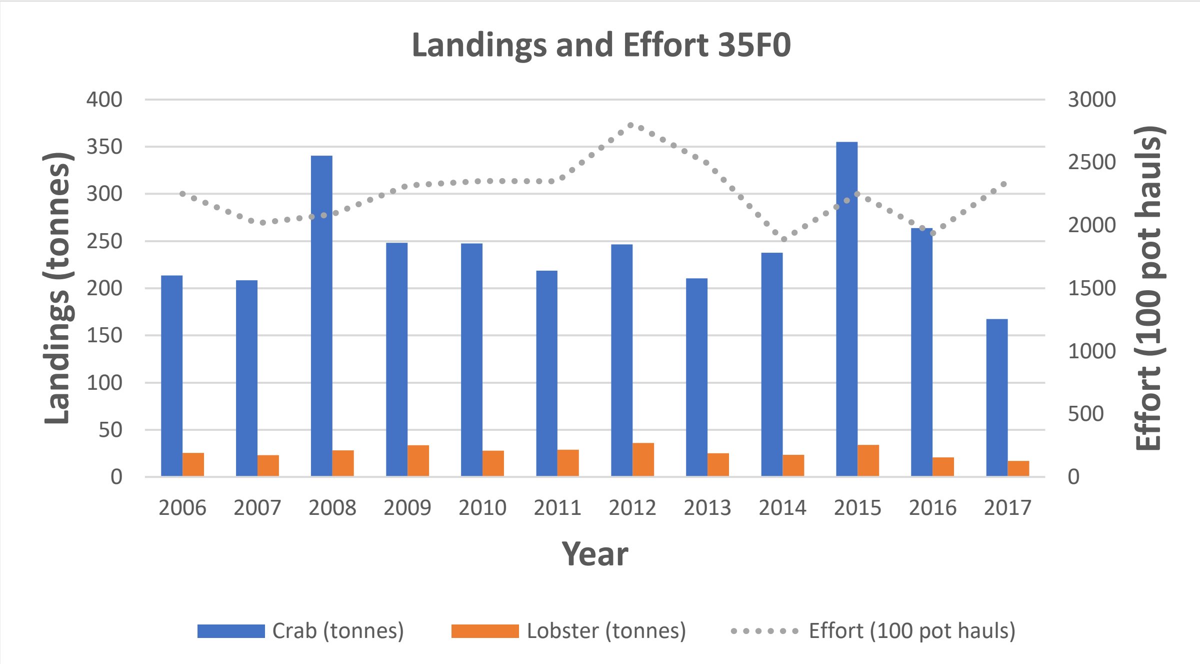


Figure 19. Summary of annual effort (dashed line) and landings by species.

Effort has remained relatively stable throughout the dataset period with only minor fluctuations around the annual mean. An observable peak occurred in 2012 before dropping to an unprecedented low. Between 2014 and 2016 effort remained at or below the annual mean however 2017 has seen a steady increase, rising just above the annual mean.

C. pagurus dominate the catch within this area. Landings have typically fluctuated between 200-250 tonnes, exceeding 300 tonnes 2008 and 2015. Welby (2016) indicates that these exceptional years of 300 tonnes do not coincide with increased effort, therefore it can be assumed that abundance of the species was particularly high on the ground for these years. As with previous statistical areas, landings of *H. gammarus* have remained relatively stable across the period of the dataset, however following a peak in 2015 there has been a decrease in catch for 2016 and 2017. Previous peaks in landings for *H*. *gammarus* have accompanied increases in effort, therefore with a current increasing trend in effort for 2017, there is potential for landings to increase somewhat following the return of all MSAR recording forms.

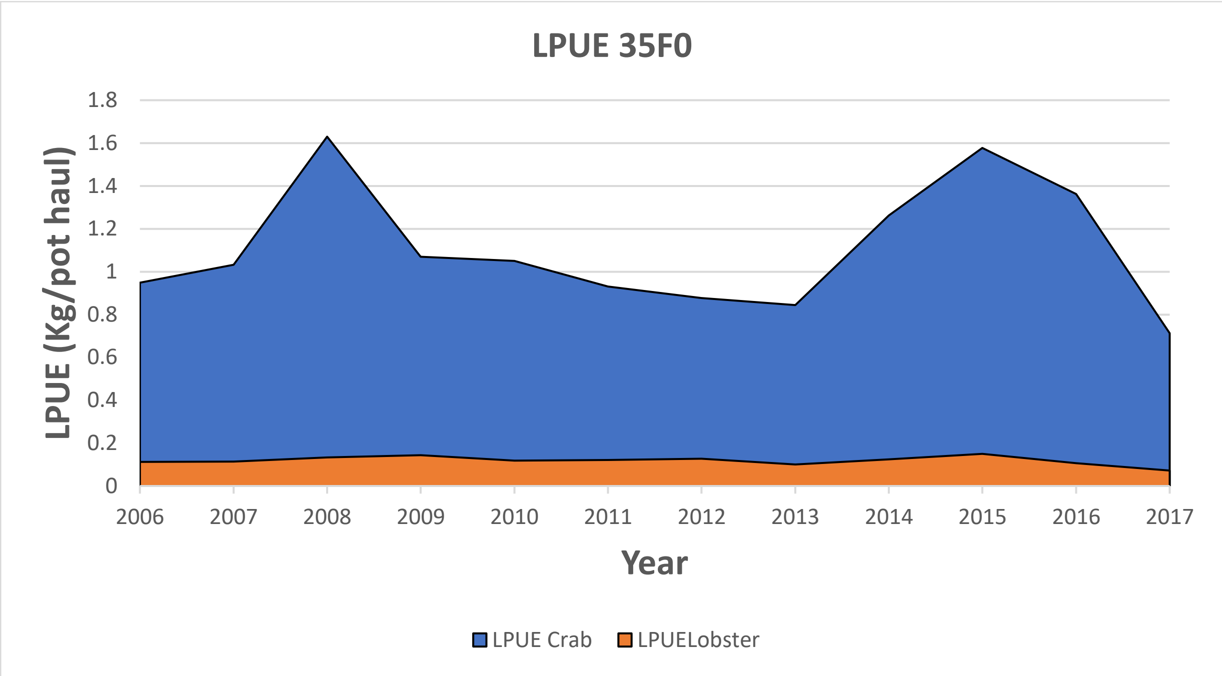
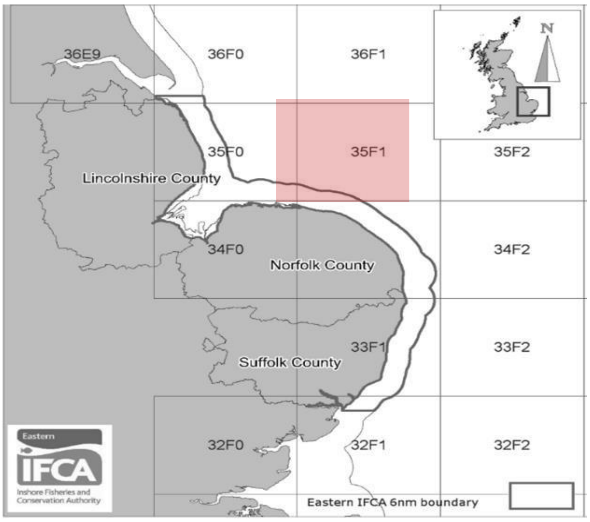


Figure 20. Annual LPUE for ICES statistical rectangle 35F0.

LPUE has been consistently high for *C*. *pagurus* across the dataset in this area, regularly fluctuating just below or just above 1Kg/pot haul. Peaks occurred in both 2008 and 2015, exceeding 1.5 Kg/ pot haul coinciding with years when landings were particularly high. Effort was not concurrently high in these 2 years, which suggests an increase in LPUE/landings is attributable to more individuals on the fishing grounds. LPUE has dropped to 0.7 Kg/haul in 2017, an unprecedented low in the dataset period, suggesting increasing levels of exploitation for the species in this area.

LPUE for *H*. *gammarus* remained consistent throughout the period of the dataset with very minor peaks in 2009, 2012 and 2015. There was an unprecedented low in LPUE in 2017, but comparatively there was very minor variability between this and other years.

Summary Statistics 35F1



ICES rectangle 35F1 falls largely outside of the 6nm district limits, however as the third most productive potting ground in the district it is still considered within this assessment as it is fished by a few ports and vessels originating within the EIFCA boundary.

Figure 21. ICES rectangle 35F1.

Table 8. 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	15	2427	201.3	179.7	21.6
2010	9	17	1539	174.8	158.2	16.6
2011	6	14	1699	161.6	143.2	18.4
2012	6	16	1438	83.7	72.2	11.5
2013	6	9	551	46.4	42.5	3.9
2014	6	8	1048	91.9	81.6	10.3
2015	5	9	506	60.6	54.1	6.5
2016	4	9	618	90.1	83.4	6.7
2017	5	10	702	64.0	58.1	5.9
Mean	**6.7**	**12.1**	**1179.3**	**111.8**	**100.5**	**11.2**
SD	**1.8**	**2.7**	**158.7**	**52.2**	**170.6**	**5.3**

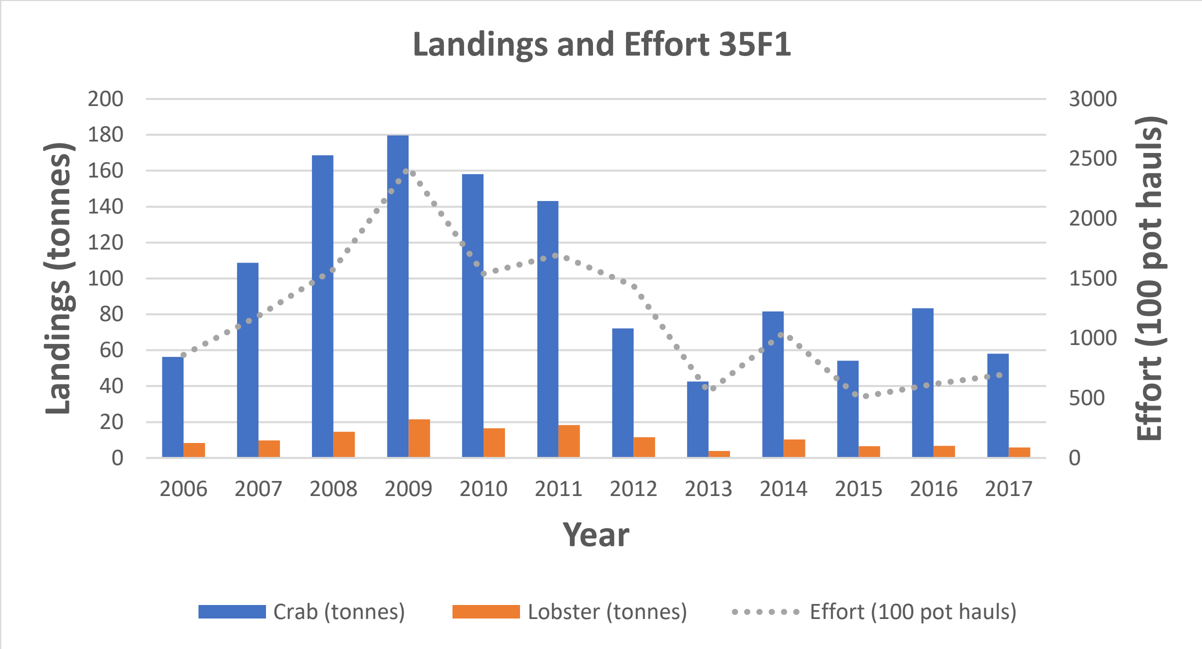


Figure 22. Summary of annual effort (dashed line) and landings by species.

Following an increasing trend in effort between 2006 and 2009 which saw landings in *C. pagurus* rise concurrently there has been a generally declining trend in both effort and landings to a low of just over 40 tonnes in 2013. 2014 saw a minor peak before dropping once more to just below 40 tonnes. Since 2015 there has been another increasing trend in effort which has continued to rise in 2017 although landings figures have dropped. *H. gammarus* follows a similar trend with landings following the pattern of effort, however fluctuation in landings is far less pronounced. *C. pagurus* dominates the catch in this area, as is seen in other areas in the district.

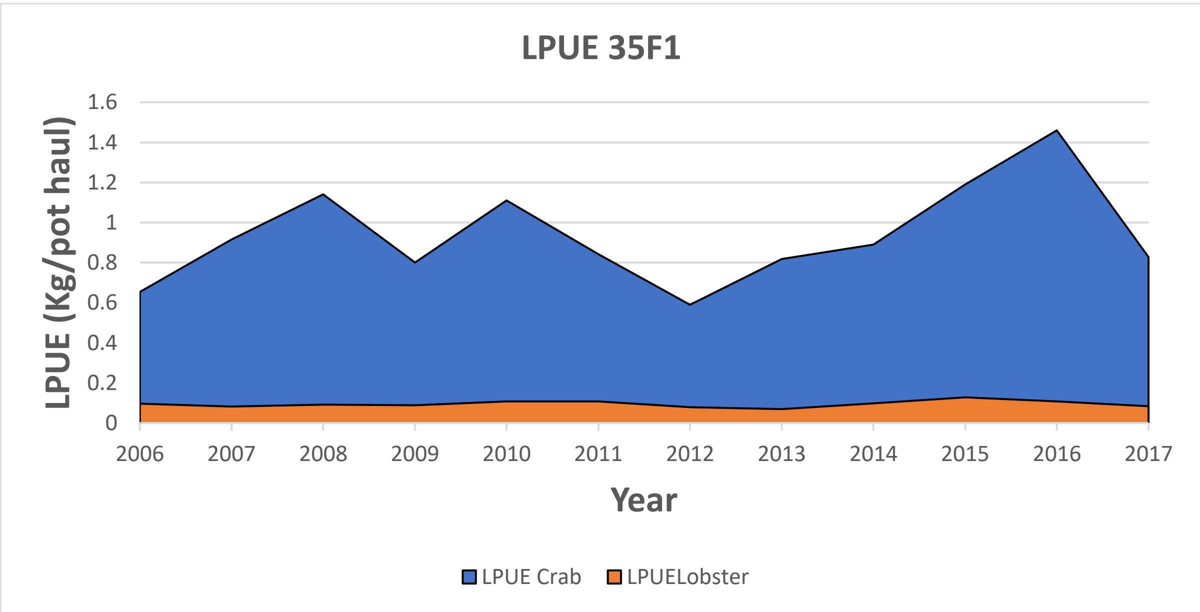


Figure 23. Annual LPUE for ICES statistical rectangle 35F1.

LPUE for *H*. *gammarus* fluctuates minorly between years whereas LPUE for *C*. *pagurus* contrasts with a high level of variability. LPUE has remained consistently high for C. *pagurus*, with notable dips in LPUE in 2009 and 2012. LPUE has dropped again in 2017, close to the average annual mean. LPUE for *H*. *gammarus* has remained stable across the dataset period, with very minor inter-annual fluctuations.

Bio-sampling – Mortality Estimates

Total mortality (Z) estimates by sex and species were calculated using a length converted catch curve methodology. This quantifies the rate at which the frequency of individuals in a population declines with size, attributing decline to death (mortality) either naturally or through fishing. Fishing mortality (F) can then be calculated by subtracting natural mortality (M) from Z.

Results

Estimates of mortality from bio-sampling conducted in 2017 are presented in table 9. Sampling effort was significantly higher for *C*. *pagurus* than for *H*. *gammarus* with 10 times as many individuals sampled of *C*. *pagurus* compared with *H*. *gammarus.* This is attributable to ease of access to samples of *C*. *pagurus.* Of those individuals sampled for both species, approximately double the number of males were sampled when compared to females.

Table 9: Total Mortality (Z) & Fishing Mortality (F) estimates from 2017 bio-sampling data for *C. pagurus* male (CM), *C. pagurus* female (CF), *H. gammarus* male (HM) and *H. gammarus* female (HF).

Species/Sex	Sample Size (n)	Z (rate)	Z (%)	F (rate)	F (%)
CM	4177	0.878	58	0.678	49
CF	2302	0.9192	60	0.7192	51
HM	403	0.855	57	0.655	48
HF	214	0.8037	55	0.6037	45

H. gammarus displayed the lowest estimate of F with female mortality estimates only slightly lower than males in 2017. In contrast, estimates for females in 2016 were considerably different to males, and lower than female estimates for 2017. *H*. *gammarus* male estimates have remained the same as were seen in 2016. Estimates of F for both sexes of *C*. *pagurus* were considerably lower than 2016, however they remain consistently close to each other as was reported in 2016.

Yield per recruit analysis was used to assess the effects of fishing mortality on the population. Results of the analysis are presented below alongside target reference points Fmax and F0.1. Fishing mortality rates for 2017 were found to exceed maximum recommended exploitation rates (Fmax) for both sexes of *C*. *pagurus* and *H*. *gammarus* and remain significantly higher than F0.1, the predicted rate at which maximum protective effect on the stock is provided. Comparatively, estimated mortality for both sexes of *C*. *pagurus* in 2017 have improved significantly from those in 2015 and 2016. Estimated mortality for *H. gammarus* females fell below the Fmax reference point in 2016, however this year's assessment has seen it rise again to above reference point but not to significantly high levels seen in 2015 for the species. Estimated mortality for male lobster was marginally lower than 2016. In comparison, 2015 saw significantly higher levels of exploitation, with estimates closer to female lobsters of the same year.

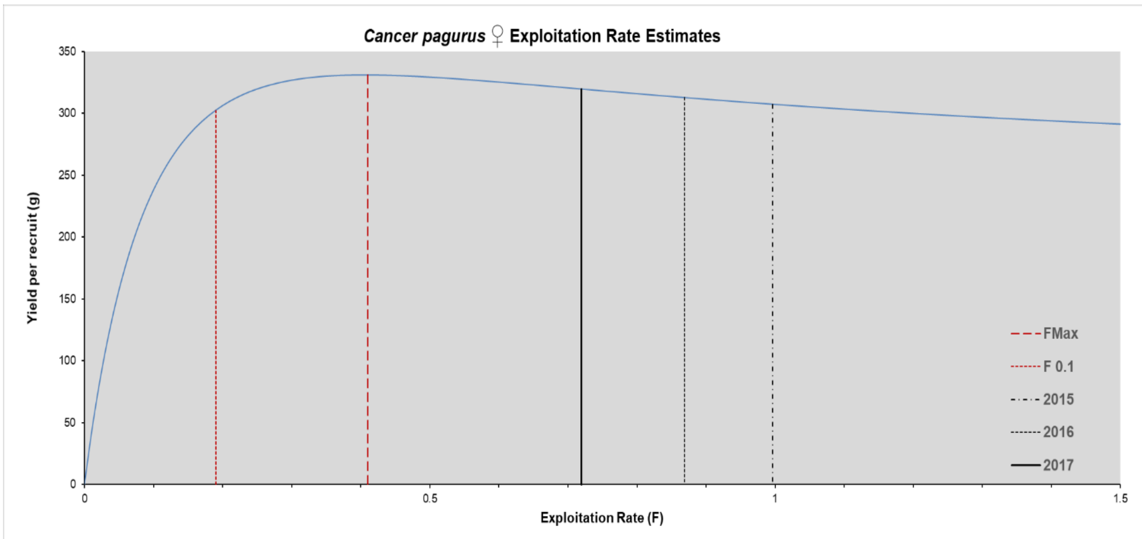


Figure 24: YPR Curves for *C. pagurus* females (CF) estimating exploitation rate for 2017 in comparison to estimates from 2015 and 2016, against target reference points Fmax and F0.1.

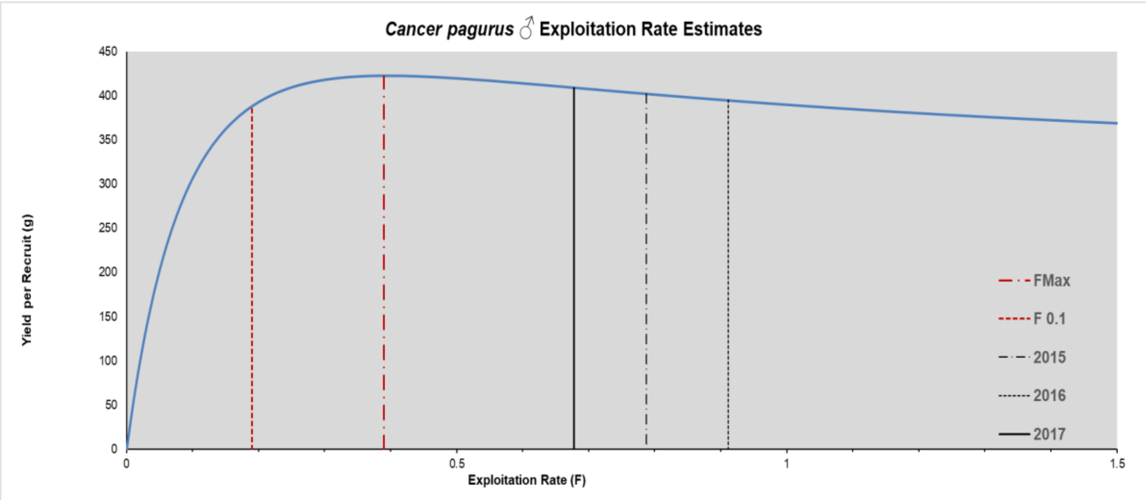


Figure 25: YPR Curves for *C. pagurus* males (CM) estimating exploitation rate for 2017 in comparison to estimates from 2015 and 2016, against target reference points Fmax and F0.1.

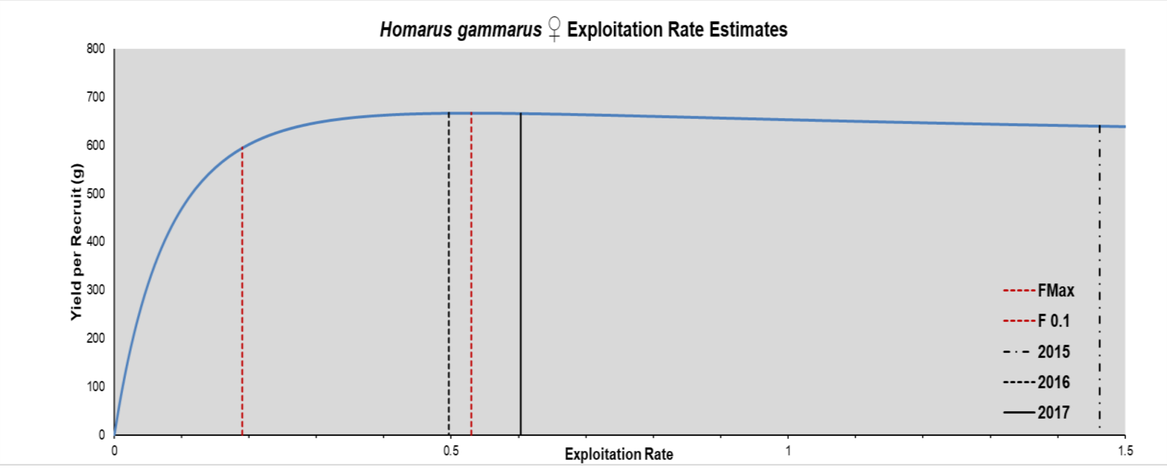


Figure 26**:** YPR Curves for *H.* gammarus females (HF) estimating exploitation rate for 2017 in comparison to estimates from 2015 and 2016, against target reference points Fmax and F0.1.

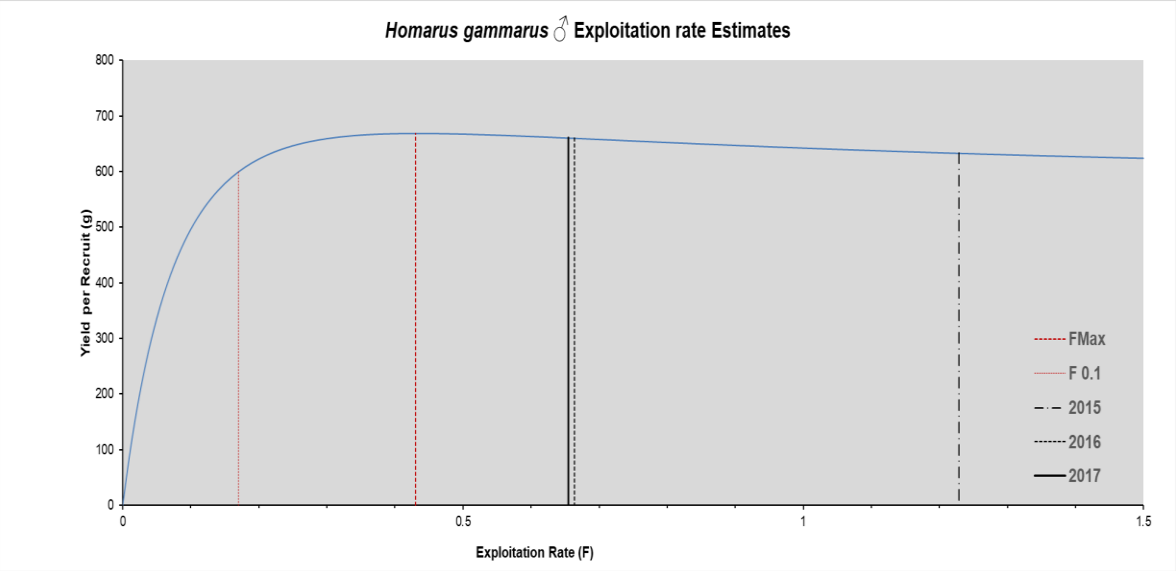


Figure 27: YPR Curves for *H. gammarus* males (HM) estimating exploitation rate for 2017 in comparison to estimates from 2015 and 2016, against target reference points Fmax and F0.1.

Table 10 presents changes to fishing mortality needed to meet target reference points. The greatest change will be required by stock experiencing the highest mortality rate to attain the necessary target values. It is expected that all changes to exploitation rate to meet Fmax will result in increased yield per recruit. In contrast the opposite is expected for F0.1.

Table 10: Estimated Changes in Fishing Mortality (F) required to reach reference points Fmax and F0.1 and expected yield per recruit change.

Species/Sex	**Fmax rate**	**% reduction in F required**	**% yield per recruit change**	**F0.1 rate**	**% reduction in F required**	**% yield per recruit change**
CM	0.39	25	3.3	0.19	40	-5.1
CF	0.41	27	3.5	0.19	42	-5.4

HM	0.43	20	1.3	0.19	40	-9.2
HF	0.53	7.1	0.1	0.19	35	-10.7

Discussion

Increases in sampling effort since 2015, primarily through access to processors has increased the acquisition of data, allowing for a greater quantity of individuals to be measured during each sampling occasion. This enables length converted catch curve and yield per recruit analysis to be carried out to evaluate fishing mortality and its effect on stock in quantifiable terms. This provides a robust method for monitoring stock dynamics, assessing how responsive a stock is to exploitation and identifying reference point objectives from which necessary changes in fishing mortality can be estimated.

Whilst sampling effort has increased for *C*. *pagurus* through this approach, providing high confidence in mortality rate estimates it has not been as beneficial for *H*. *gammarus* as sampling effort has remained low in 2017. Landings of *H*. *gammarus* are lower, presenting fewer opportunities to measure individuals, with four times and 10 times as much *C*. *pagurus* sampled in 2016 and 2017 respectively. Welby (2016) suggests salt water tank storage enables mixing of individuals making sampling difficult with the potential for erroneous results.

Confidence levels derived from low sampling effort in *H*. *gammarus* are reflected in mortality rate estimates from 2015-2017, for example mortality rates for *H*. *gammarus* females in 2015 were excessively high, however in 2016 it fell below the target reference point (Fmax). In 2017 it has returned above the target reference point but considerably lower than was observed in 2015. Similarly, for *H*. *gammarus* males 2015 was an excessively high year, whereas it dropped significantly in 2016, and in 2017 it has dropped slightly closer to the Fmax point. Exploitation rates appear to be heading in the right direction, however due to these fluctuations in mortality estimate it is difficult to have confidence in these results. This further strengthens the need for a revised sampling approach for *H. gammarus*, and supported by the most recent Cefas reporting (Cefas 2014) on stock of the species in East Anglian waters highlighting that inconsistencies in sampling coupled with insufficient data are making confident analysis of current stock levels difficult. Variability of this magnitude when assessing mortality estimates is most likely the result of low sampling effort for the species, and requires consideration of a revised approach to increase sampling effort and build confidence in the mortality estimates. Management objectives based on the confidence in current results for *H*. *gammarus* would not afford the correct level of protection, therefore sampling effort will need to be increased for the species.

Confidence in mortality estimates for *C*. *pagurus* are significantly higher, driven by higher sampling effort and consistency of results between years. Minor variability has occurred for male and female *C*. *pagurus,* females have fallen closer to the Fmax reference point steadily since 2015 – 2017, whereas exploitation rates for males increased from the reference point in 2016, higher than 2015 and have now dropped back closer to the reference point in 2017 with both sexes of crab demonstrating an all-time low since increased sampling effort in 2015. Variation in *C*. *pagurus* is most likely representative of realistic changes in exploitation rate and population dynamics.

F values for *C*. *pagurus* males and females remain similar, (49% and 51% respectively), as was observed in 2016 suggesting that neither sex is particularly susceptible to exploitation with equal opportunity of mortality through fishing. Both sexes of *C. pagurus* are currently under pressure from growth overfishing due to high rates of exploitation on stocks. Based on the results of the analysis fishing mortality rate would need to be reduced by ~30% to achieve maximum recommended exploitation rates (Fmax), and by ~45%to ensure maximum protective effect on the stock (F0.1).

Conclusions

Estimates of mortality for *C*. *pagurus* identify high levels of exploitation in the districts stock, indicating the presence of growth overfishing. Annual landings have decreased in all but one of the districts ICES rectangles (32F1) however this said it is important to note that MSAR data will continue to be sent in until mid-year and the cut off point for the 2017 study is the 9th March, with data included in the study representing all data that has been collected thus far since the introductions of MSARs in 2016.

Welby (2016) suggests that annually increasing landings and CPUE for *C*. *pagurus* over the 3 years preceding the 2017 stock assessment indicates substantial numbers of juvenile individuals recruiting to the fishery in recent years, potentially due to strong spawning events in the past 3-5 years, however he highlights that the precise cause is still uncertain. A general trend in decreased landings across the district matched with decreasing CPUE suggests that the fishery may have been impacted through high levels of landings reported in 2016.

Notably, CPUE has decreased for *C*. *pagurus* across the district, apart from the traditional inshore fishing grounds off the North Norfolk Coast (34F1) which has continued to rise since 2013. ICES Rectangle 34F1 has remained the most heavily fished ICES rectangle in the district for *C*. *pagurus* with landings lower than 2016, but relatively high when compared to landings of crab for 2016 and the subsequent year of 2017 in other ICES rectangles.

Addison (2004) suggests that observable trends of increased landings correlate closely to strong recruitment years, which was identified as the potential catalyst for the highest recorded peak in landings for crab since the introduction of MSARs between 2014-2016, peaking at 1057 tonnes in 2016 (Welby, 2016), therefore it is possible that reductions in landings for 2017, equating to 587 tonnes for *C. pagurus*, is a result of lower recruitment to the district, indicating that the peak year of 2016 has had an effect on recruitment levels for the 2017 fishery.

Following a peak in 34F1 in 2016 for *C. pagurus* after an increasing trend in landings from 2014, the current landings level in 2017 has been matched by decreasing effort, however CPUE has continued to rise in this area suggesting that larger individuals are being removed from the area with potential to impact on next year’s fishery, or impact offshore areas such as 35F0 and 35F1 where more mature individuals would naturally migrate from inshore areas following North/North West routes against prevailing currents.

Offshore areas (35F0 and 35F1) are influenced by recruitment patterns taking place in inshore waters, particularly 34F1 which receives larval recruits from the north as it provides settlement substrate seldom found along the districts coastline. 35F0 saw decreasing crab landings since peaking in 2015, however lobster has remained stable. Effort continues to rise this year in the area. 35F1 saw landings peak in 2009 reflecting a peak in effort of the same year. Landings have risen and fell since 2012, whilst currently lower than 2016, effort has risen again this year. These fishing grounds link intrinsically with what is occurring in the inshore area. CPUE has dropped for both areas in 2017, suggesting less individuals on the fishing grounds, potentially due to the peaks seen inshore in 2016 which have removed some of the stock that would otherwise migrate to these grounds.

Deficiency in data gives low confidence in mortality estimates for *H*. *gammarus,* however stock status reports published by Cefas (2014) estimate that exploitation levels for the most recent point indicate that exploitation levels remain high, a pattern which has been consistent throughout the duration of reporting (Cefas 2004). Furthermore, Cefas (2014) highlight that data for *H*. *gammarus* is inconsistent and insufficient for assessments required to assess accurately the current level of stock, however they tentatively suggest that the species is more heavily exploited than *C*. *pagurus* within the district and that growth overfishing is occurring.

Comparatively, landings and CPUE for *H*. *gammarus* are stable throughout the district for the dataset period, with minor fluctuations around the annual mean. This indicates that fishing activity is not influencing recruitment to the point of reducing contemporary levels of stock biomass, however fishing activity may be inhibiting potential increase in species abundance through recruitment overfishing.

Mortality estimates coupled with yield per recruit analysis indicate that both target species are being fished beyond recommended maximum exploitation levels, although a higher level of confidence can be afforded to *C*. *pagurus*. Following an increasing trend in landings for *C*. *pagurus* between 2014-2016, uncertainty surrounded the rapid growth of the fishery from years preceding 2014. Continued increase in landings in 2017 would infer the need for a number of questions surrounding the sustainability of the fishery however, landings have reduced significantly since the high of 2016. Landings data collected through MSAR return were cross referenced with Marine Management Organisation (MMO) data on 2017 landings of crab/lobster in the district were similar, with a discrepancy of a fraction of a tonne overall. This indicates that although all MSAR forms have not been returned to date, the overall landings for both target species is not expected to rise significantly. Therefore, 2017 figures of 687 tonnes combined landings is a representative figure of the landings when comparing with landings of previous years.

It was previously suggested by Welby (2016) that precautionary control measure should be considered to limit further increases in fishing, and as bare minimum controls should ensure effort levels are not allowed to increase beyond existing levels. This was suggested during an increasing trend in landings that saw combined landings rise to over 1000 tonnes in 2016 coupled with increasing CPUE. Lower landings in 2017 were potentially driven by this 2016 peak, therefore control measures should afford protection to the current level of stock, whilst capping effort at contemporary levels.

In line with duties under MACAA and the MSFD, opportunity exists to introduce technical measures in order to address issues identified within the fishery. The benefits of these measures include reducing the rate of exploitation (as identified with fishing mortality estimates), 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. Ultimately, improved communication with the industry and their inclusion in a stepwise approach during decision making and regulating will help promote potential management measures.

Inherent risk exists if the assumption is made that stricter sustainability objective measures are needed for *H. gammarus* when compared with *C*. *pagurus*, based on higher fishing mortality. Fisheries targeting these species operate as mixed fisheries; using the same gear in the same area to catch both species concurrently. Candidate measures will need to be proportionate. Any measures implemented on one species has the potential to impact on the other, influencing the fishery with potential detriment. A robust monitoring regime should accompany management measures, focusing on catch data from returns and sampled landings.

Recommendations

Sampling effort of *C*. *pagurus* has reached a point where data requirements are achievable, with a high level of confidence in results. In contrast, sampling for H. *gammarus* falls short of this target and as yet has failed to provide a confidence level in results from which appropriate control measures could be based. A revised approach for surveying *H*. *gammarus* at processors will be an intrinsic part of recommendations moving forward. The development of assessment methods and data capture/analysis toolkits by Welby (2016) are at the forefront of fisheries science and are kept up to date through close liaison with Cefas.

Following this report, recommendations and knowledge gaps include:

- Addressing high fishing mortality through capped effort at contemporary levels.
- A revised bio-sampling methodology for H. *gammarus* is required to ensure sufficient data is acquired to model data with confidence.
- Continuation of Bio-sampling and MSAR data acquisition and analysis to facilitate management and the subsequent monitoring of necessary measures, including monitoring of data to establish patterns in migration and recruitment.
- Potential technical measures need assessing to understand possible benefits for management objectives. These include exploration of a potential increase of 5mm in Minimum Landing Size, from 115mm to 120mm, affording increased protection to the spawning stock. There is potential for this to be introduced in incremental steps. This would include the adaptation of escape hatches for crab, and as a mixed fishery would have a knock effect for the lobster fishery. This may be overcome by using different pots for different species.

- Ensure analysis toolkits for the stock assessment are current, providing opportunity to promote better working relationships between organisations and maintain and build relationships with industry members to promote knowledge sharing and inclusion in decision making.

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Further reading to support the assessment

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