Eastern IFCA

Inshore Fisheries and Conservation Authority

RESEARCH REPORT

2016

Crab and Lobster Stock Assessment

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Executive Summary

With duties under Section 153 of the Marine and Coastal Access Act (2009) to ensure the sustainable exploitation of sea fisheries resources, and objectives of achieving good environmental status in all EU marine waters by 2020 set by the Marine Strategy Framework Directive (2008), ensuring sustainable exploitation of commercial fish populations is a key objective of the Inshore Fisheries and Conservation Authorities.

Important potting fisheries targeting Brown crab and European lobster operate throughout the Eastern IFCA district with key production areas situated off the North Norfolk and Lincolnshire coast. In 2013 this project was initiated with the aims of developing methods to assess these fisheries and provide the information necessary to decide whether or not a need to manage these fisheries existed.

Landings and effort data from Monthly Shellfish Activity Returns indicate a general trend of increasing landings throughout the district in recent years, largely driven by increased landing of brown crab. Much of this can be attributed to inshore grounds off the North Norfolk coast which have experienced significant annual increases in landings and Landings per Unit Effort for this species in recent years. The driver behind these increases is uncertain however; it is possibly a result of strong spawning and consequent recruitment years in the area. No such trends are apparent for European lobster, which has remained relatively consistent throughout the records with lower figures for landings.

Despite favourable landings figures, analysis of the effects of fishing mortality on the stock indicate that brown crab is being exploited beyond the maximum recommended reference point. Similar analysis for European lobster was inconclusive due to insufficient data for the model.

Conclusions are that while this fishery is not being exploited at levels that should raise immediate concern, it is being exploited beyond recommended thresholds. Minimum management recommendations would be to cap effort at contemporary levels and consider the implementation of technical measures that protect spawning capacity, and pre-recruit juvenile component of the stock.

Introduction

Background

Pot fisheries targeting crustaceans operate throughout the EIFCA district from Saltfleet in Lincolnshire down through Norfolk and as far as Felixstowe Ferry at the Authority's Southern limits. Whilst prevalent throughout the district most activity is focused along the North Norfolk coast; an area with a long tradition of fishing for brown crab (*Cancer pagurus*) and European Lobster (*Homarus gammarus*).

Most vessels active in the EIFCA district fall into the <10m category and the fishery historically operated within 2nm (MAFF 1975), being more accessible to vessels without the capacity to fish further out. However, advances in technology, including the introduction and advancement of motor engines, improved vessel design and fishing gear has steadily increased the range that potters can operate over (Turner et al 2009). Despite this a significant number of operators still fish traditional grounds often within sight of the shore, consequently the fleet is composed of a mixture of vessels with varying capability; smaller single manned boats targeting inshore grounds and larger crewed vessels that can access less pressured deeper water further offshore for larger fish.

Crab and lobster are specifically targeted through the deployment of static gears consisting of a string of 20-30 pots baited with dead fish. This gear is typically left to soak for 24-48 hours before being hauled, cleared and reset. Each vessel will fish several shanks checked on a rotational basis, hauling between 100-500 pots each trip.

Catch is sorted at sea with any undersize or poor quality animals being returned immediately, the rest is landed before being sold either to processing factories, private orders or direct to the consumer. Due to the nature of the gear, mortality rates of bycatch are incredibly low in pot fishing compared to other fishing gears, consequently discards have a high chance of survival allowing them to grow on to a size where they will recruit to the fishery or improve in condition

Pot design can vary depending on the preference of the fishers using them (fig 1). Traditionally inkwell and creel style pots were deployed however; parlour pots are becoming increasingly popular. The design of parlour pots helps to improve catch retention, allowing longer soak times between hauls so that pots do not need to be worked as frequently. Recently some fishers have switched to PVC coated wire mesh pots of a similar design to those used by lobstermen fishing off the East coast of the USA.

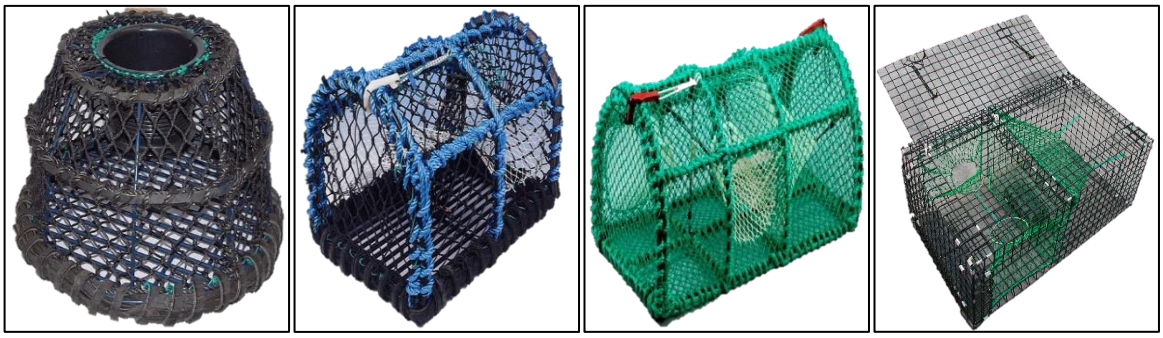

Figure 1: Various pot designs from traditional inkwell and creels to modern parlour and PVC coated wire.

The fishery is largely seasonal, with the main season for *C. pagurus* commences around late March to early April with peak landings in May and June before dropping off through to late September/early October. The *H. gammarus* season tends to follow closely behind, starting around mid-May/June, peaking in June/July before again dropping off through autumn and into winter.

H. gammarus is one of the highest value/kg, commercially exploited shellfish species found in UK waters. Its distribution extends from the Arctic Circle and into the Mediterranean but is mainly centred on the British Isles where a high proportion of landings originate (MAFF 1996). Lobsters favour rocky reef and rough ground where they typically shelter in crevices between rocks and boulders. The availability of suitable habitat of this type has been postulated as a factor influencing the carrying capacity and size structure of *H. gammarus* populations (Seitz et al 2014). The Norfolk population has been noted as being comprised of individuals that are on average smaller than those found in other areas. An investigation by Graham (1949) explored the concept that this was due to genetic isolation resulting in a “dwarf race” emerging

however; this was dismissed and a later study instead suggested that a lack of suitable refugia for large animals was a more likely cause (Howard 1980).

While sharing a similar geographic range as *H. gammarus, C. pagurus* is found on a wider range of habitat types, ranging from rocky reefs to soft mud and sand. As with *H. gammarus*, studies have revealed a smaller average size in *C. pagurus* in North Norfolk when compared to adjacent areas. Unlike *H. gammarus* however this has not been associated with habitat limitations but is believed to be a consequence of migration patterns and recruitment regimes (Eaton 2003). This smaller average size is reflected by a lower MLS for *C. pagurus* in the EIFCA district compared to other areas. *C.pagurus* takes approximately four years to recruit to the fishery.

Figure 2: Juvenile lobser, *Homarus gammarus* (Left) and freshly caught Brown crab *Cancer pagurus* (Right)

District Landings and Value

MSAR (Monthly Shellfish Activity Return) records collated from the <10m fleet between 2006-2015 indicate average annual landings in the district of ~748 tonnes for target species combined however; recent years have seen landings significantly higher than this average (913 tonnes and 950 tonnes for 2014 and 2015 respectively).

Brown crab accounts for most of the crustacean landings in the district each year with lobster accounting for less than a quarter of total landings (Average catch proportions = 87% crab and 13% lobster 2006-2015). Despite the large disparity in landed proportions, crab and lobster contribute more equally to the mean value of the catch due to the higher sale value of lobster. Annually the fishery is worth ~£2.2 million with crab and lobster contributing 54% and 46% to this respectively.

Beyond monetary value many of the towns and ports in this area have a strong association with crab and lobster fisheries and this industry has become an intrinsic part of their culture and character. This heritage has become the basis for several events that take place throughout the year and helps to drive tourism in the area.

Management

The 2015/16 Strategic Assessment placed fisheries for crab and lobster as a high priority based on the limited regulation in place to manage the fishery e.g. effort, gear or catch control, combined with low confidence in activity data. This acted as the driver to consider management needs along with 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).

EIFCA carries the responsibility under Section 153 of the Marine and Coastal Access Act 2009 (MACAA) to ensure the sustainable exploitation of sea fisheries resources. Additional objectives are also set by the Marine Strategy Framework Directive 2008 (MSFD) to achieve Good Environmental Status (GES) in EU marine waters by 2020; in this case issues identified with the crustacean fishery resonate with descriptor 3.

Descriptor 3 implies 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.

Good Environmental Status is achieved only if all three attributes are fulfilled. This implies that all commercially exploited stocks should be in a healthy state and that exploitation should be sustainable, yielding the Maximum Sustainable Yield (MSY). As such there is increasing pressure to ensure that management is in place to support the sustainability of commercially exploited stocks.

Fisheries for brown crab and European lobster are currently managed nationally through MMO licencing and regionally by IFCA byelaw while international EU regulations set limits on minimum landing size (MLS). EU MLS restrictions for crab are also 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)). No new entitlements are currently being authorised by the MMO effectively limiting entry into the fishery.

MLS in the EIFCA district are set at 115mm carapace width (CW) for *C. pagurus* and 87mm carapace length (CL) for lobster. MLS for *C. pagurus* was nationwide however, reviews in 1986 and 1990 saw this raised in other districts to between 130-160mm however; the area falling within EIFCAs jurisdiction was given derogation to retain the smaller MLS based on the perception that individuals in the Norfolk population are on average smaller than in other areas (Addison & Bennett 1992). Table 1 highlights all regulations relevant to trap fisheries targeting crustaceans in the EIFCA district.

Table 1: Current regulations relating to EIFCA crustacean fisheries

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	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: - Re-deposition 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

Assessment

In 2013 a project was initiated with the objective of furthering the understanding of potting fisheries within the EIFCA district and the goal of developing the techniques necessary to carry out stock assessments at a local level. The long-term aim is to develop a robust monitoring regime that uses analysis of contemporary data to inform an adaptive management approach, ensuring the health of stocks and the viability of this important fishery.

This report represents the culmination of these efforts, utilising catch return data and biometric sampling to generate summary statistics for the most important fishing grounds and to estimate mortality by species and sex using length converted catch curve models.

Data Sources

Monthly Shellfish Activity Returns (MSARs)

Monthly Shellfish Activity Returns (MSARs) are catch reports recorded by fishers on a standard form and then collected by EIFCA and produce a foundation dataset. This uncertainty became the driver to develop more sophisticated assessments that account for and can detect changes in population dynamics and demographics.

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. Due to the manner that spatial data are reported it can be difficult to discern whether activity has occurred inside or outside the 6nm EIFCA boundary. Activity is frequently reported in areas that straddle this boundary however, all data have been included in this assessment as the determination of overall stock status is the objective and not simply those components of the stock that fall within EIFCA's jurisdiction. MSAR data arrives as a paper carbon copy of the original records; these copies are then digitised and captured in a bespoke Access database allowing the data to be easily queried.

These data allow basic fisheries statistics to be calculated for the most important grounds by ICES statistical rectangle. Previous reports have used this data to model important fishing grounds using surplus production methods. While the results of these models have been useful as indicative tools describing the current state of the fishery there is a degree of uncertainty attached to the results these models generate and their effectiveness in monitoring change in the fishery either due to biological influences or resulting from changes to management.

Biosampling - Port and Processors

Figure 3: Eastern IFCA Inshore Fisheries and Conservation Officer collecting biosampling data.

To provide data to describe population dynamics and model mortality, EIFCA Inshore Fisheries and Conservation Officers (IFCOs) and Research Officers (ROs) undertook biosampling at ports and processors.

This involved sampling a proportion of the catch of randomly selected vessels at the point of landing on an ad hoc basis, and visiting processors to measure catch held in storage. Standard size and sex of animals, area fished (ICES statistical rectangle) and number of pots hauled are recorded, along with estimates of the weight of sampled animal and total weight of vessel landings. These data were used to model mortality using length converted catch curve, allowing estimation of fishing mortality. Yield per recruit methods were used to derive biological reference points against which contemporary mortality estimates could be measured. A full method for this process is given in previous reports (Welby 2015).

Monthly Shellfish Activity Returns - Summary Statistics

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

In this study, Statistical Rectangles have been used to define the boundaries of grounds fished by operating in the district and carry out analysis on a site by site basis. This delineation is facilitated by the requirement for fishermen submitting MSAR forms to report ICES Statistical Rectangles they have fished on any given day.

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

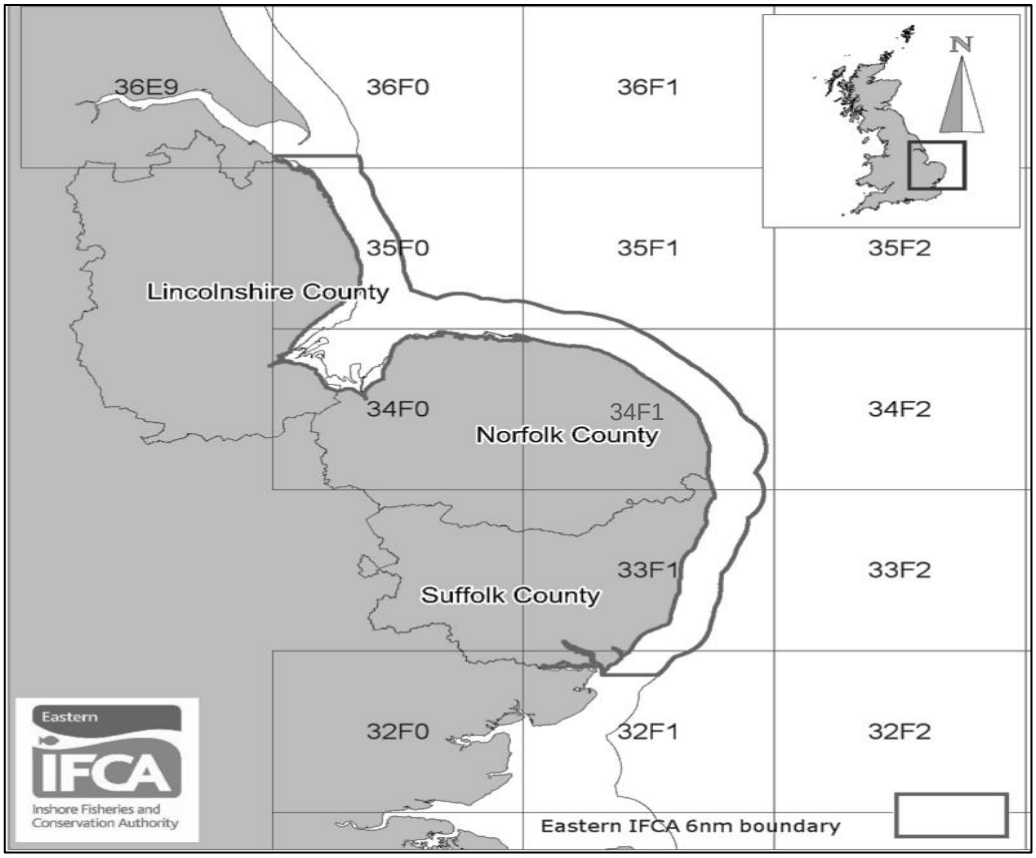

Figure 4: Map of the Eastern IFCA district showing ICES Statistical Rectangles and 6nm Boundary.

District Overview

The last three years have seen an increasing trend in total landings. Highest recorded landings (Since the introduction of MSARs) have occurred in 2014, 2015 and 2016 sequentially with total landings (crab and lobster landings combined) exceeding 1000 tonnes in 2015 and 2016.

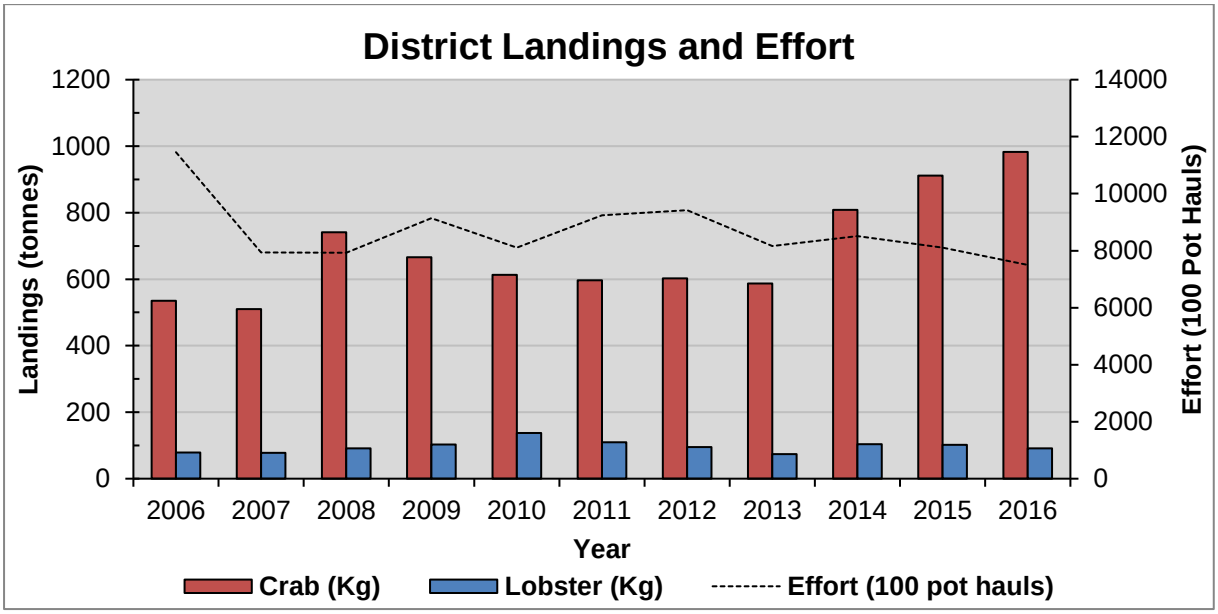

Figure 5: District Summary of Annual Effort (Dotted Line) and Landings by Species.

Catches of *C. pagurus* are driving these annual increases, growing by more than 200 tonnes between 2013-14, 100 tonnes 2014-15 and 70 tonnes 2015-16. Landings of crab since 2014 (2014 = 809 tonnes, 2015 = 911 tonnes & 2016 = 982 tonnes) have far exceeded the annual mean of 687 tonnes (SD±148 tonnes).

In comparison catches of *H. gammarus* have remained relatively stable and have not expressed the same increasing trend, fluctuating around an annual mean of 97 tonnes (SD±17 tonnes).

The higher market value of *H. gammarus* compared to *C. pagurus* has historically offset the disparity in landed weight in terms of catch value however; the difference in landed weight between the two species in 2016 and the lower than average landings of *H. gammarus* means that *C. pagurus* landings are worth almost twice as much as *H. gammarus* for this year.

Table 2: Annual Value of District Potting Fisheries by Species and Total.

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%)	£2.5
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%)	£2.8
2016	£1.9 (66%)	£0.9 (34%)	£2.9
Mean	**£1.4 ±0.3 (56%)**	**£1.0 ±0.2 (44%)**	**£2.4 ±0.3**

Effort (pot hauls) has remained relatively stable across the dataset besides the peak in 2006 and as such cannot explain the variability and recent trend of increasing landings of *C. pagurus*. Effort stability combined with increasing catch is reflected in landings per unit effort (LPUE) for crab, which has increased progressively from 2012 (0.64 Kg/pot) to its current high in 2016 (1.3 Kg/pot).

LPUE for *H. gammarus* has remained relatively constant throughout the period of the dataset and continue to do so into 2016 (0.12 Kg/pot) with only minor fluctuations around the mean (0.11 Kg/pot ±0.08).

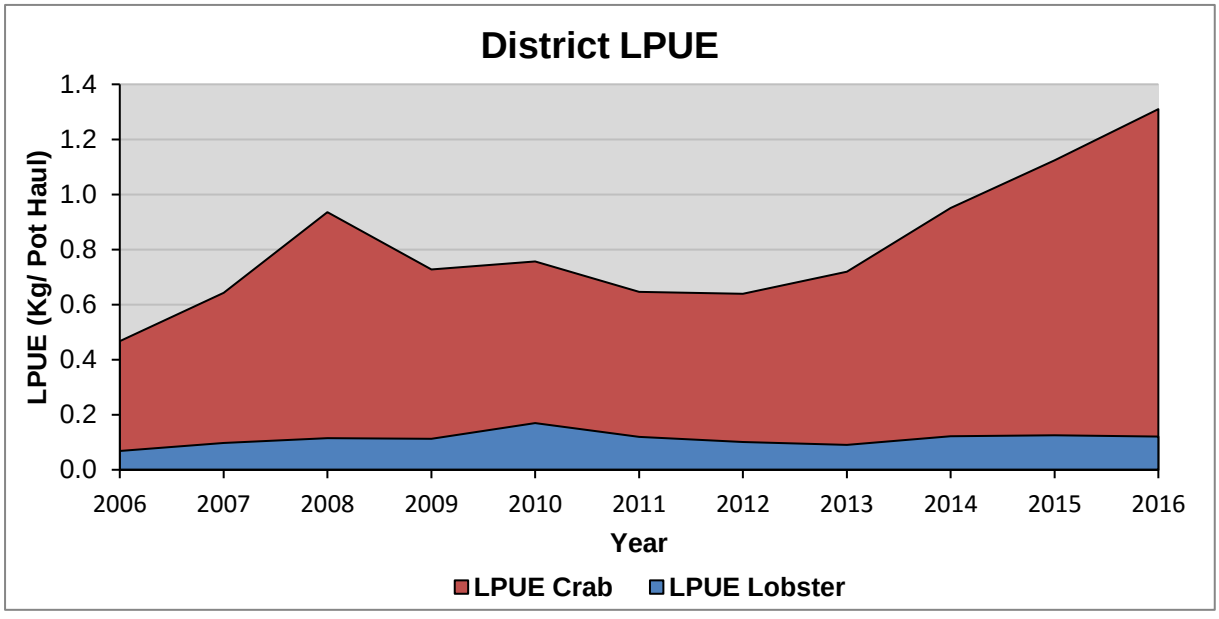

Figure 6: District Annual LPUE by Species.

Summary Statistics 32F1

This area overlaps significantly with Kent & Essex IFCA, being located at the Southern limits of the district. It is fished by a small number of ports and vessels from our district which is reflected by relatively low levels of reported effort and landings. *H. gammarus* has typically dominated catches in this area however; there has been a steady decline in effort and landings from this area over the period of the dataset.

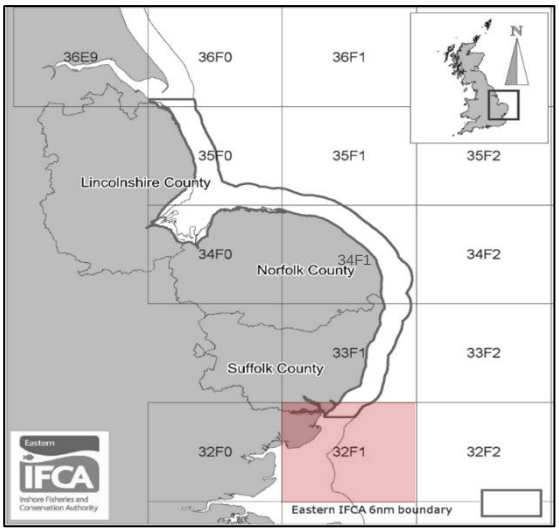

Table 3: 32F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	11	189	2.1	0.7	1.4
2007	3	13	223	8.8	2.8	6.0
2008	5	13	165	6.6	2.8	3.8
2009	2	6	96	4.6	1.7	2.9
2010	5	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
Mean	**3**	**9**	**117**	**3.2**	**1.1**	**2.1**
SD	**1.47**	**2.57**	**56.12**	**2.34**	**0.87**	**1.54**

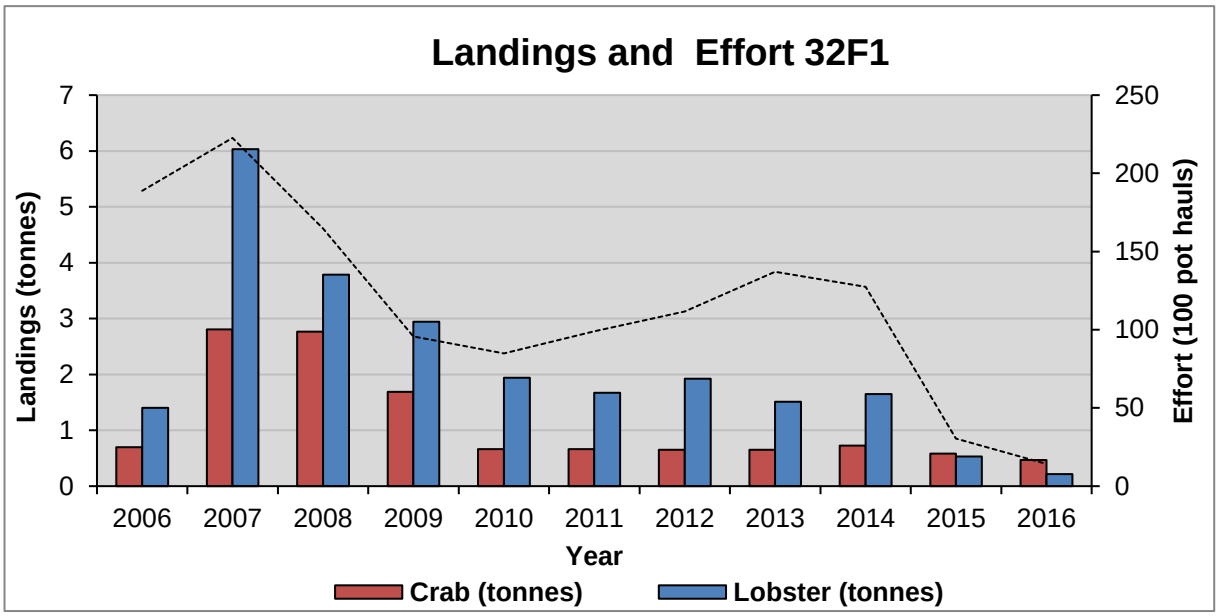

Figure 7: 32F1 Summary of Annual Effort (Dotted Line) and Landings by Species.

The data show a general decline in effort with the most recent years (2015 & 2016) falling to dramatically low levels. This trend is reflected in landings with a notable decline in *H. gammarus* catch since its peak in 2007 to current lows of less than half a tonne in 2016. Due to the decline in landings of *H. gammarus*, and despite no increase in their landings, *C. pagurus* dominated the catch in this area for 2015 and 2016.

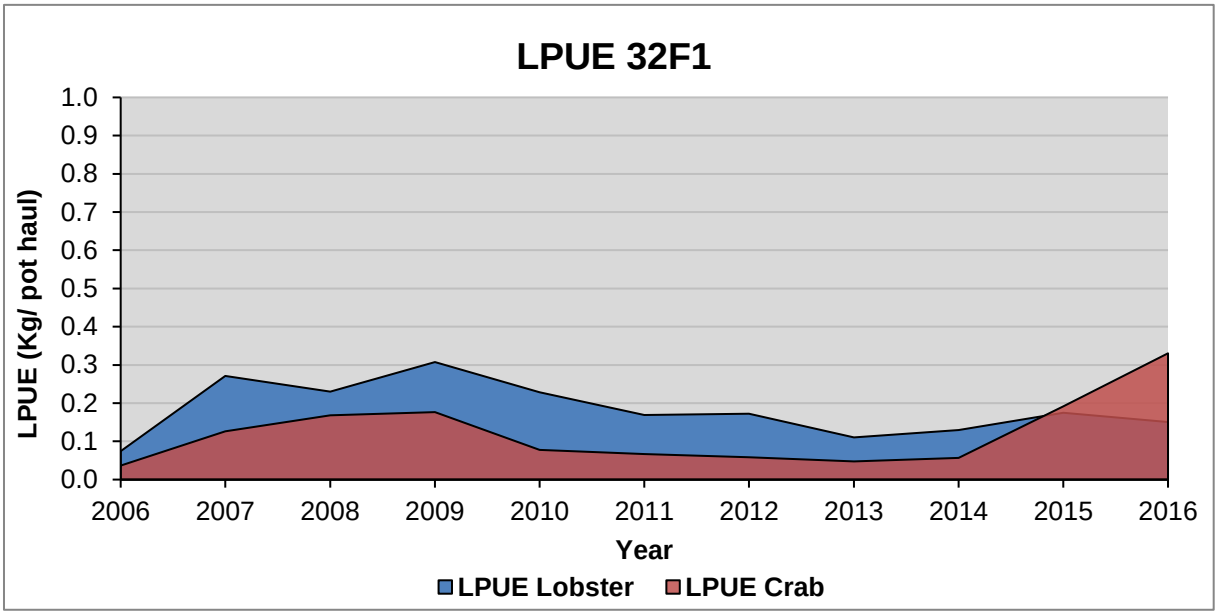

Figure 8: 32F1 Annual LPUE by Species.

Despite minor interannually fluctuations LPUE has remained relatively stable throughout the course of the dataset for both *H. gammarus* and *C. pagurus*. There is an observable incline in LPUE for *C. pagurus* from 2014 – 2016 attributed to the decline in effort over these years rather than an increase in catch. This tends to suggest that low effort levels are not limiting catches of crab; rather that abundances of crab on the ground are low.

LPUE for *H. gammarus* remains relatively stable throughout the dataset including the period of declining effort in 2015 & 2016; indicating that the decline in reported landings for this species is largely attributable to declining effort. Summary Statistics 33F1

Summary Statistics 33F1

This area situated off the Suffolk coast covering an area between the Orford and Lowestoft is fished by a small number of ports and vessels compared to other areas and this is reflected in the relatively low landings and effort compared to the Norfolk coast. Landings fluctuate annually but have rarely differed significantly to the annual mean until recently.

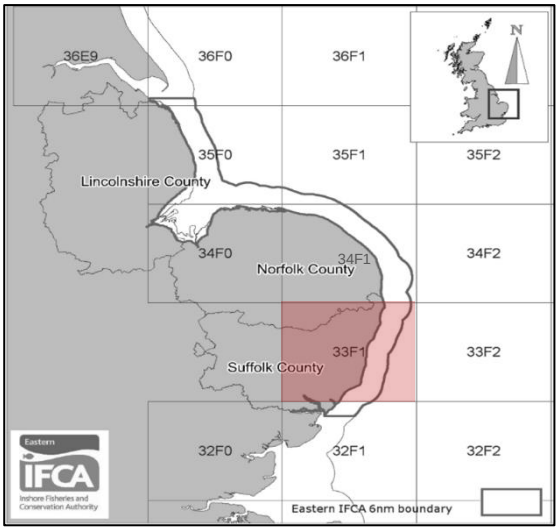

Table 4: 33F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

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
Mean	**7**	**20**	**287**	**17.3**	**11.5**	**5.8**
SD	**0.75**	**2.49**	**133.39**	**3.69**	**3.16**	**1.77**

Effort in this area peaked in 2006 before experiencing a rapid decline to 2008.

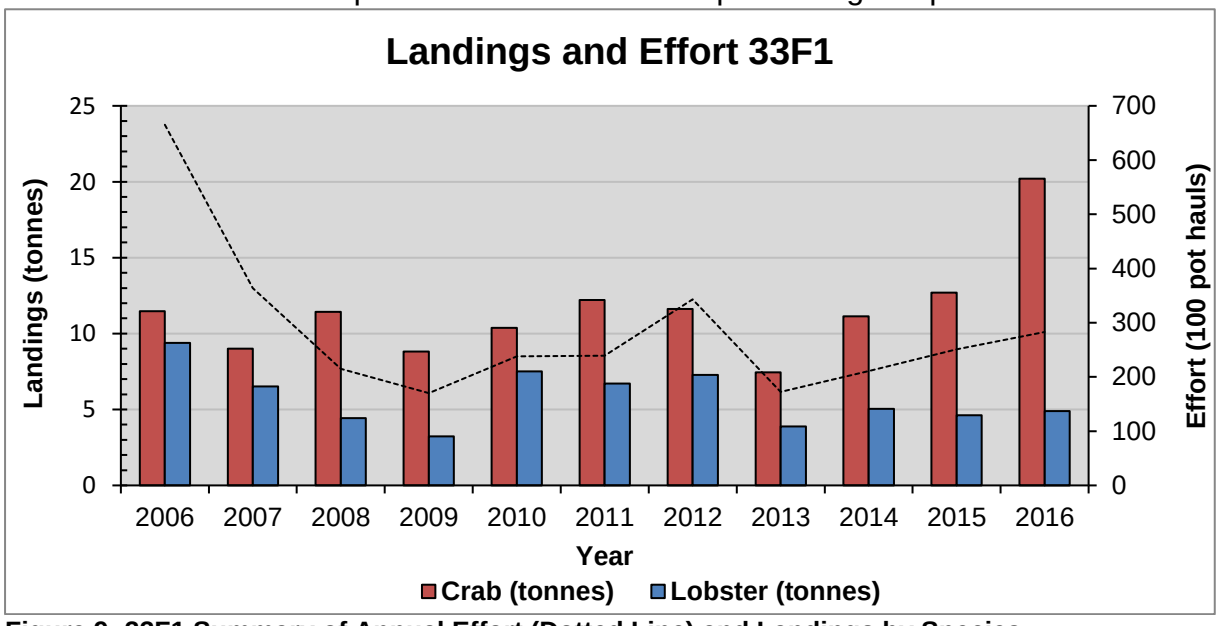

Figure 9: 33F1 Summary of Annual Effort (Dotted Line) and Landings by Species.

Since then effort has shown minor inter-annual fluctuations around the mean. A small

peak occurred in 2012 before effort dropped off again in 2013 however; it has increased steadily again over the last three years approaching the average in 2016.

For the most part landings for both *H. gammarus* and *C. pagurus* have remained relatively stable. Landings of *H. gammarus* have shown annual fluctuations around the mean of 5.8 tonnes (SD ± 1.8); recent years (2013 – 2016) have seen landings drop below this average though not significantly. *C. pagurus* landings have seen a notable increase in 2016 varying significantly from the mean of 11.5 tonnes (SD ± 1.83).

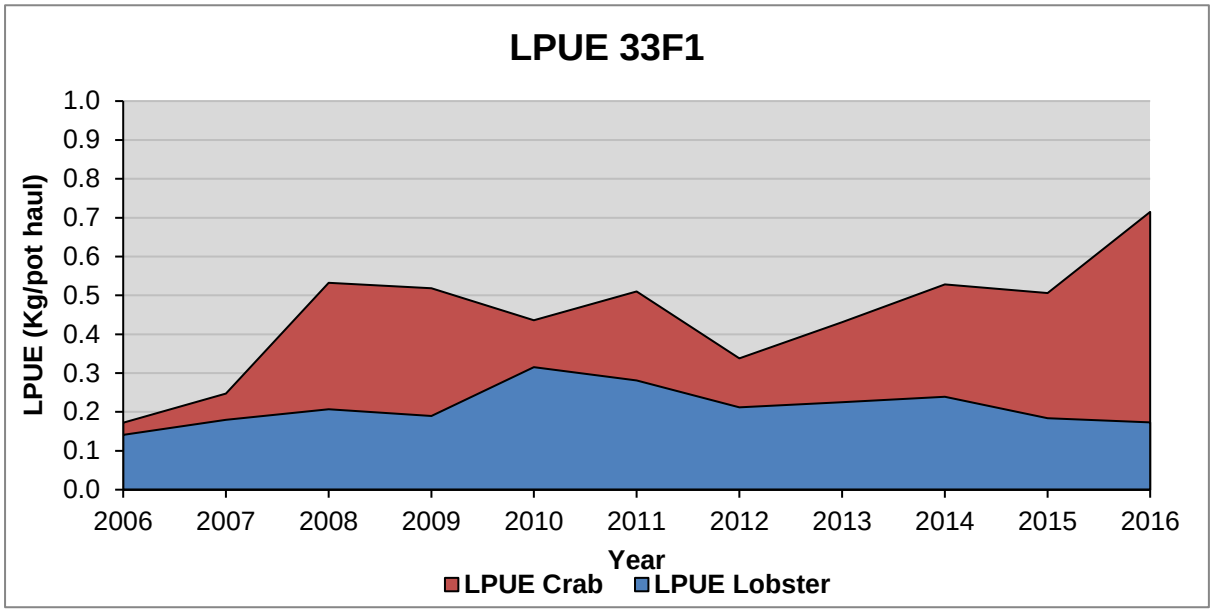

Figure 10: 33F1 Annual LPUE by Species.

Despite the observable fluctuations in effort LPUE for *H. gammarus* has remained relatively stable throughout the dataset however; greater variability in LPUE is observable for *C. pagurus*. Lowest LPUE for *C. pagurus* is observed in 2006 when effort was at its peak; rising swiftly as effort fell to 2008. As effort increased in 2012 another drop in LPUE was observed suggesting a link between effort and LPUE for *C. pagurus* in this area. The current trend of increasing landings and effort is mirrored by LPUE for *C. pagurus* with 2016 having the highest LPUE for this species in this area.

Summary Statistics 34F0

Straddling the border between Norfolk and Lincolnshire this area is composed mainly of The Wash and a short section of the North Norfolk coast. It is an area that has only been regularly fished relatively recently. Relatively little effort is currently dedicated to crab and lobster fishing however; this seems to be increasing. No returns detailing catch or effort were submitted for 2007 and 2008.

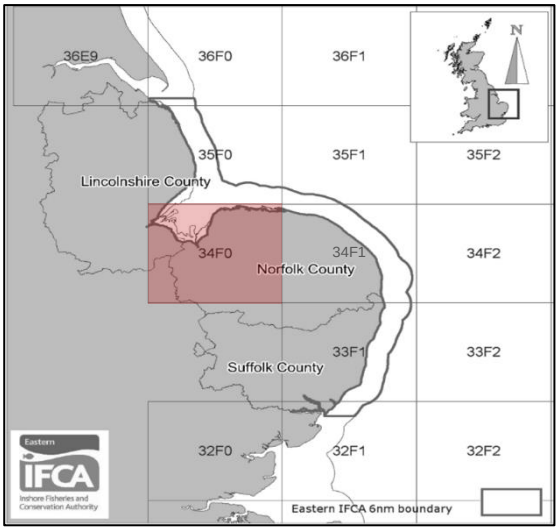

Table 5: 34F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	1	1	0.4	0.0	0.03	0.0
2007	0	0	0	0.0	0.0	0.0
2008	1	1	0	0.0	0.0	0.0
2009	2	3	22	1.8	1.6	0.2
2010	3	3	151	7.7	4.5	3.2
2011	5	7	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
Mean	**3**	**3**	**84**	**8.4**	**7.3**	**1.1**

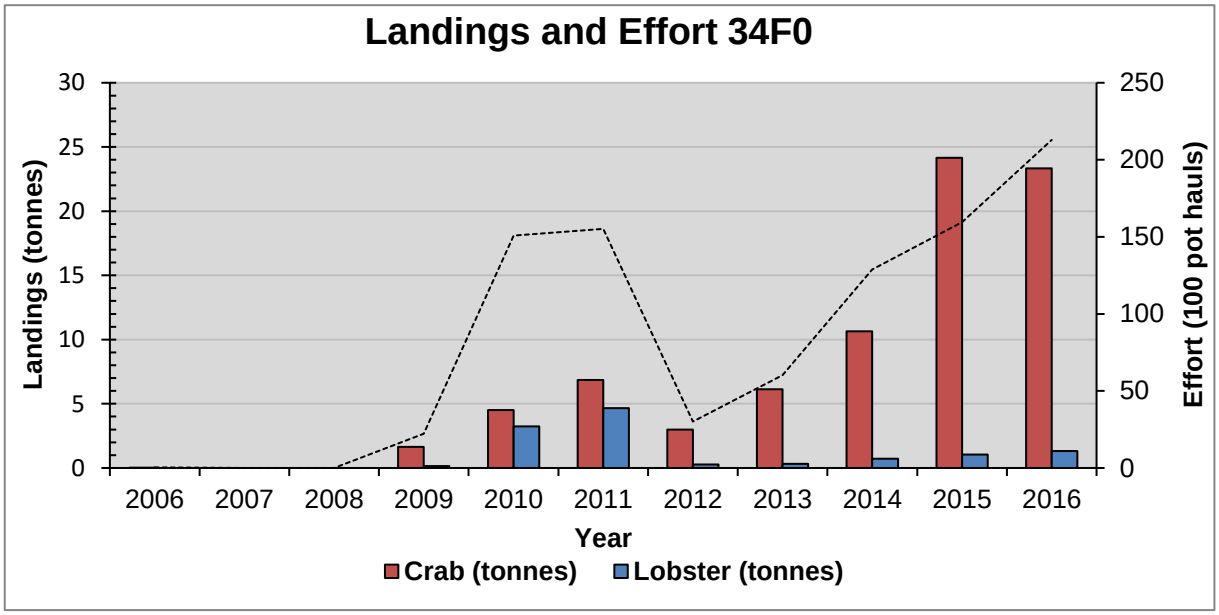

Figure 11: 34F0 Summary of Annual Effort (Dotted Line) and Landings by Species.

Effort has been erratic in this area with little or no effort reported for the first three years of recording before peaking in 2010 - 2011 and then dramatically dropping off again in 2012. Effort has since gradually increased year on year to its current peak in 2016.

Landings have followed the general trend of effort, increasing as effort goes up and dropping as it declines as in 2012. During early reporting, catches of *C. pagurus* and *H. gammarus* were relatively even however; Landings have been dominated by catches of *C. pagurus* since 2012 with landings of this species increasing in line with increasing effort. Recent years (2015 & 2016) have seen landings of *C. pagurus* significantly greater than the average.

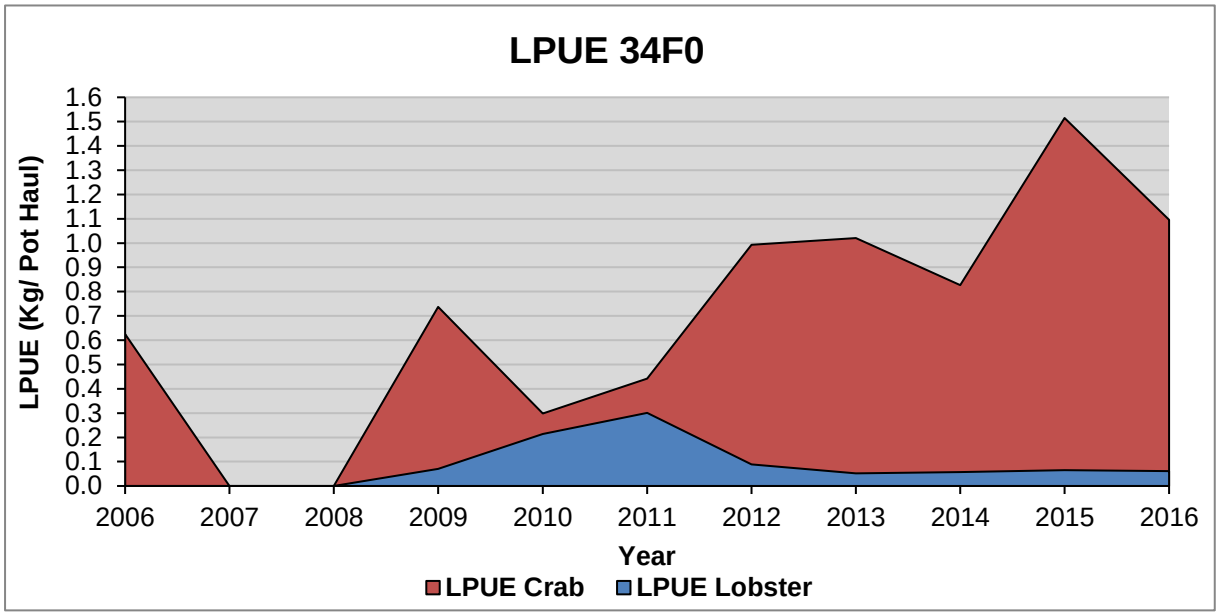

Figure 12: 34F0 Annual LPUE by Species.

LPUE for *C. pagurus* has shown considerable variability over the period of the dataset which may be explained in part by the fact that this area has only been regularly fished relatively recently and that the ground is still being explored for fishing hotspots. Compared to some other areas in the district Annual LPUE for *C. pagurus* is often relatively high suggesting that the species may be abundant in this area.

LPUE for *H. gammarus* peaks in 2010 & 2011 before dropping to stable levels in 2012 -2016; suggesting that populations of *H. gammarus* may have been more abundant, but have since been depleted.

Summary Statistics 34F1

This the primary fishing ground for vessels operating out of Cromer and is fished by many vessels from ports along the North Norfolk coast. The high number of vessels fishing this area is reflected in the effort and landings figures which have increased over recent years to make this the most productive potting ground in the district. Crab constitutes the main component of catches in this area, though much of the lobster caught in the district also comes from this area.

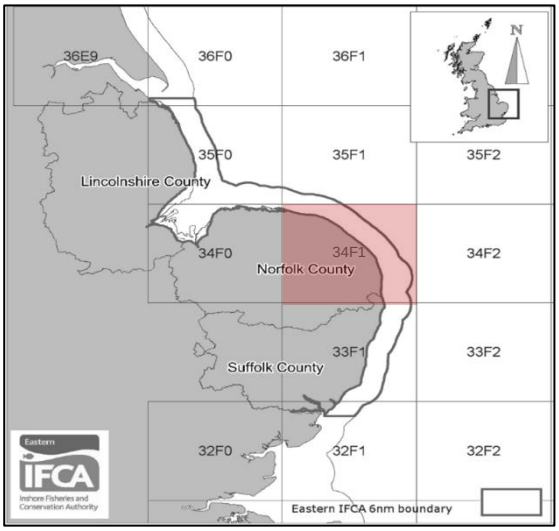

Table 6: 34F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

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
Mean	**14**	**42**	**3690**	**270.3**	**238.7**	**31.7**

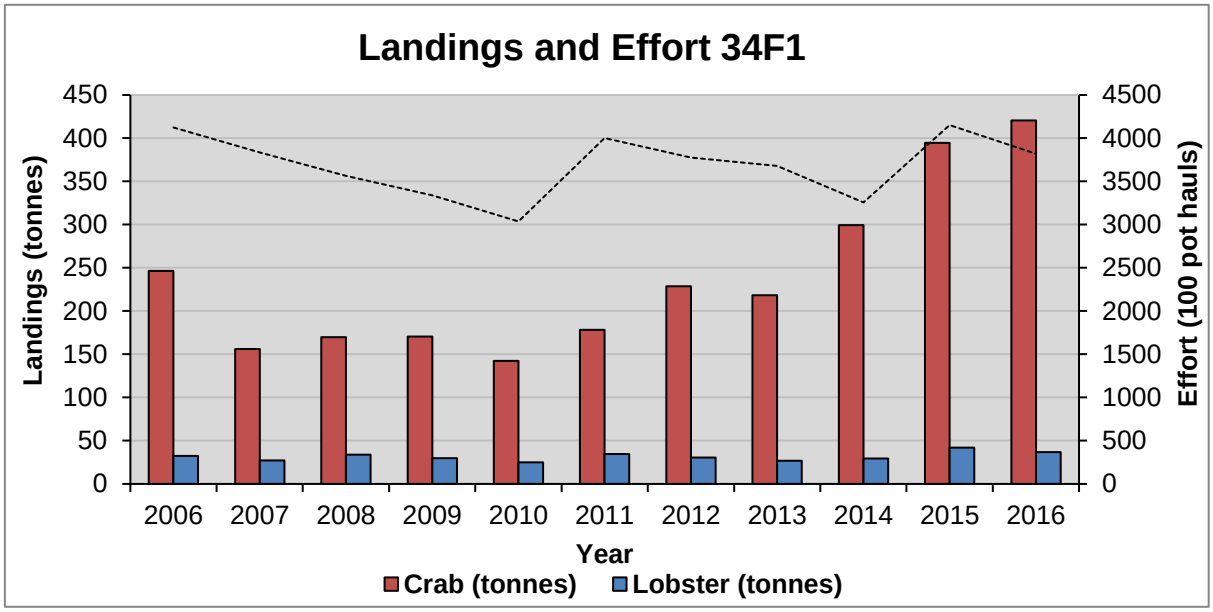

Figure 13: 34F1 Summary of Annual Effort (Dotted Line) and Landings by Species.

Effort in this area has followed an almost cyclical pattern over the period of the dataset, rising to peaks of ~400 thousand pot hauls/year before gradually dropping off over several years to ~300 thousand hauls/year. This pattern is apparent between 2006 – 2010, 2011 – 2014 and appears to have begun again in 2015.

Landings from this area are dominated by *C. pagurus* which on average accounts for more than 7 times the weight of landed catch compared to *H. gammarus*. Recent trends have seen reported landings of *C. pagurus* increase by ~100 tonnes each year (2013 – 2014) with landings of this species exceeded 400 tonnes in this area in 2016. By comparison landings of *H. gammarus* have remained relatively stable with only minor annual fluctuations around the mean (31.7 tonnes ± 4.7).

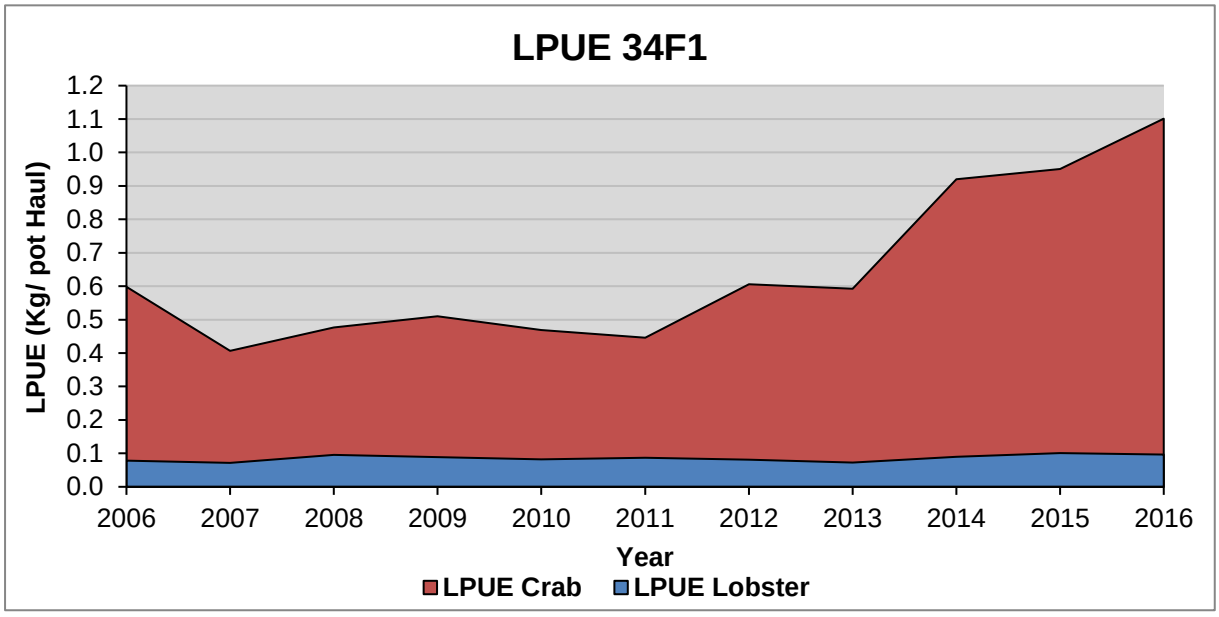

Figure 14: 34F1 Annual LPUE by Species.

LPUE has seen a stepped increase for *C. pagurus* since 2011 to its current high of 1.1 Kg/pot haul. Increasing LPUE is undoubtedly the driver behind the recent year on year increase in landings for this species and suggests that either *C. pagurus* abundance has increased in this area or that they have become more catchable due to behavioural changes or modified fishing practices.

In Contrast LPUE for *H. gammarus* has remained stable throughout the period of the dataset with only minor annual fluctuations. This suggests that whatever drivers are influencing recent trends in *C. pagurus* are not affecting populations of *H. gammarus*.

Summary Statistics 35F0

This is main offshore potting ground fished by vessels operating out of Wells and Lincolnshire as well as vessels from North of the EIFCA district. This has historically been the most productive potting area in the district however; recent years have seen it surpassed by 34F1. While this area is fished by vessels landing outside of the district only records originating from vessels landing within EIFCA district are considered here.

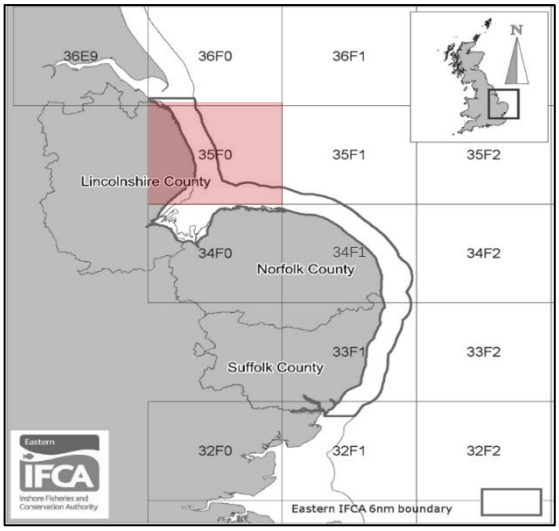

Table 7:Statistical Rectangle 35F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	13	2251	239.2	213.7	25.4
2007	4	12	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
Mean	**3**	**14**	**2250**	**281.5**	**253.7**	**27.8**

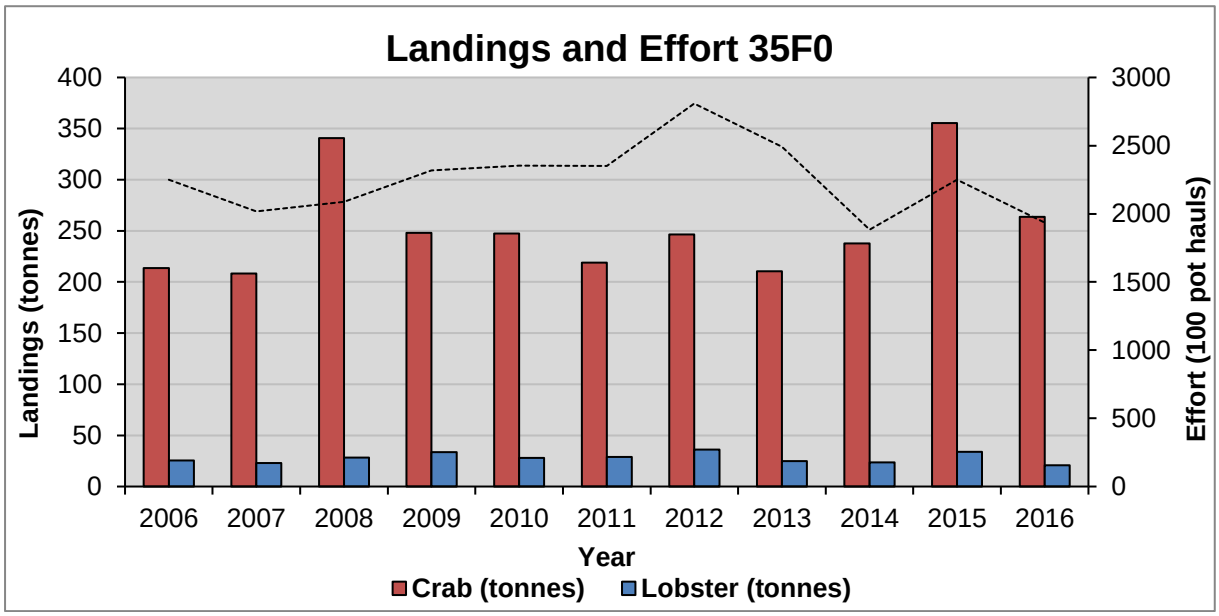

Figure 15: 35F0 Summary of Annual Effort (Dotted Line) and Landings by Species.

Effort remains relatively stable throughout the dataset with only minor fluctuations around the mean. Peak effort is occurred in 2012 before dropping off into 2014, since then it has remained at or below the annual mean for the dataset.

As with other areas off the North Norfolk Coast, Landings in this statistical rectangle are dominated by large catches of *C. pagurus*. Landings of this species are typically stable from year to year fluctuating between 200 – 250 tonnes. Exceptional years occurred in 2008 and 2015 when landings exceeded 300 tonnes. It is notable that these exceptional years do not coincide with a reported increase in effort. Landings of *H. gammarus* have remained relatively constant throughout the data however; it is worth noting that peaks in landings for this species often accompany increasing effort (e.g. 2009, 2012 & 2015).

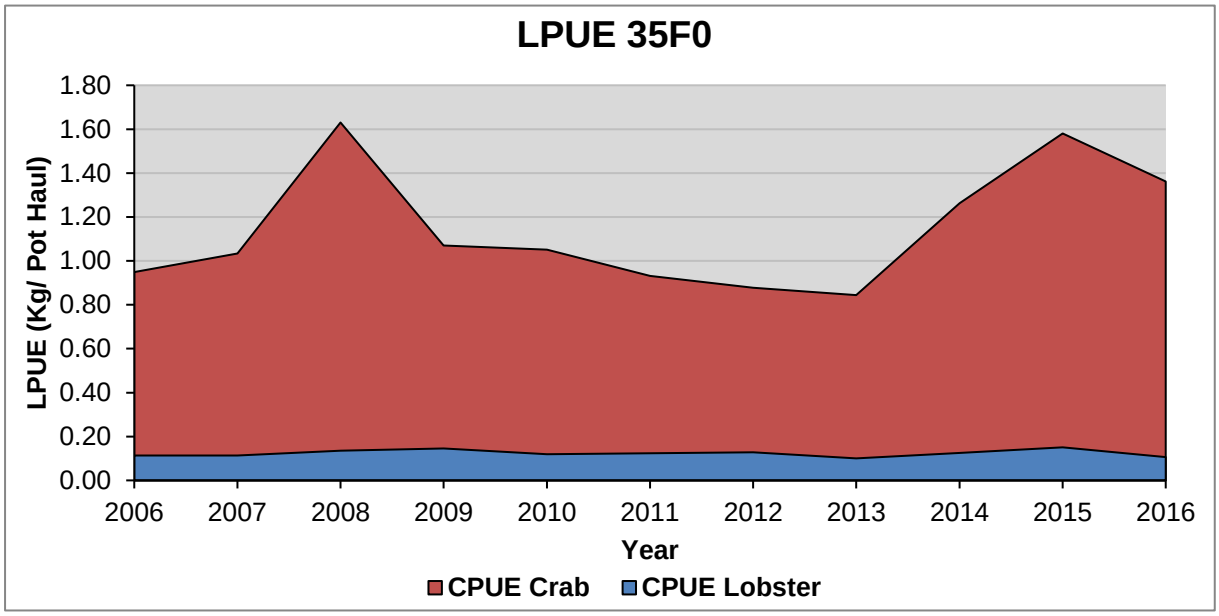

Figure 16: 35F0 Annual LPUE by Species.

LPUE for *C. pagurus* is consistently high in this area, regularly approaching or exceeding 1Kg/pot haul. Peaks occur in 2008 and 2015, when LPUE exceeded 1.5Kg/pot haul. These peaks coincide with years when landings were elevated. Effort levels were not exceptional during these years suggesting that the increased landings/LPUE are attributable to increased vulnerability to gear for the species, possibly due to higher abundance of fish on the ground during these years.

Similar to other areas, LPUE for *H. gammarus* remains constant throughout the data with no notable variation around the average.

Summary Statistics 35F1

The third most productive ground in the district much, of which falls outside of the 6nm district limits. Despite this it is still considered in this assessment as it is fished by several ports and vessels originating from within the EIFCA district and it is plausible that the stock associated with this area is part of a larger stock that includes and influences inshore areas.

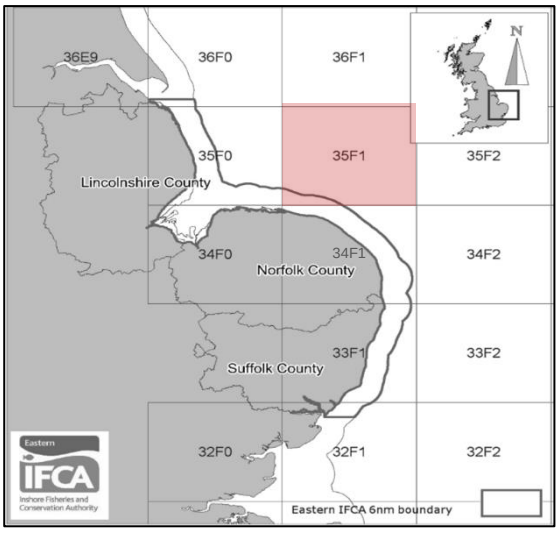

Table 8:35F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

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
Mean	**7**	**12**	**1223**	**116.1**	**104.4**	**11.6**

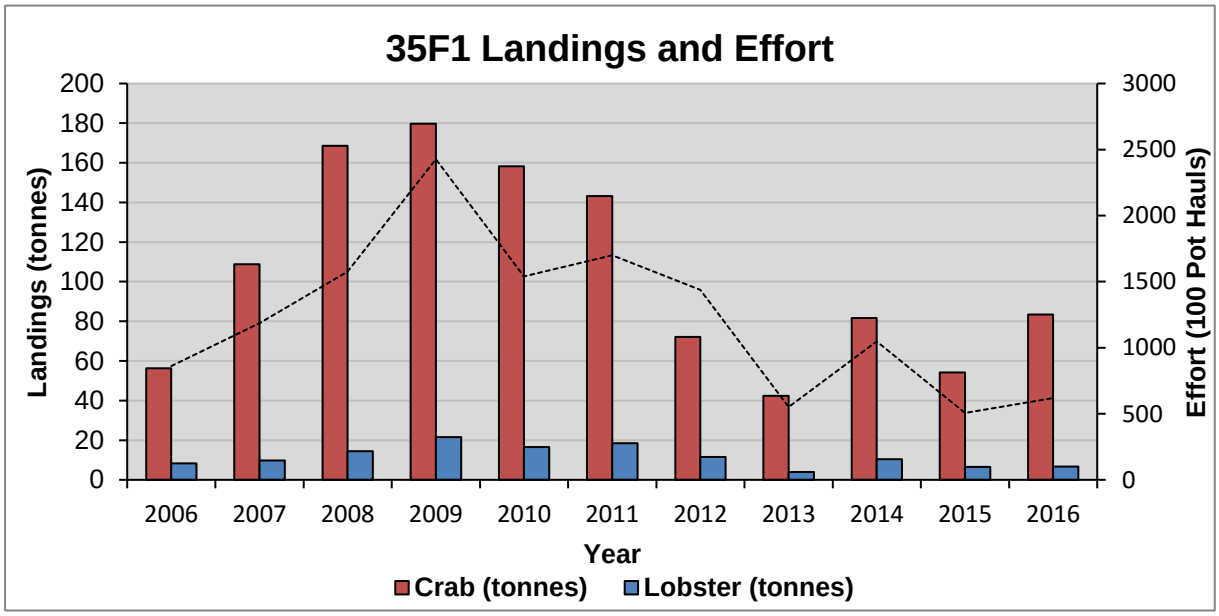

Figure 17: 35F1 Summary of Annual Effort (Dotted Line) and Landings by Species.

Following a period of increasing effort from 2006 to its peak in 2009 there has been a declining trend in effort in this area. At its peak effort was similar to adjacent area 35F0 however; contemporary levels of effort have fallen below this considerably.

Trends in landings closely follow effort, with landings of *C. pagurus* and *H. gammarus* increasing or decreasing in line with effort. Peaks in landings for both species occur in 2009 before declining again as effort drops off. As seen in other areas off the North Norfolk Coast *C. pagurus* is the dominant species in the catch with *H. gammarus* accounting for only 10% (±1.97) of the catch on average.

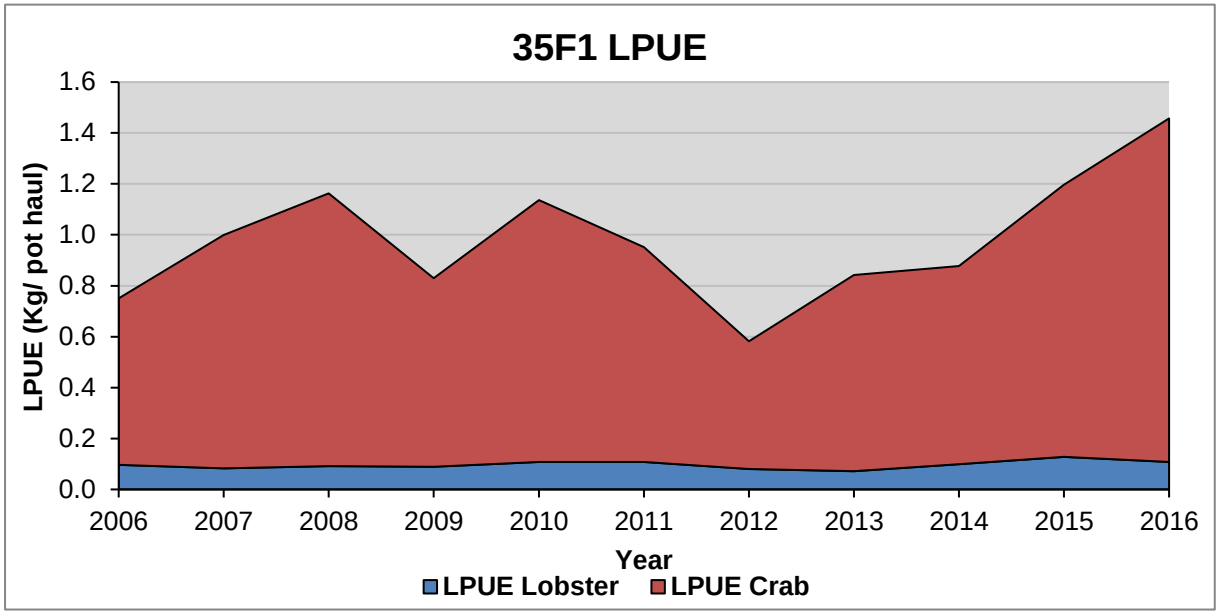

Figure 18: 33F1 Annual LPUE by Species.

LPUE for *H. gammarus* displays only very minor inter-annual fluctuations, in contrast LPUE for *C. pagurus* is much more variable. LPUE for *C. pagurus* does not seem to be intrinsically linked to effort as it is seen to vary in line and in contrast to effort with no clear pattern. There is a notable trough in LPUE for this species in 2009, when effort reached its peak however; and LPUE has been increasing since 2012 following the general trend of decreasing effort and reflecting LPUE trends for this species observed throughout the district.

Biosampling - Mortality Estimates

Estimations of total mortality (Z) by sex and species were derived using length converted catch curve methods. This method quantifies the rate at which the frequency of individuals in a population declines with size, attributing this decline to death (mortality) either through natural circumstances or fishing. From Z, fishing mortality (F) can be estimated by subtracting natural mortality (M) from Z. Full details of this method are covered in Welby (2015).

Results

Table 9 presents estimates of mortality from biosampling carried out in 2016. Sampling effort was considerably higher for *C. pagurus* than for H*. gammarus* with *C. pagurus* accounting for almost 4 times as many samples as *H. gammarus* largely due to the ease of access to samples of this species. Sample effort was relatively even between the sexes for both species.

Table 9: Total Mortality (z) & Fishing Mortality (F) Estimates from 2016 biosampling 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	2563	1.112	67	0.912	60
CF	2111	1.068	66	0.868	58
HM	549	0.864	58	0.664	48
HF	370	0.697	50	0.497	39

Lowest estimate of F was for *H. gammarus* with female mortality estimated considerably lower than male. This contrasts with estimates from 2015 when mortality estimates for this species was notably higher (Welby 2015). Estimates for *C. pagurus* were similar for both sexes and were close to estimates from 2015.

The effect of fishing mortality was estimated using yield per recruit analysis. Resulting curves are presented below along with target reference points Fmax and F0.1. Current rates of fishing mortality were found to exceed maximum recommended exploitation rates (Fmax) in most cases and be well beyond those predicted to provide the maximum protective effect on the stock (F0.1). Estimated mortality for *H. gammarus* females was found to fall below Fmax reference levels in this year's assessments, contradicting findings in 2015 when mortality for this species was significantly higher.

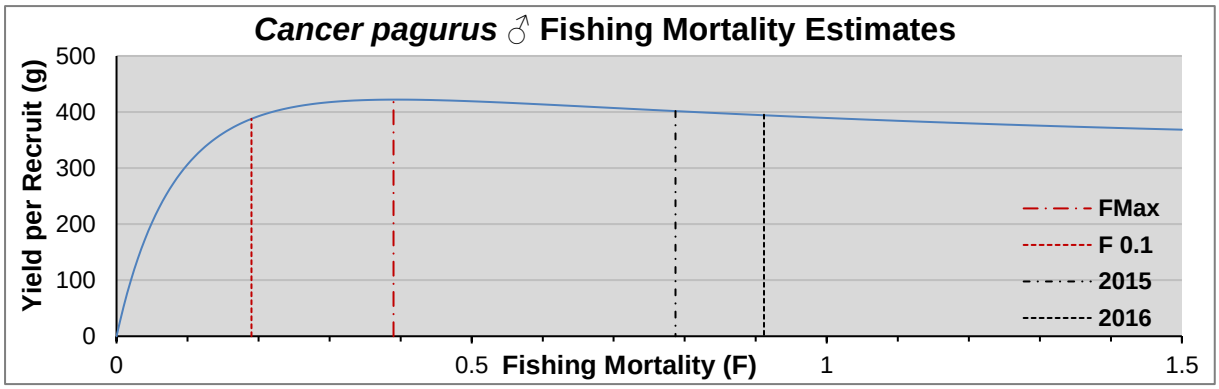

Figure 1919: YPR Curves for *C.pagurus* Males Including Current Estimates of Fishing Mortality (2015 & 2016) and target reference points Fmax and F0.1.

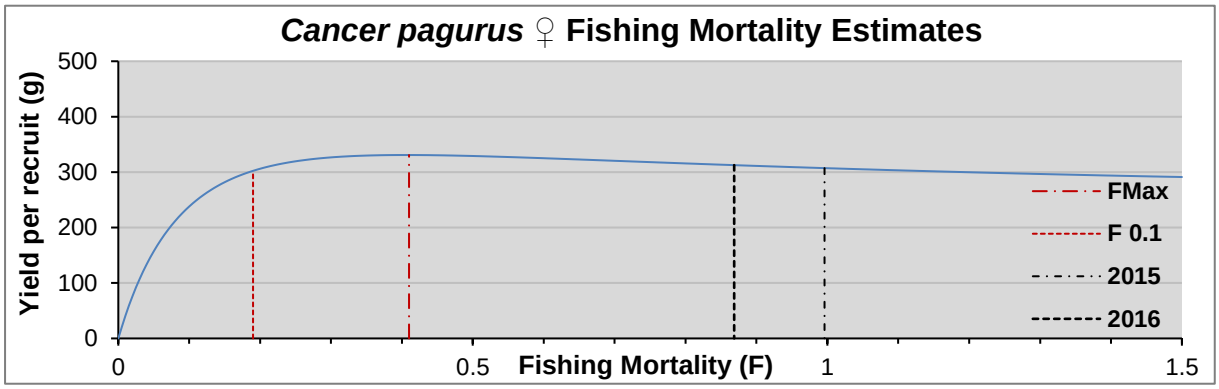

Figure 2021: YPR Curves for *C.pagurus* Females Including Current Estimates of Fishing Mortality (2015 & 2016) and target reference points Fmax and F0.1.

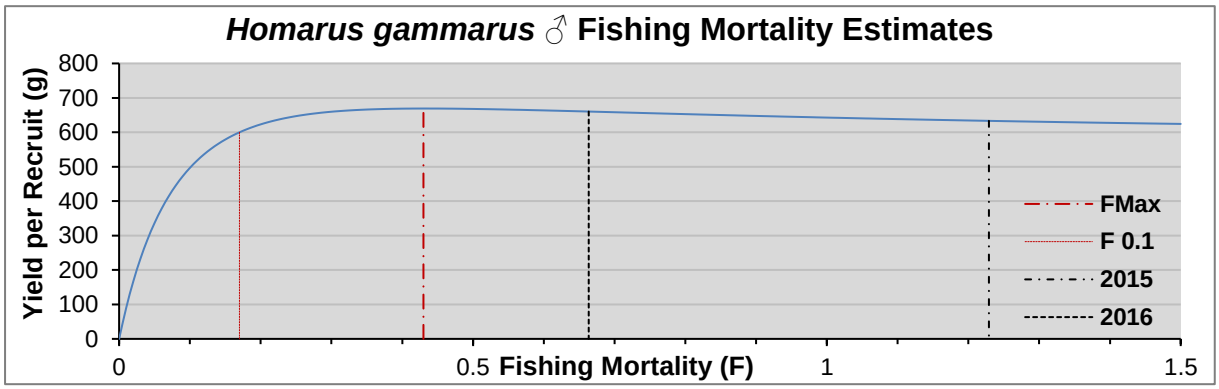

Figure 2120: YPR Curves for *H.gammarus* Males Including Current Estimates of Fishing Mortality (2015 & 2016) and target reference points Fmax and F0.1.

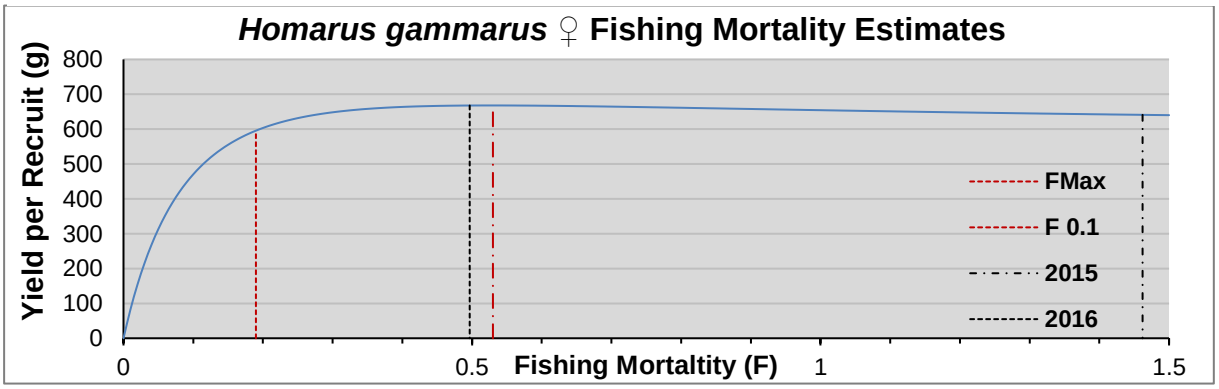

Figure 22: YPR Curves for *H.gammarus* Males Including Current Estimates of Fishing Mortality (2015 & 2016) and target reference points Fmax and F0.1.

Changes to fishing mortality required to meet target reference points are presented below. As would be expected those components of the stock experiencing the highest mortality rate require the greatest change to attain these targets. In all cases changes to exploitation pattern to meet Fmax is expected to result in increased yield per recruit however the inverse is true for F0.1.

Table 10: Estimated Changes in Fishing Mortality (F) Required to Meet Reference Points Fmax and F0.1 and Expected Change to Yield per Recruit.

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	41	6.7	0.19	54	-1.9
CF	0.41	37	5.8	0.19	52	-3.3
HM	0.43	20	1.3	0.19	40	-9.2
HF	0.53	*-3.4	*0.02	0.19	*27	*-10.8

Discussion

Length converted catch curve and yield per recruit analysis allow for evaluation of fishing mortality and its effect on the stock in quantifiable terms, providing a method for monitoring stock dynamics, assessing how a stock responds to exploitation, and estimating the level of change necessary to achieve reference point objectives.

The requirement for sufficient data is important for this method and as such it has only been possible since sampling effort was increased in 2015. Data collection in 2016 followed the approach developed in 2015, with sampling carried out at processors allowing a greater quantity of measurements to be taken during a single sampling occasion and vastly increasing sampling effort.

While this approach has certainly proven beneficial in ensuring that *C. pagurus* is sampled in sufficient numbers to provide confident mortality rate estimate, it has not had the same level of impact on increasing sample effort for *H. gammarus*. This species is more difficult to sample in large numbers as; they are not landed in as great an abundance as *C. pagurus* therefore present fewer opportunities to measure per visit; they are often stored in saltwater tanks, where they are free to roam and mix after return from being measured, making it difficult to determine if an individual has already been sampled or has not and ease of access to tanks is not always feasible.

Sampling effort for *H. gammarus* has been low for both 2015 and 2016. Mortality estimates resulting from sample data has also varied considerably between years for this species, for example mortality estimates for *H.* gammarus females was excessively high in 2015 however; in 2016 it fell below the target reference point Fmax. Inconsistency in mortality estimates is likely an artefact of the low sampling effort that this species is afforded. Low sample effort and inconsistency between years makes it difficult to have confidence in results for this species and as such it would be imprudent to base any management objectives around these estimates as they stand. It would be sensible to increase sample effort for this species and it may be necessary to consider a revised approach to sampling strategies, that ensures opportunities to obtain samples for this species are optimised.

High sample effort and consistency of results between years lends greater confidence to estimates of mortality for *C. pagurus*. Estimates have varied from 2015 increasing for males and decreasing for females however; this variation is minor compared to that seen for *H. gammarus* and likely reflects actual changes in exploitation rate and population dynamics. Estimates of F are reasonably similar for both male and female *C. pagurus* indicating that both sexes are equally susceptible to fishing. Results indicate high rates of exploitation on *C. pagurus* stocks in the district with both males and females experiencing growth overfishing. Based on these results fishing mortality rate would need to be reduced by ~40% to optimise yields and achieve maximum recommended exploitation rates (Fmax), and by ~55% to achieve the maximum protective effect on the stock (F 0.1).

Conclusions

Mortality estimates for *C. pagurus* specify high levels of exploitation for this species and indicate that growth overfishing is occurring. Despite this there does not appear to be any significant impact on recruitment. Annually increasing landings and CPUE in many of the fishing grounds suggests that substantial numbers of juvenile crabs have been recruiting to the fishery in recent years, possibly due to strong spawning events in the past 3-5 years however; the precise cause is still uncertain.

The most notable changes have occurred on the traditional inshore grounds off the North Norfolk coast (34F1) which would be the settlement area for larvae carried on currents from spawning areas further North. If the findings of Addison (2004) are correct, and the observable trend of increasing landings is related to strong recruitment years, then migration patterns should see these aggregations move North/North West against prevailing currents, from inshore areas and into deeper water as they mature.

If this is the case, then offshore areas (35F0 & 35F1) may see increased landings and CPUE in coming years, as animals mature and migrate out of inshore areas. A possible consequence may be declining catches from inshore areas as animals move offshore, unless inshore populations continue to be sustained by larval recruitment.

Estimates of mortality are for *H. gammarus* are unreliable based on the available data however; Cefas stock status reports (2004) indicate that this species is even more heavily overexploited than *C. pagurus* within the district; and that growth overfishing is occurring.

Stability in landings and CPUE suggest that fishing activity is not adversely influencing recruitment to the point that it is reducing contemporary levels of stock biomass however; it may be that fishing activity is supressing the potential for increase in abundance of this species in the district and as such recruitment overfishing may be an issue. Alternatively, or in addition, lack of suitable habitat may be limiting carrying capacity for this species in the district as was suggested in a previous study carried out by Howard (1980).

Given indications that *C. pagurus* and *H. gammarus* are being fished beyond maximum recommended exploitation levels, and that considerable uncertainty exists around the apparent boom in crab landings; it would be advisable to consider precautionary control measures to ensure that further increases in fishing are prevented. As a bare minimum, controls should ensure that levels of effort are not allowed to increase beyond existing levels.

In view of the issues identified in the fishery, and the duties under MACAA and the MSFD the use of technical measures should also be considered. Such measures would seek to further reduce the rate of exploitation and; promote an increase in the proportion of older/ larger individuals in the stock; prevent or reduce incidental mortality on immature pre-recruits; maintain or improve reproductive potential in the stock; promote custodianship from industry and involvement in the decision making and regulating process.

Higher fishing mortality on *H. gammarus* compared to *C. pagurus* leads to the presumption that this species will require stricter measures to ensure sustainability objectives are achieved. This presents an inherent risk when considering management of these species as the fisheries targeting them operate as mixed fisheries; utilising the same gear often in the same general areas to capture both species concurrently. Consequently, any measures implemented for one species will have potential to influence fishing activity for the other. Careful consideration will have to be given to any candidate measures to ensure that their effect is proportionate.

Any management measures should be accompanied by continued monitoring of catch data, both from returns and sampled landings to allow their effectiveness to be assessed.

Recommendations

The Crustacean stock assessment project has reached a point where the establishment of data requirements; development of assessment methods; development of survey strategies and data capture/ analysis toolkits have reached a state of total or near completion. As a result of completed works the following recommendations and knowledge gaps have been recognised:

- Establish a management plan that addresses the issue of high fishing mortality; as a minimum, effort should be capped at contemporary levels.
- Explore potential technical and control measures and assess their potential in achieving management objectives.
- Review and improve biosampling survey strategy to ensure sufficient sampling of *H. gammarus*.
- Maintain and build upon working relationships with other organisations and members of industry to ensure that knowledge up to date and emergent issues are quickly identified.
- Monitor CPUE and landings data from MSARs to establish patterns and that could be used to indicate recruitment and migration patterns.
- Continue with acquisition and analysis of biosampling and MSAR data to maintain a time series dataset, facilitating monitoring and management.

References

The following includes reference materials from previously published reports that although not cited within the text, have been used to reach the conclusions presented above and may be of interest to the reader.

Addison, J.T., Bennett, D.B., (1992). *Assessment of minimum landing sizes of the edible crab, Cancer pagurus L., on the east coast of England*. Fish. Res. **13: 67–88**

Addison, J.L. & Lovewell, S.R.J., (1991) Size composition and pot selectivity in the lobster (Homarus gammarus L.)) and crab (Cancer pagurus L.) fisheries on the east coast of England*. ICES Journal of Marine Science* **48: 79-90**

Bennett, D.B., (1995). *Factors in the life history of the edible crab (Cancer pagurus L.) that influence modelling and management*. ICES Marine Science Symposia. **199: 89-98**

Chapman, C.J., (1994) *Assessment on crab and lobster (Scotland)*, FRS Marine Laboratory.

Eaton, D.R; Brown, J; Addison, J.T.; Milligan, S.P.; Fernand, L.J., (2003) *Edible crab (Cancer pagurus) larvae surveys off the east coast of England: implications for stock structure.* Fisheries Research. **65**: **191-199**

Graham, M., (1949) *A note on the theory of a dwarf race of lobsters on the Norfolk coast.* Journal of the Marine Biological Association **28: 481-487**

Hilborn, R., Walters, C.J., (1992). *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*. Chapman & Hall, New York, **570 pp.**

Howard, A.E., (1980) *Substrate controls on the size composition of lobster (Homarus gammarus) populations.* ICES Journal of Marine Science*.* **39: 30-133**

Howard, A.E., (1982) *The distribution and behaviour of ovigerous edible crabs (Cancer pagurus) and consequent sampling bias*. Journal du Conseil*.* **40: 259-261**

King, M., (2007) *Fisheries biology, assessment and management*. Second edition. Oxford: Blackwell Publishing ltd. **pp:379**

Linnane, A., Mazzoni, D., Mercer, J.P., (2000) *A long-term mesocosm study on the settlement and survival of juvenile European lobster Homarus gammarus L. in four natural substrata*. J. Exp. Mar. Biol. Ecol. **249: 51–64.**

MAFF (1975) *The Norfolk Crab Investigations*. Laboratory leaflet No. 30, Fisheries Laboratory, Lowestoft, Suffolk. **12pp**.

Seafish (2012) Best Practice guidance for fishing industry financial and economic impact assessments. **pp:54**

Seitz, R.D., Wennhage, H., Bergstrom, U., Lipcius, R.N., Ysebaert, T., (2014). *Ecological value of coastal habitats for commercially and ecologically important species.*ICES Journal of Marine Science. **71: 648-665**.

Smith, M.T., Addison, J.L., (2003) *Methods for stock assessment of crustacean fisheries*. Fisheries Research **65: 231–256**

Turner R.A., Hardy M.H., Green J., and Polunin N.V.C., (2009) *Defining the Northumberland Lobster Fishery***.** Report to the Marine and Fisheries Agency, London

UK Sea Fisheries Statistics (2013) Available online at: https://www.gov.uk/government/statistical-data-sets/uk-sea-fisheries-annual-statistics-report-2013

Welby, P.R., (2015) *Crab and Lobster Stock Assessment***.** Eastern Inshore Fisheries and Conservation Authority Annual Research Report**. pp:42**