



Inshore Fisheries and
Conservation Authority

**RESEARCH REPORT
2015**

**Crab and Lobster Stock
Assessment**

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Contents

1. EXECUTIVE SUMMARY	ERROR! BOOKMARK NOT DEFINED.
2. INTRODUCTION	4
3. DATA SOURCES, STUDY AREA AND METHODS	6
3.1. Data sources	6
3.2. Site Information	7
3.2.1. Area of Study	7
3.2.2. Catch and effort, trends and distribution	8
3.3. Methods	9
3.3.1. Port/processor based biosampling	9
3.3.2 Surveys at sea	9
3.3.3. Surplus production models	10
3.3.4. Length converted catch curve and yield per recruit analysis	11
4. RESULTS	12
4.1. ICES Statistical Area Summary Statistics and Surplus Production Models	12
4.1.1. ICES Statistical Rectangle 32F1	12
4.1.2. ICES Statistical Rectangle 33F1	15
4.1.3. ICES Statistical Rectangle 34F0	3
4.1.4. ICES Statistical Rectangle 34F1	21
4.1.5. ICES Statistical Rectangle 35F0	23
4.1.6. ICES Statistical Rectangle 35F1	25
4.2. Commercial Vessel Surveys	28
4.3. Length Converted Catch Curve and Yield per Recruit Analysis	29
5. DISCUSSION	31
5.1. Landings Effort and Spatial Distribution	31
5.2. Population Trends	32
5.3 Fisheries Models	33
6. CONCLUSION	34
6.1. Summary of Recommendations	34
7. ACKNOWLEDGEMENTS	34
8. REFERENCES	35

1. 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 populations of commercially exploited fish species are healthy (descriptor 3) is of paramount importance. IFCAs must have a firm understanding of the fisheries operating within the bounds of their districts. This project was conducted to provide information pertinent to crustacean potting fisheries operating within the bounds of the EIFCA district. Early analysis of data from Monthly Shellfish Activity Returns (MSAR) highlighted North Norfolk as the focal point for potting activity within the district and provided direction for further studies. Trends in effort and landings for the district were found to be stable or displaying an increasing trend and indicated no cause for immediate concern. Modelling using surplus production methods was met with limited success leading to the conclusion that this method should no longer be relied upon as the main form of assessment. Spatial resolution of MSAR data regarding fishing grounds was found to be poor with recommendations to improve this using vessel sightings data. Surveys at sea carried out aboard a commercial vessel indicated an even sex ratio in both *C.pagurus* and *H.gammarus* stocks, with an even distribution of animals above and below current minimum landing size (MLS). Implications are that an increase to MLS of *C.pagurus* in the district previously discounted on the basis of economic impact may now be feasible. Length converted catch curve and yield per recruit analysis indicated that fishing effort in the North Norfolk fishery was above biological reference points (F_{max} & $F_{0.1}$) suggesting that growth overfishing is occurring. Changes to fishing pattern required to meet reference targets were calculated, suggesting that substantial reductions to fishing mortality may be necessary to achieve sustainability in the fishery. Improvements in the way that data is collected and used are proposed with the main recommendations provided below.

Recommendations

- Continue capture of MSAR data to facilitate the assessment of trends in landings effort and spatial distribution of the fishery.
- Consider the potential of vessels sightings data to improve the resolution of effort distribution.
- Quantify the current number of pots being fished by district and area and consider linking to effort distribution derived from sightings.
- Continue capturing biosampling data from vessel landings with a focus on sampling at processors. Consider extending this approach beyond Norfolk where feasible.
- Ensure biosampling strategy is rigorous and carried out regularly so as to capture data throughout the course of the potting season.
- Continue to build capacity within the IFCA in the use of fisheries assessment methods.
- Consider the implications of potential management measures using cost benefit/risk based analysis.

2. Introduction

Potting fisheries operate throughout the EIFCA district from Saltfleet in Lincolnshire down through Norfolk and as far as Felixstowe Ferry at the Authority's southern limits in Suffolk. The majority of this activity however is concentrated along a relatively small stretch of coastline along the North Norfolk coast. This area has a long tradition of fishing for crab and lobster with earliest recorded accounts of the fishery dating back to the early part of the 18th century (MAFF 1966). In 2010 reported landings for *C.pagurus* to ports within the district equated to approx. 612 tonnes with a first sale value of £1.2 million while *H.gammarus* landings were approx. 136 tonnes worth £1.5 million (Appendix fig 31). This equates to around 6% and 10% of landings to English ports by UK vessels respectively (UK Sea Fisheries Statistics 2013) and represents a substantial contribution to both local and national economies. 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; Sheringham for example hosts an annual festival to celebrate the fishery, while Cromer crab is a nationally recognised product.

The majority of vessels active in the fishery fall into the <10m category the major differences being between those that are beach launched and those that operate out of harbours. Traditionally the fishery has operated within 2nm, being more accessible to vessels without the capacity to fish further out. 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 (Turner et al 2009). Despite this a significant number of operators still fish traditional grounds often within sight of the shore.

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 a number of shanks checked on a rotational basis and 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 when 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. 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. Lobster season tends to follow closely behind crab 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). From hatching it takes ~5 years for a lobster to recruit to the fishery and by this time the animal will have moulted several times. Moulting of males and females tends to be staggered, with males shedding earlier in the year than females facilitates mating which generally occurs between a newly moulted female and a hard shelled male. Eggs are afforded some level of protection as they are carried by the female for up to 12 months before hatching into the planktonic. The larval phase lasts 10 -35 days, during which time they go through three stages of development before settling to the benthos. Despite studies very little is known about the natural behaviour of early benthic phase juveniles as and they are rarely observed in the wild (Linnane et al 2001).

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 and similar to *H.gammarus*, moulting is staggered between the sexes to allow for mating between soft shelled females and hard shelled males. As with *H.gammarus* the female will carry the eggs throughout incubation (7-9 Months) releasing the young as larvae into the plankton. Once released the larvae remain in the plankton for around two months before settling into the intertidal benthos (Bennett 1995). During the incubation period it is believed that females cease active feeding and consequently they are only rarely caught in pots (Howard 1982). As a consequence of this seasonal variation in the sex ratio of catch has previously been observed, with females generally more abundant in spring and early summer before males begin to dominate in late summer-autumn as the females commence their moult (Brown & Bennett 1980).

Fisheries targeting *C.pagurus* and *H.gammarus* are currently managed at a national level through MMO licencing and regional level by EIFCA byelaws (Appendix fig 26). No new entitlements are currently being authorised effectively limiting entry into the fishery. International level EU regulations on minimum landing size (MLS) regulate the removal of animals from the fishery. These MLS 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. The area falling within EIFCAs jurisdiction was given derogation to retain the smaller MLS to reflect the smaller individuals typical of the Norfolk population and to mitigate potentially debilitating effect that changing MLS would have on this fishery (Addison & Bennett 1992). In addition to MLS, *H.gammarus* are afforded additional protection under ‘The Lobsters and Crawfish (Prohibition of Fishing and Landing) Order 2000’ prohibiting the fishing for or landing of lobsters bearing a V-notch; or that have been mutilated in such a manner as to obscure a V-notch. V-notching is practice aimed at preserving brood stock and involves cutting a V-shaped notch into the tail of a lobster (usually berried females). This animal is then effectively protected from fishing allowing it to reproduce several times over 2-3 years until the notch grows out. Local fishermen also have a keen

interest in the sustainable management of their fishery; the first statutory regulation for the management of a crab fishery was born out of the desire for Norfolk fishermen to protect the stocks upon which their livelihoods depended (MAFF 1966).

Despite the relative importance of potting fisheries within the EIFCA district this sector has attracted very little attention in terms of assessment or management until fairly recently. With duties under Section 153 of the Marine and Coastal Access Act 2009 (MACAA) and objectives set by the Marine Strategy Framework Directive 2008 (MSFD) to achieve Good Environmental Status (GES) in EU marine waters by 2020 there is increasing pressure to ensure that commercially exploited stocks are managed sustainably. In 2013 a project was initiated with the objective of improving the understanding of potting fisheries within the EIFCA district and the goal of developing the techniques necessary to carry out stock assessments at the 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 progresses that goal by providing preliminary stock assessments using surplus production, length converted catch curve and yield per recruit techniques. Population analysis has also been carried out using field based studies that consider the un-landed component of the commercial catch.

3. Data Sources, Study Area and Methods

3.1. 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 provide the foundation dataset, allowing basic fisheries statistics to be calculated, and modelling using surplus production methods. 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 in which 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.

Port and processor based biosampling

MSAR data provides details regarding landings and effort but offers no information on population dynamics of the stock. As such is only suitable for carrying out simpler approaches to stock assessment. More sophisticated analytical methods require information on age or size frequency of animals collected by sampling commercial catch (Smith & Addison 2003). To provide this data, Inshore Fisheries and Conservation Officers (IFCOs) undertook port based biosampling whilst carrying out enforcement duties. IFCOs sampled a proportion of the catch of randomly selected vessels at the point of landing on an ad hoc basis. Standard size and sex of animals (Appendix fig 27 & 27), 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. In 2015 additional sampling at shellfish processors was started allowing for larger samples to be obtained. Processors store catch by vessel to facilitate payment and record area fished in a similar manner to MSARs, allowing samples to be traced to vessel and grounds fished. Data collected from port based biosampling were used to carry out length converted catch curve and yield per recruit, allowing estimation of fishing mortality and biological reference points. Methods are presented below in section 3.3.4.

Commercial vessel surveys

To further expand on port based biosampling and provide insight into the un-landed component of the catch, additional monthly surveys at sea were carried out between April and August in 2014. Surveys took place on-board *Richard William* a commercial vessel operating out of Cromer, with sampling carried out alongside normal fishing operations. Vessel selection was based primarily on size, as the majority of vessels operating in this area could not provide adequate space for surveys to be carried out safely. Methods for surveys at sea are also presented below.

3.2. Site Information

3.2.1. Area of Study

The EIFCA district stretches from Haile Sand Fort in the north to Felixstowe in the south, encompassing the counties of Lincolnshire, Norfolk and Suffolk and extending out to six nautical miles from their coastlines. This expanse forms the greater area of study for the project, however, a previous study utilising MSAR data (Welby 2014) revealed the vast majority of potting activity occurs along the North Norfolk Coast (Appendix fig 35), as such this area provided the focus for later aspects of the project including data collection for population analysis and size based fisheries modelling.

The EIFCA district falls within ICES statistical area IVc (Southern North Sea). This area is further divided into statistical rectangles arranged in a grid. These have been used to define the boundaries of fishing grounds in the district. This delineation is supported by requirements to report ICES statistical area fished on any given day. Areas falling within the boundaries of EIFCAs authority are shown in Appendix 3 (Figure 31). Effort is unevenly distributed across grounds being concentrated in certain areas. These areas correspond with the position of the major contributing ports, with key production areas being situated off the North Norfolk coast. The importance of areas 34F1, 35F0 and 35F1 situated off the North Norfolk Coast is clear with each contributing >100 tonnes on average to total landings annually.

3.2.2. Catch and effort, trends and distribution

MSAR data was used to describe potting fisheries in the EIFCA district. Table 1 presents a summary of fishery statistics for the district. These are presented graphically in the Appendix (fig 31 & 32).

Table 1: Landings, effort and reported fishing days for pot fisheries operating within the EIFCA district taken from MSARs. Landings are given in tonnes with annual percentage contribution to total of each species given in parenthesis.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean
<i>Cancer pagurus</i>	535 (87%)	510 (87%)	741 (89%)	666 (87%)	613 (82%)	597 (84%)	603 (86%)	587 (89%)	809 (88%)	853 (90%)	652 (87%)
<i>Homarus gammarus</i>	78 (13%)	77 (13%)	91 (11%)	103 (13%)	137 (18%)	110 (16%)	95 (14%)	74 (11%)	104 (12%)	97 (10%)	97 (13%)
Total	614	588	833	769	751	707	698	662	913	950	748
Effort (100 hauls)	11455	7940	7925	9145	8029	9216	9627	7849	8226	8695	8965
Fishing days	6512	5468	5868	5587	5690	6169	11698	15314	14116	11032	8745

C.pagurus accounts for the majority of crustacean landings in the district each year with *H.gammarus* accounting for less than a quarter of total landings. Landings have remained relatively stable since MSAR reporting began in 2006 with only minor fluctuations around the mean. Despite the large disparity in landed weight, *C.pagurus* and *H.gammarus* contribute more equally to the annual mean value of the catch (Table 2).

Table 2: Value of landings of *C.pagurus* and *H.gammarus* by year for EIFCA potting fisheries. Figures are based on estimated average wholesale values of £2/kg for *C.pagurus* and £11/kg for *H.gammarus*. Percentage contribution to total value of each species is given in parenthesis.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Mean
<i>C.pagurus</i> Value (millions)	£1.1 (55%)	£1.0 (55%)	£1.5 (60%)	£1.3 (54%)	£1.2 (45%)	£1.2 (50%)	£1.2 (53%)	£1.1 (59%)	£1.4 (58%)	£1.7 (61%)	£1.2 (54%)
<i>H.gammarus</i> Value (millions)	£0.9 (45%)	£0.9 (45%)	£1.0 (40%)	£1.1 (46%)	£1.5 (55%)	£1.2 (50%)	£1.1 (47%)	£0.8 (41%)	£1.0 (42%)	£1.1 (39%)	£1.0 (46%)
Total Value (millions)	£1.9	£1.9	£2.5	£2.5	£2.7	£2.4	£2.3	£1.9	£2.4	£2.8	£2.2

As with landings, effort (reported as pots hauled) has remained relatively constant. Reported fishing days vary throughout the year increasing from early spring to peak in July before declining again through autumn and into winter (Appendix fig 33) indicating the seasonal nature of the fishery.

3.3. Methods

3.3.1. Port/processor based biosampling

Biometric data describing individuals landed were collected as catch was landed to port, or, in the case of processor samples, animals were held in cold storage and on measured when EIFCOs were available. Once a suitable sample was found details such as date of sampling, Vessel name and PLN (port, letters and numbers), area fished (ICES statistical rectangle), pots hauled, soak time, bait used and species sampled were recorded on the sample sheet (Appendix fig 30). When catch was small all animals were sampled, in instances when catch was larger a subsample was taken. In both cases sample weight (kg) were obtained either through estimation at ports or using a set of scales at processors. When subsamples were taken weight of total vessel catch was also recorded. Individual animals in the sample were sexed and size was recorded to standard measurements, carapace length (CL) for *H.gammarus* and carapace width (CW) for *C.pagurus* as shown in appendix (Figure 27 & 28). Measurements were taken to the nearest millimetre (rounded down) using a set of calibrated Vernier callipers. Once sampling of a vessel was complete the next available vessel was sampled in the same way until all samples had been obtained.

3.3.2 Surveys at sea

Surveys at sea were carried out once per month in 2014 between April and August, on board the fishing vessel *Richard William* during normal commercial operations. As such survey area was dependant on where the vessel operator had set gear prior to trips being organised and so was not standardised. Despite this much of the gear sampled was situated within 2nm of the shore and within sight of Cromer pier. Commercial gear consisted of a mix of traditional wooden framed creels and modern steel framed parlour pots. Much of this gear also contained escape gaps constructed from sections of drainpipe fitted to the one end of the gear (parlour end in parlour pots). Gear was fished in shanks of 25 with approx. 20 meters between each pot. Gear was baited with a variety of baits however; this usually consisted of salmon and plaice frames, with linen wrapped scad used when targeting *H.gammarus*. Surveys were carried out by a single research officer each trip.

During the course of the survey similar details were recorded as used for biosampling including; individual animal's measurements, area fished to ICES statistical rectangle (34F1) survey date, vessel details, soak time and bait used for pots hauled. In addition, shank location was noted by recording a waypoint at the start of hauling using a handheld GPS (data not included here at the request of the vessel operator). On hauling the first shank, the whole catch of the first pot was emptied into a fish box with shank and pot number being recorded. Shank number related to the order shanks were hauled on that trip, with shank one being the first hauled, shank two the second and so on. Pot number was designated in a similar manner with the first pot on a shank hauled being pot number one and the last pot being number twenty-five. All *H.gammarus* were recorded as a priority with sex and size of all animals recorded using the method described for port based biosampling. Any undersize (< 87mm) or soft shelled animals were immediately returned to the sea, with landable animals being passed to the vessel operator. The same process was then repeated for *C.pagurus* until all animals in the fish box had been recorded. The next pot to be hauled was then used to obtain the next sample

noting the new pot number and other sample details on a new record sheet. As normal fishing operations were being carried out, pots were seldom sampled in sequence, with 3-4 pots frequently hauled in the time between refilling of the fish box. As such records obtained for *C.pagurus* were subsamples of each shank, with typically 4-5 pots from a shank of 25 being sampled. *H.gammarus* catch was much lower than *C.pagurus* and as such it was possible to record all animals caught. If *H.gammarus* was caught in a "non-sample" pot it was immediately recorded and noted as catch for that shank. As such all *H.gammarus* were documented during the course of a trip with and recorded by shank while subsamples of *C.pagurus* were documented and recorded by pot. This process was repeated until the vessel operator had completed their days fishing. This typically resulted in 10 shanks hauled for a total of 250 pots.

3.3.3. Surplus production models

Catch and effort data from MSARs was used to carry out surplus production analysis using the Schaefer model which assumes that the stock biomass increases over time in a symmetric S-shaped curve until it reaches maximum carrying capacity (King 2007). Increase in biomass is assumed to be most rapid at a point where the stock is at half of its maximum unexploited biomass and suggests production and therefore yield of that stock would be at its maximum when the stock is reduced to this point. Assuming equilibrium conditions, fishery removals that are equal to half of the stocks maximum biomass would be balanced by growth and reproduction in the stock resulting in MSY (King 2007).

After sorting by year and ICES statistical area catch and effort data was first converted to CPUE by dividing catch (kg) by effort (100 pot hauls) for each year to produce a time series of CPUE (kg/100 pot hauls) for each area. Resulting time series of CPUE were then plotted against effort with parameters for intercept (a) and slope (b) of the resulting linear regression used to parameterise the Schaefer model equation given below (Equation 1). C = catch, f = effort and a and b are parameters from the regression of CPUE against effort.

$$\text{Equation 1. } C=af+bf^2$$

Parabolic curves were then generated by applying the equation to a series of hypothetical fishing efforts, beginning with zero effort and ending at a point elevated beyond contemporary levels that resulted in a zero catch. Following this MSY was estimated using equation 2 and optimum fishing effort (f_{Opt}) using equation 3.

$$\text{Equation 2. } MSY = a^2/4b$$

$$\text{Equation 3. } f_{Opt} = a/2b$$

This process was carried out for *C.pagurus* and *H.gammarus* as well as total catch. Resulting curves were plotted in Excel with contemporary catch and effort data overlaid to allow direct comparison with modelled results.

3.3.4. Length converted catch curve and yield per recruit analysis

In order to carry out catch curve analysis length frequency data collected from port based biosampling was first converted to age frequency using inverse of the Von Bertalanffy Growth Formula (VBGF) (Equation 4) and the growth parameters given in table 3. t = pseudo age at length, L_t = Length at time and t_0 = age at length zero (Chapman 1994).

$$\text{Equation 4. } t = \left(-\frac{1}{K}\right) \ln(1 - L_t/L_\infty) + t_0$$

Log transformed frequencies were then plotted against pseudo age using R statistical software. A regression was line fitted through the descending points on the resulting curve starting from points where animals had fully recruited to the fishery (t_c) and terminating where data reliability was compromised due to small sample size.

Pseudo age at t_r was selected to correspond with CW = 120mm for *C.pagurus* due to landing restrictions imparted by processors. Pseudo age at t_r for *H.gammarus* corresponded with MLS = 87mm CL. The slope of this regression provided estimates of total mortality rate (Z) which was then converted to fishing mortality rate (F) by subtracting natural mortality (M), assumed to be 0.2. Rates were then converted to percentage biomass loss using equation 5 where x is substituted for Z , F or M .

$$\text{Equation 5. } \% \text{ biomass loss} = 1 - \exp(x)$$

To provide an insight into how exploitation rates are affecting stocks, yield per recruit models were constructed. The first step in this process was to convert growth parameters for L_∞ into weights (W_∞) using Equation 6 and size/weight parameters a and b given in table 3.

$$\text{Equation 6. } W = aL^b$$

Yield per recruit curves were then generated using the method described by King (2007), which uses a series of five calculations the sum of which is multiplied by a hypothetical rate of F to provide an estimate of yield per recruit for any given rate. Rates of F used in this analysis ranged between 0 and 1.5. Once plotted rates of F derived from catch curve analysis were added indicating current rates of exploitation. Biological reference points F_{max} and $F_{0.1}$ were calculated from the curves as the highest achievable yield and the point on the curve where slope= 10% of its initial value respectively. Changes in current rates of F necessary to meet these references point were then calculated, with the results converted to percentage changes using equation 5.

Table 3: Parameters used in the construction of length converted catch curves and yield per recruit models. Values obtained from Chapman (2004).

<i>Cancer</i>	Parameters						
	VBGF		Size/Weight			Recruitment	
<i>pagurus</i>	k	L_∞	a	b	W_∞	t_r	t_c
Male	0.191	240	0.000059	3.214	2635	3.33	3.58
Female	0.196	240	0.00032	2.8534	1981	3.33	3.58
<i>Homarus</i>	Parameters						
	VBGF		Size/Weight			Recruitment	
<i>gammarus</i>	k	L_∞	a	b	W_∞	t_r	t_c
Male	0.0913	209.25	0.000126	3.36	7903	5.886	5.886
Female	0.1088	168.71	0.000919	2.922	5585	5.886	5.886

4. Results

4.1. ICES Statistical Area Summary Statistics and Surplus Production Models

This section uses effort and landings data from MSARs to carry out surplus production analysis on ICES Statistical Rectangles focusing on 32F1, 33F1, 34F0, 34F1, 35F0 and 35F1 where possible, as well as providing summary statistics for each area.

4.1.1. ICES Statistical Rectangle 32F1

This area overlaps significantly with Kent & Essex IFCA being located at the southern limits of the EFICA district. It is fished by a relatively small number of ports and vessels from our district which is reflected in effort and landings (Table 1). Lobster generally accounts for a greater proportion of catch in this area than crab however; this difference is not significant, indicating that this area operates as more of a mixed fishery than areas such as those along the North Norfolk coast that are more reliant on a large landings of crab.

Table 1: Statistical Rectangle 32F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	11	189	2.1	0.7	1.4
2007	3	13	223	8.8	2.8	6.0
2008	5	13	165	6.6	2.8	3.8
2009	2	6	96	4.6	1.7	2.9
2010	5	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	2.3	0.7	1.6
2015	2	6	59	1.1	0.5	0.5
Mean	3	10	128	3.5	1.1	2.3

Annual landings display a decreasing trend between 2007 and 2010 before levelling off to ~2 tonnes/year thereafter (fig 1, I). Effort is seen to decline in a similar trend to landings however a gradual increase is observed between 2010 and 2014. A notable drop in landings and effort is observed in 2015 however; this is probably an artefact of returns being received late and is likely to change. A similar artefact was recorded in 2014 with total landings originally recorded as ~1 tonne however; forms received in 2015 later increased this. Lobster is the primary species landed in this area with less dependence on large catches of crab typical of North Norfolk (fig 1, II). The declining trend and plateaux seen in total landings is reflected by similar trends for both lobster and crab. Decreasing landings is therefore not likely to be attributable to a decline in either species specifically but may be indicative of reduced catchability in both.

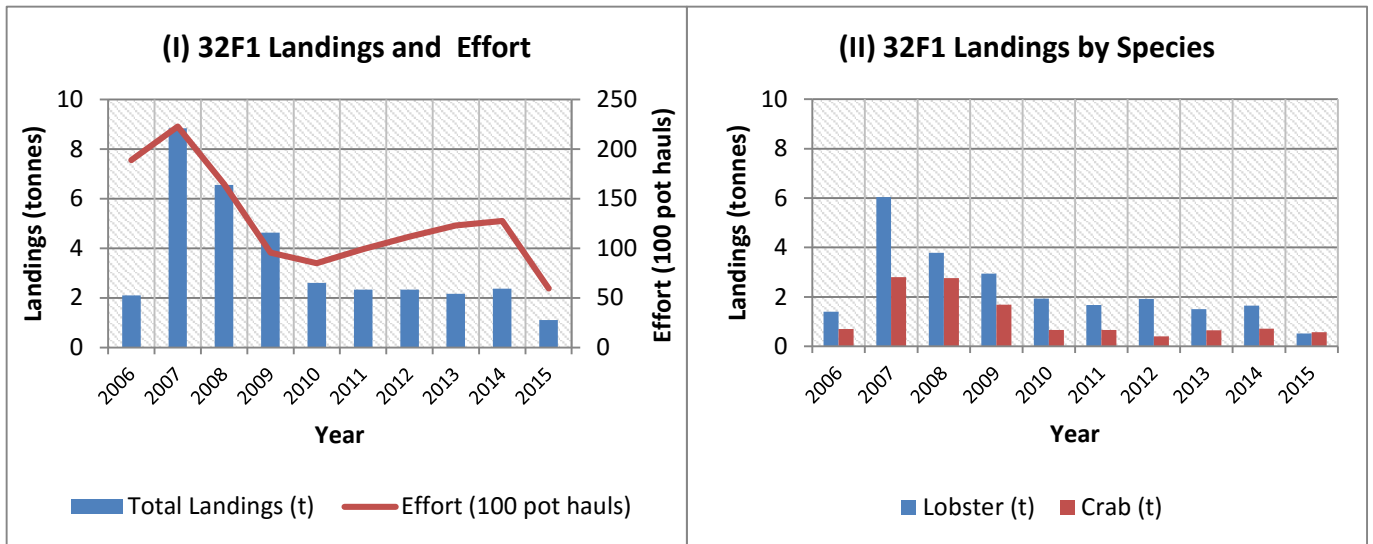


Figure 1: 32F1 annual summary of total landings and effort (I) and landings by species (II).

Effort and landings are loosely correlated in this area (fig 2). This relationship is fairly apparent between 2007-2010 suggesting a causal link between increasing effort and total landings. It should be noted however that increases in effort subsequent to this (2010-2014) do not result in increased landings as would be expected.

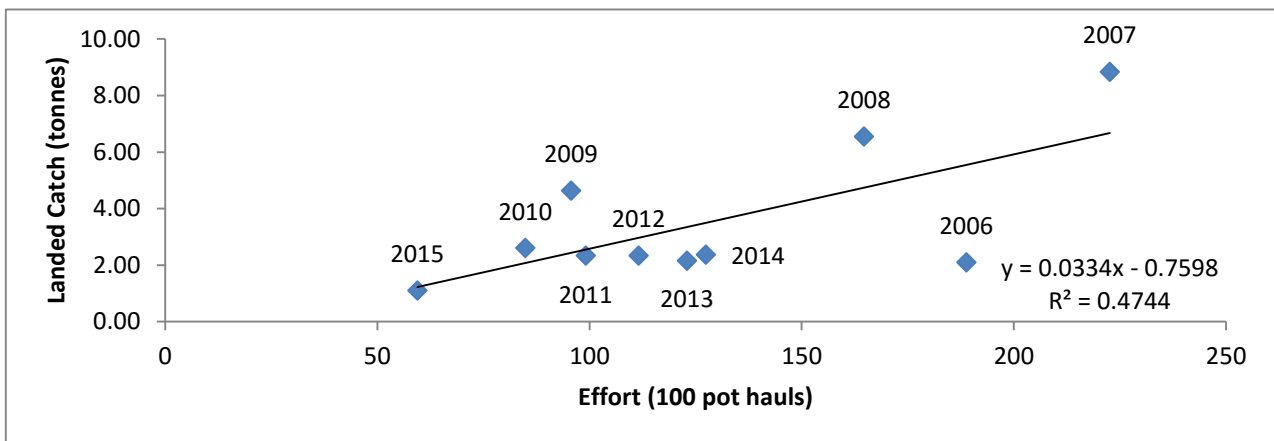


Figure 2: Correlation of landings against effort for ICES statistical area 32F1.

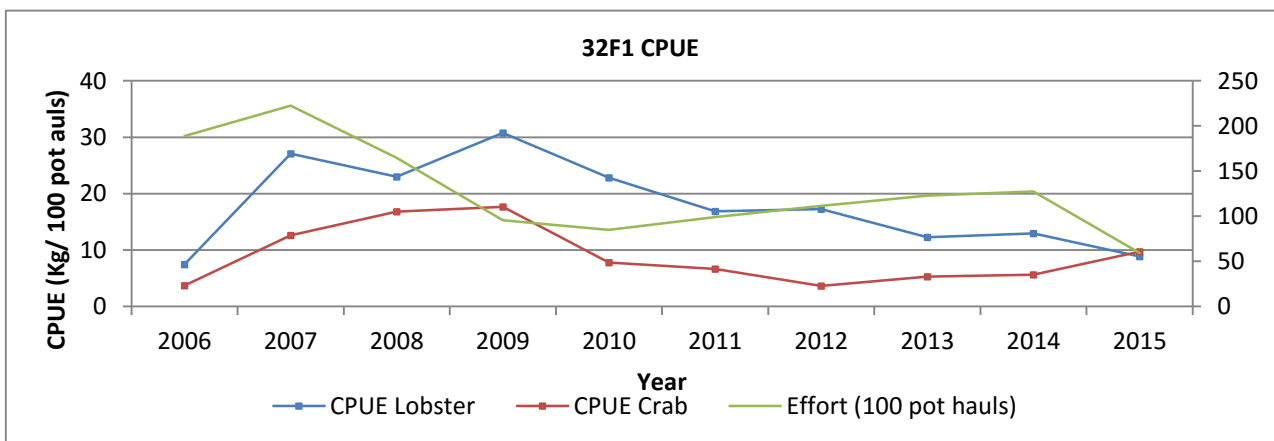


Figure 3: 32F1 Annual CPUE for *H.gammarus* & *C.pagurus* (Effort included on secondary axis for reference).

Surplus Production Model

MSAR data appears to capture two distinct phases in the fishery, a steady decline between 2006-2010 and subsequent stability at ~2 tonnes/year total landings between 2010-2014. Regression of effort against CPUE for model parameterisation was therefore carried out using data points between 2010-2014, this is a change from analysis in previous years which used all data points however; 2010-2014 records present the current status quo in the fishery of reduced but stable returns and should therefore produce estimates more accurate for the current state of the system. 2015 was excluded from the regression as there is reason to believe that data for this year is incomplete.

Surplus production models produced by parameters derived from this regression are presented in figure 3 (below). Resulting estimates of MSY are fairly conservative (2.5 tonnes total, 1.9 tonnes lobster & 0.6 tonnes crab) yet consistent with contemporary landings figures from the area. Data from MSAR records fit the predicted curve well with regard to MSY however the model indicates that increasing effort is not currently resulting in increased yields, a trend also observed in figure 1. In economic terms this suggest that the fishery appears capable of producing similar returns with lower effort and therefore costs. Effort levels similar to those recorded in 2010 when effort was marginally below optimum are approaching the balance point in terms of f_{Opt} and would likely result in the optimum economic gain for fishers exploiting this ground.

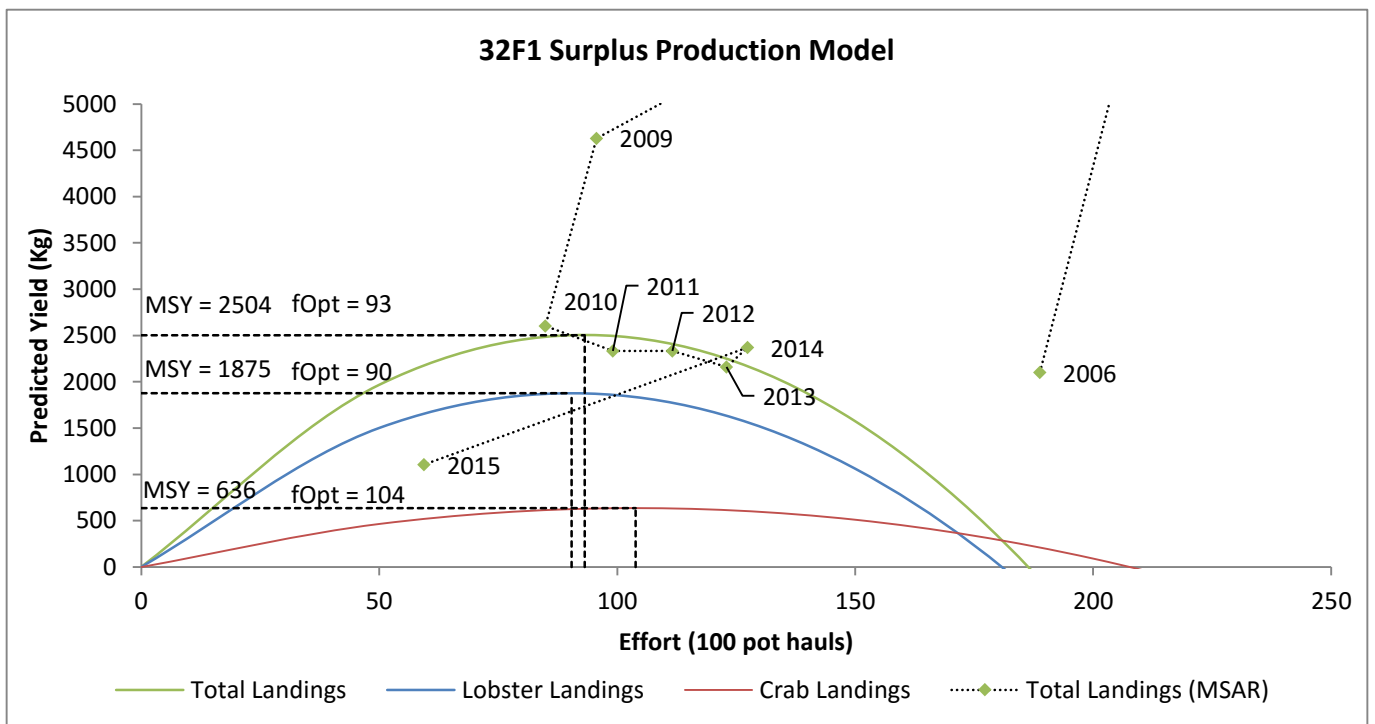


Figure 4: Surplus production model for area 32F1 using parameters from regression of effort/CPUE between 2010 and 2014. Recorded total landings from MSAR included for comparison (2007 & 2008 outside bounds of chart).

4.1.2. ICES Statistical Rectangle 33F1

This area is situated off the Suffolk coast covering an area between the Orford and Lowestoft. Again it is fished by a small number of ports and vessels compared to other areas in the district which is reflected in lower recorded landings and effort than the more productive grounds on the Norfolk coast (table 2). Total landings and landings by species fluctuate annually but are rarely significantly different to estimated means. Reported effort has seen a sharp rise in 2015 with a reported 65100 pot hauls, the highest recorded effort since 2006 (66500 pot hauls) and more than double the reported mean however; this has not been reflected by an increase in landings.

Table 2: Statistical Rectangle 33F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	8	19	665	20.9	11.5	9.4
2007	7	20	364	15.5	9.0	6.5
2008	7	17	215	15.9	11.4	4.4
2009	7	14	170	12.0	8.8	3.2
2010	7	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	215	16.8	11.6	5.2
2015	8	19	651	16.8	12.2	4.5
Mean	7	19	327	16.5	10.6	5.9

Landings have remained fairly stable in this area with only minor inter-annual fluctuations around the mean. Lobster forms a relatively high proportion of the catch in this area however; landings of this species are still significantly lower than in more productive and heavily exploited areas on the Norfolk coast (fig5).

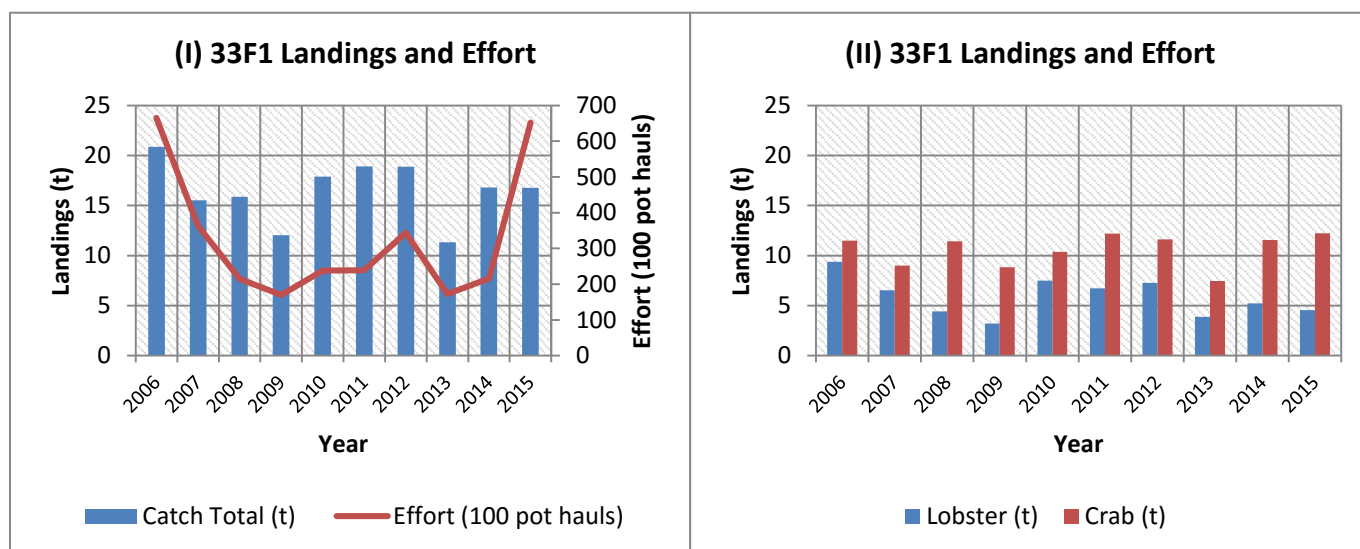


Figure 5: 33F1 annual summary of total landings and effort (I) and landings by species (II).

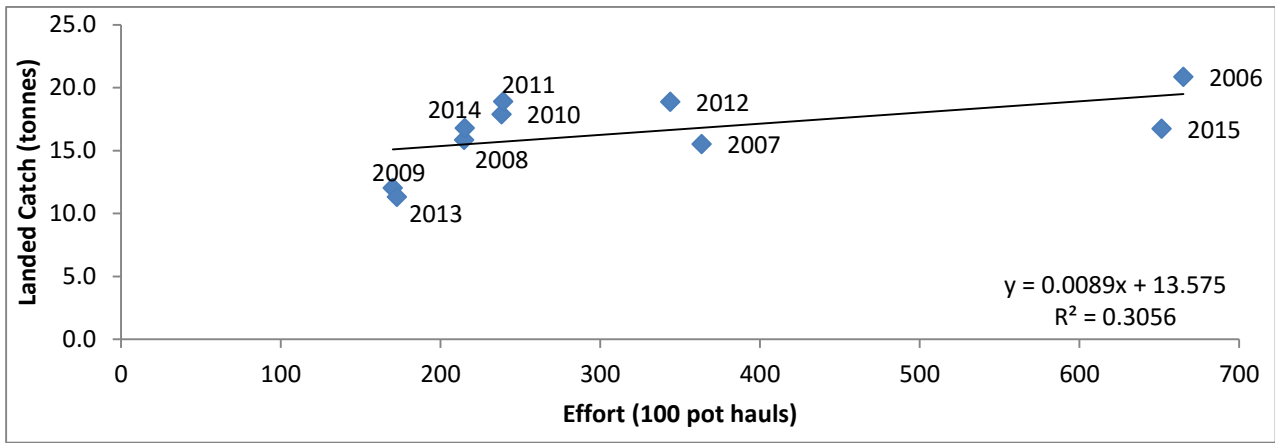


Figure 6: Correlation of landings against effort for ICES statistical area 33F1.

Effort and landings are only weakly correlated in this area (fig 4) with the majority of data points clustered to the left of the chart. Significant changes in effort such as the decrease seen between 2006 - 2007, and increase between 2014 - 2015, have not appreciably affected landings. As such it is apparent that there is no immediate benefit to increasing effort beyond ~250000 pot hauls per year.

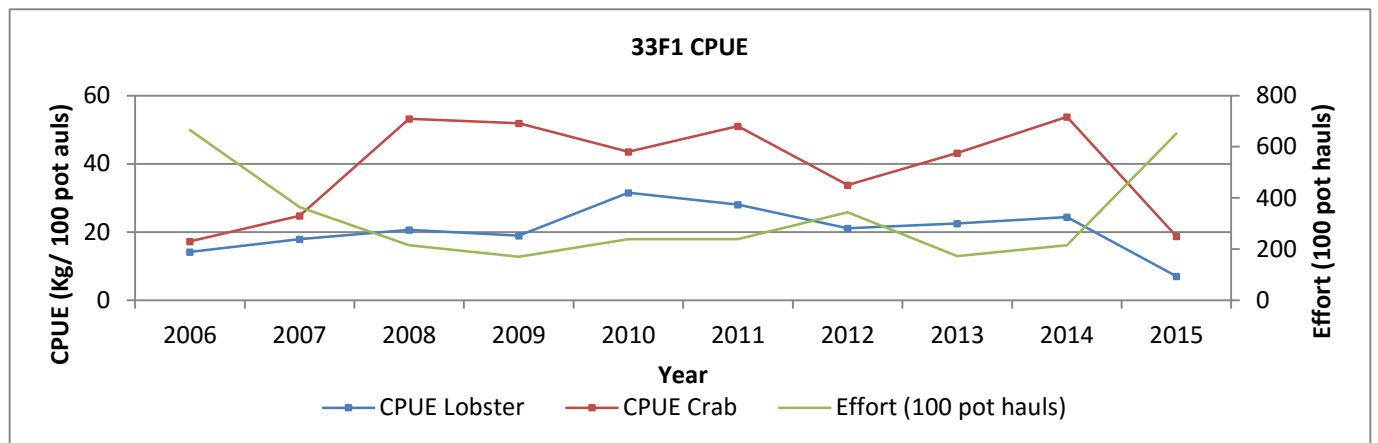


Figure 7: 33F1 Annual CPUE for *H.gammarus* & *C.pagurus* (Effort included on secondary axis for reference).

CPUE for *C.pagurus* appears to fluctuate in relation to effort in this area with increases in effort producing concurrent decreases in CPUE for this species and vice versa. Recent increases in effort have seen CPUE fall to levels similar to those observed in 2006 when effort levels were equally high. CPUE for *H.gammarus* does not appear to be as closely linked to effort levels in this area however; recent increases in effort have also resulted in reduced CPUE for this species.

Surplus Production Model

Regression of Effort against CPUE revealed a negative relationship between effort and CPUE in this area using all data points (2006-2015). Parameters derived from this relationship were used to create the surplus production model presented in figure 6.

Resulting estimates for MSY are somewhat higher than those produced by the ground over the course of the dataset (21.4 tonnes total, 7.8 tonnes lobster & 13.7 tonnes crab). Given these values it would appear the ground is capable of producing higher landings with increased effort however; it is apparent that this has not been the case when effort has been high (2006 & 2015). It appears that this fishery has been operating close to optimum effort (fOpt) in the past but may have reached well beyond this in 2015. MSAR data fits the curve of the model relatively well suggesting that it is relatively accurate in predicting how the ground will respond to changes in fishing activity.

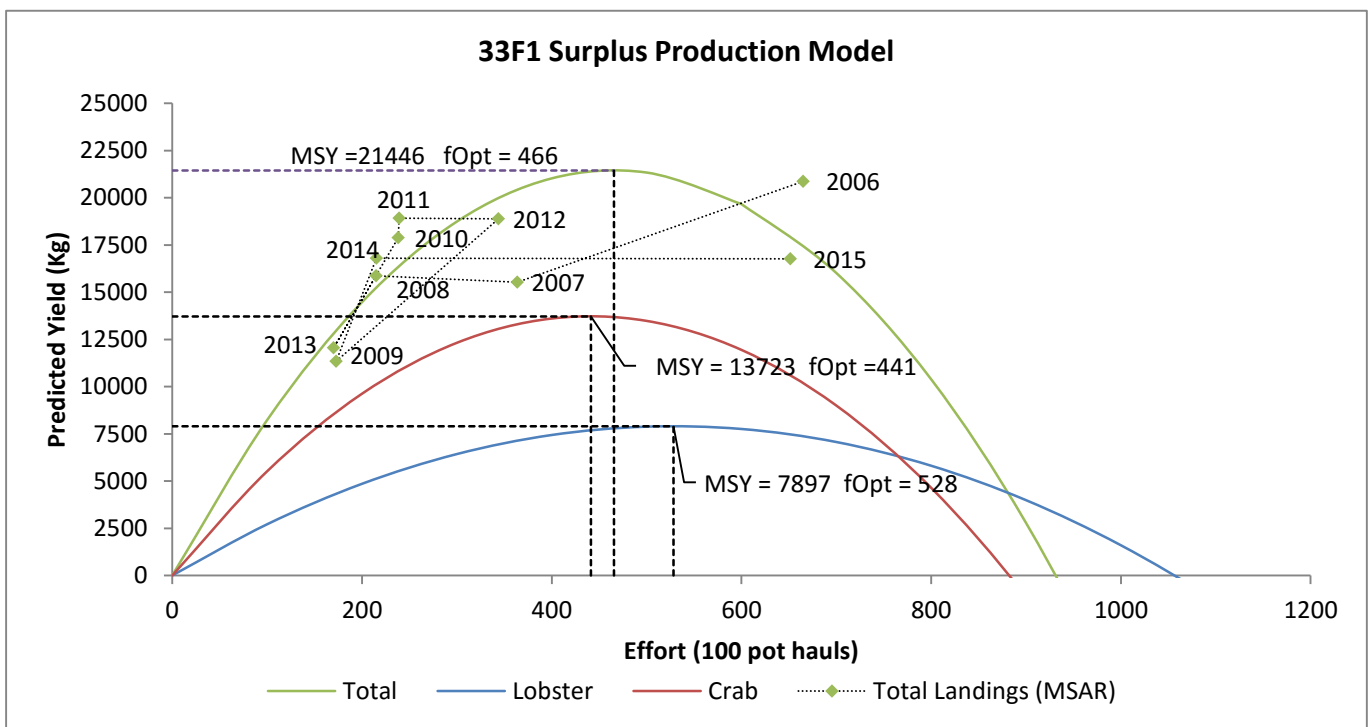


Figure 8: Surplus production model for area 33F1 using parameters from regression of effort/CPUE between 2006 and 2015. Recorded total landings from MSAR included for comparison.

4.1.3. ICES Statistical Rectangle 34F0

This area straddles the border between Norfolk and Lincolnshire and is composed mainly of The Wash and a short section of the North Norfolk coast. It is an area that has only been exploited fairly recently and relatively little effort is currently dedicated to crab and lobster fishing (Table 3). No returns detailing catch or effort were submitted for 2007 and 2008.

Table 3: Statistical Rectangle 34F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	1	1	0.4	0.03	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	1.7	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	3.3	3.0	0.3
2013	5	5	60	6.5	6.14	0.3
2014	3	4	129	11.4	10.64	0.7
2015	2	2	159	25.2	24.11	1.0
Mean	3	3	71	6.74	5.7	1.03

Effort and landings have a strong positive correlation in this area (fig 7) suggesting that the ground is capable of sustaining contemporary levels of effort and may even be able to support more. Returns for 2015 indicate elevated catch for no appreciable increase in effort. This is primarily accounted for by crab landings, which have more than doubled since 2014.

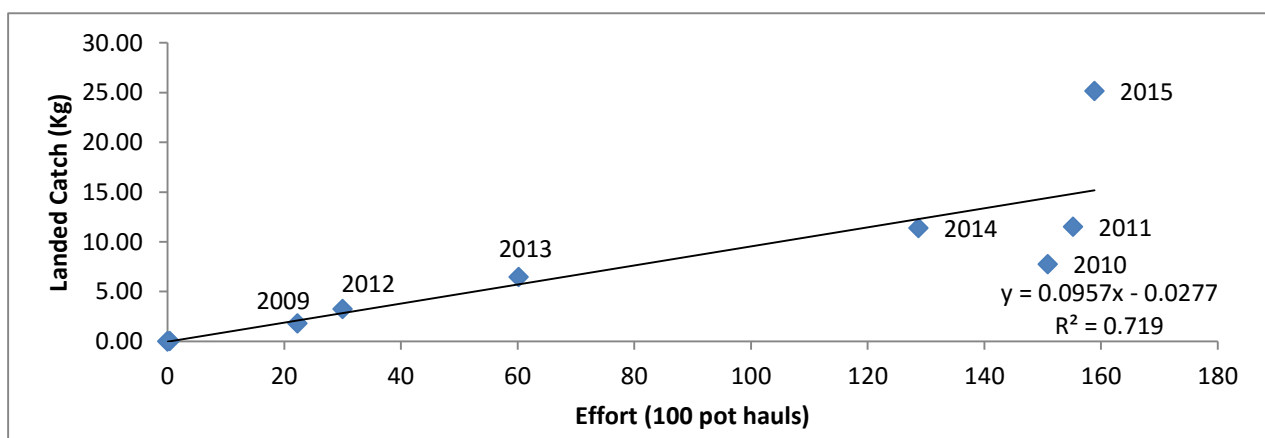


Figure 9: Correlation of landings against effort for ICES statistical area 34F0.

Landings have seen minor fluctuations around the mean (6.5 t) over the course of the dataset with changes to landings associated with changes in effort. Crab has begun to be the predominant species landed in this area in the past four years (2012-2015) with lobster forming a more significant proportion of total landings in the past. It is apparent that high landings of crab are the driver behind increasing total landings on this ground with reported landings for this species in 2015 representing a significant increase over previous years and resulted in a peak in total landings for the area.

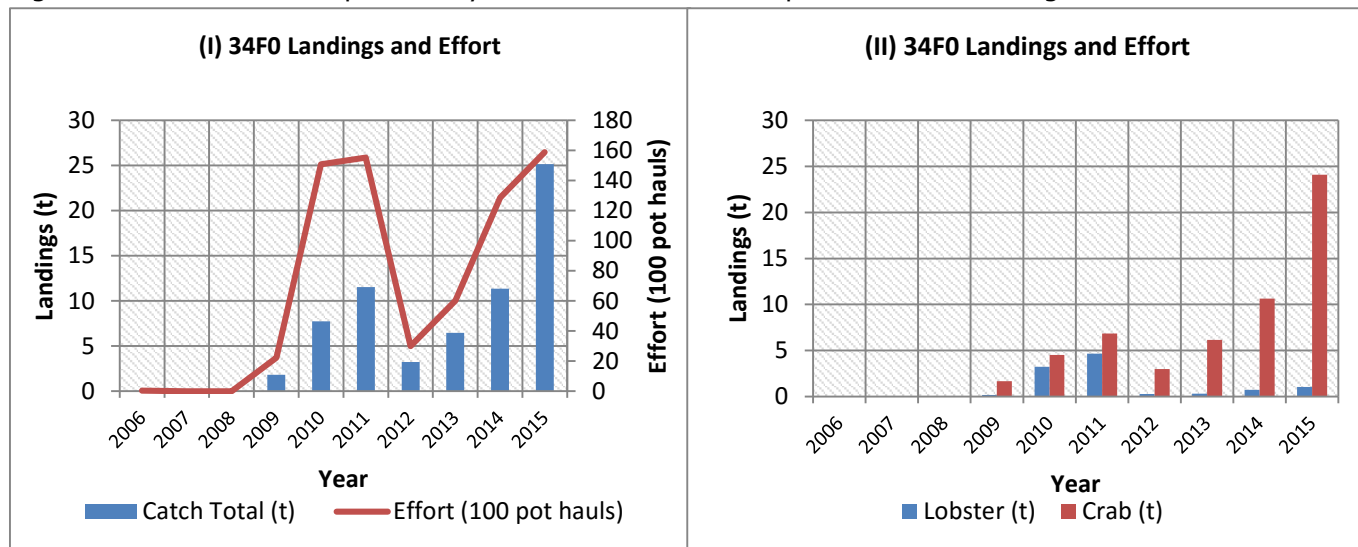


Figure 10: 34F0 annual summary of total landings and effort (I) and landings by species (II).

Catch per unit effort shows an increasing trend over the past five years (2010-2015) to peak at its current level of ~1.6kg/pot (158kg/100 pots) over the course of the year (fig 9). As seen in the landings figures this rise is being driven by increased catchability of crab resulting in higher yields per pot. A similar trend is not observable for lobster, which has seen CPUE drop off since 2011 to current levels of ~6kg/ 100 pots.

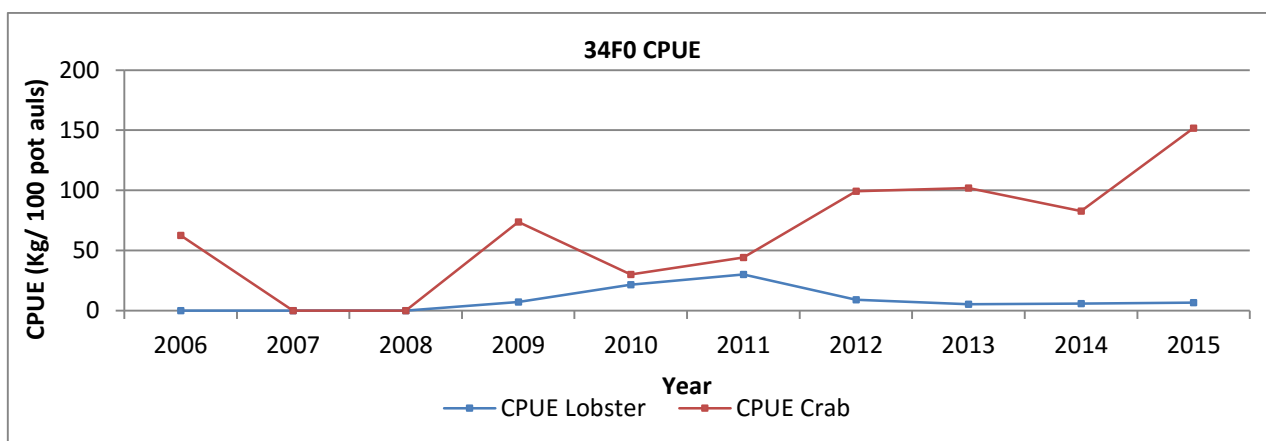


Figure 11: 34F0 Annual CPUE for *H.gammarus* & *C.pagurus*

Surplus Production Model

Regression of effort against CPUE for data between 2009 and 2015 revealed a weak negative correlation for *C.pagurus* however; correlation for *H.gammarus* was positive and only a weak negative correlation existed for total landings ($r^2 = 0.0001$). The resulting model (fig10) is therefore only suitable for predicting the response of *C.pagurus* stocks to fishing effort.

Estimates predict MSY as being close to reported landings of *C.pagurus* for 2015 (predicted MSY = 24036Kg, 2015 *C.pagurus* landings = 25149Kg) however; effort to achieve this is predicted as much higher than was reported for that year.

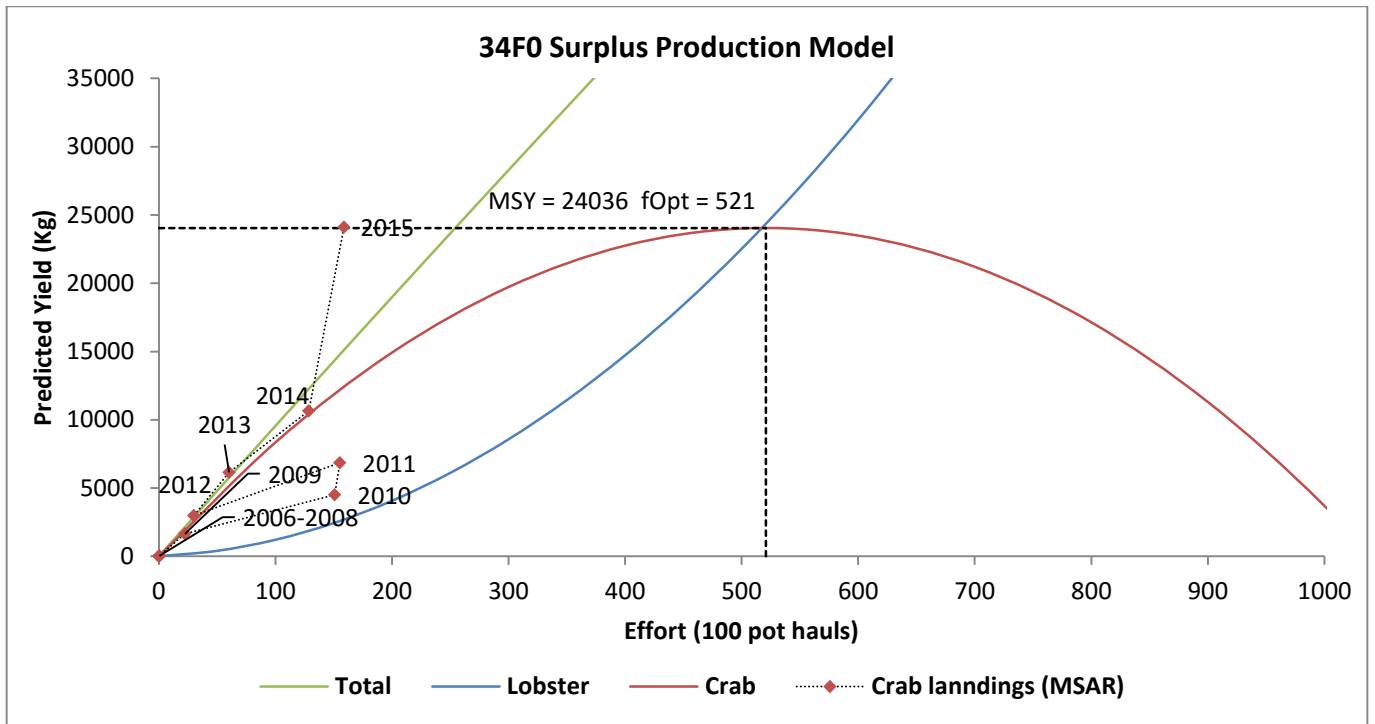


Figure 12: Surplus production model for area 34F0 using parameters from regression of effort/CPUE between 2009 and 2015. Recorded crab landings from MSAR included for comparison.

4.1.4. ICES Statistical Rectangle 34F1

One of the most productive areas for potting in the EIFCA district this is the primary fishing ground for vessels operating out of Cromer. This area is fished by a large number of vessels from ports along the North Norfolk coast, mainly day going vessels launching from beaches that fish close to shore. The high number of vessels fishing this area is reflected in the effort and landings figures which are the second highest in the district. Crab constitutes the main component of catches in this area (Table 4).

Table 4: Statistical Rectangle 34F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	17	49	4123	278.8	246.5	32.3
2007	12	37	3837	183.3	156.0	27.3
2008	13	35	3564	203.7	169.8	33.9
2009	14	37	3339	200.1	170.4	29.7
2010	13	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	3566	270.6	240.8	29.7
2014	12	38	3801	384.3	348.0	36.3
2015	14	44	4099	433.9	391.8	42.1
Mean	13	42	3714	259.5	227.3	32.1

Reported landings have increased steadily on this ground since their lowest point in 2010 to their current peak in 2015. This trend is accompanied by some minor fluctuations in effort but this alone does not appear to be significant enough to be influencing the change in landed catch (fig 11). The main driver for this trend is an increasing catch of *C. pagurus* which have seen an average increase of 49.84 tonnes landed per year since 2010 (+107.2/12.1tonnes max/min increase). Lobster landings have fluctuated around the mean during this time however their influence on total landed catch is negligible compared to crab.

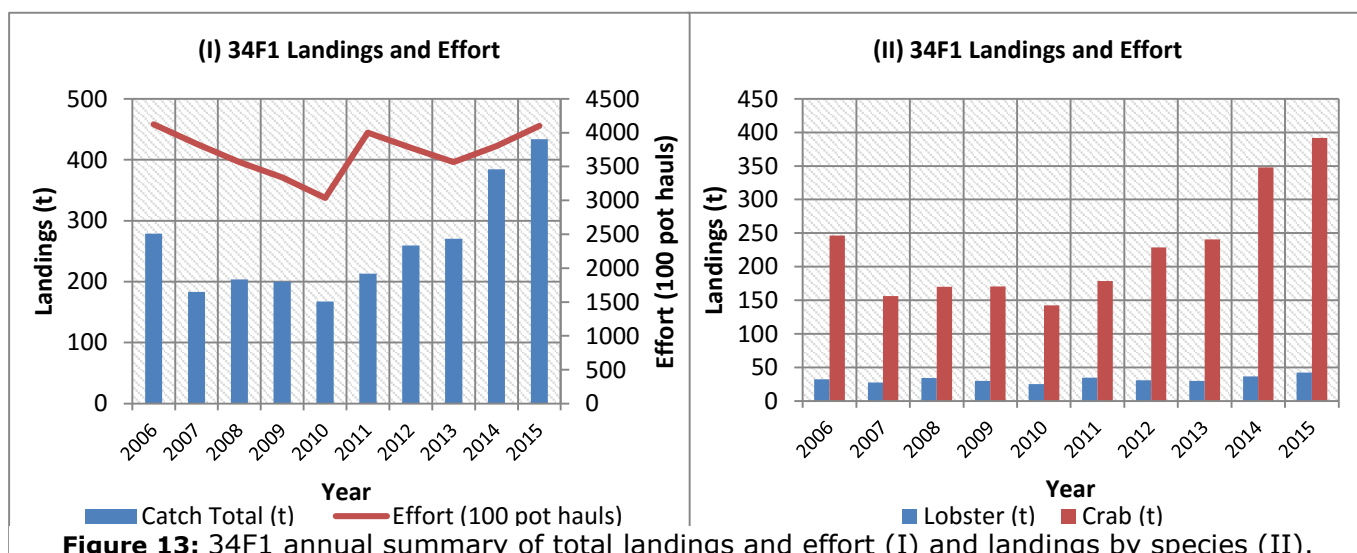


Figure 13: 34F1 annual summary of total landings and effort (I) and landings by species (II).

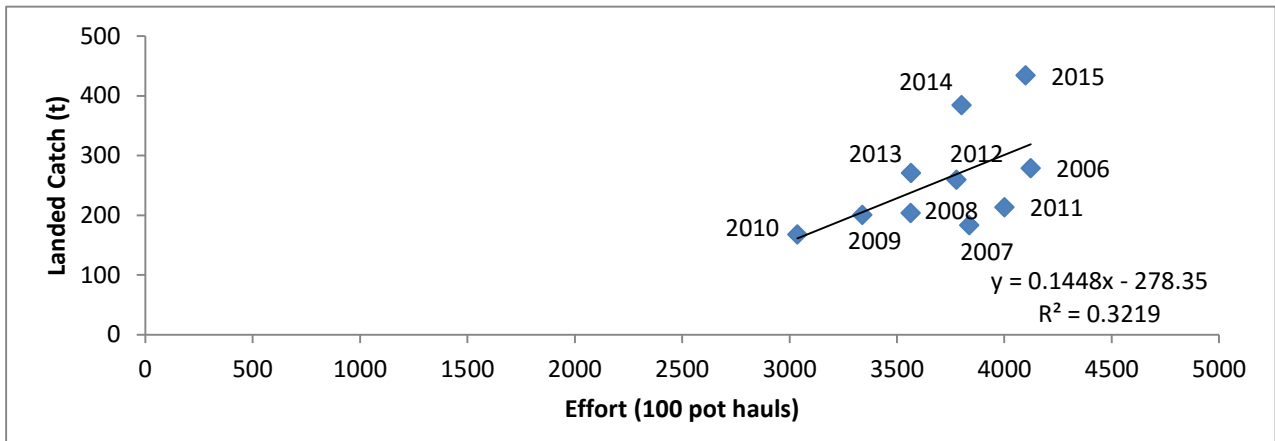


Figure 15: Correlation of landings against effort for ICES statistical area 34F1.

There is evidence of correlation between increasing effort and resulting higher catches in this area however; catch is noted to vary considerably within fairly similar effort levels (fig 12). 2008, 2012 & 2104 as well as 2006 & 2015 have experienced similar levels of effort with differing levels of catch. The apparent trend here is that years prior to 2012 have experienced lower catches while more recent years have seen this increase.

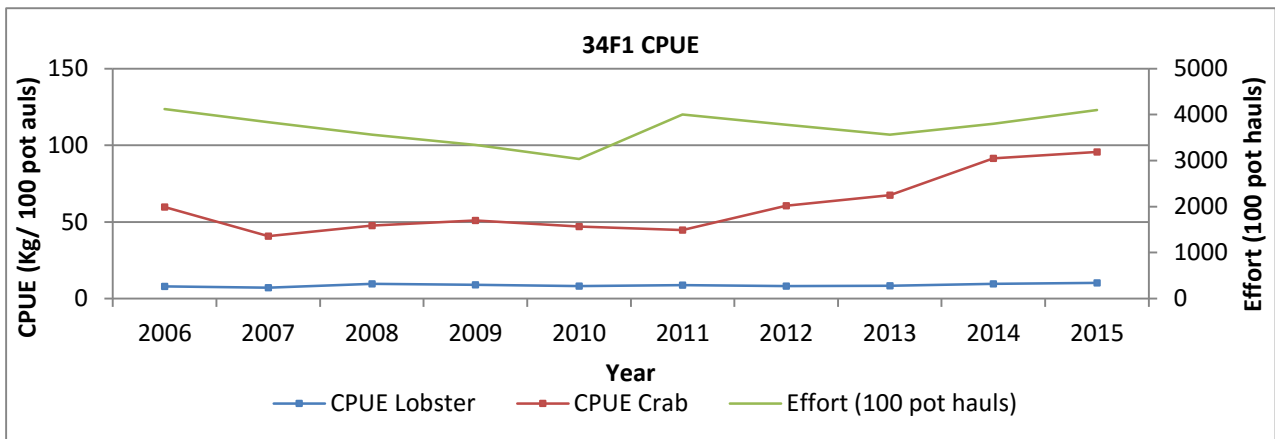


Figure 14: 34F1 Annual CPUE for *H.gammarus* & *C.pagarus* (Effort included on secondary axis for reference).

Between 2006-2013 CPUE for *C.pagarus* had remained relatively stable at ~0.5kg of landable crab per pot however; from 2013 onwards this figure rises to ~1kg of landable crab per pot in 2014/15. This is not associated with any significant changes to effort suggesting that the drivers for this change may be being influenced by factors beyond the influence of the fishery. A similar trend is not observable for lobster which retains a stable CPUE of ~10kg of landable catch per 100 pots.

Surplus Production Model

Regression analysis of CPUE against effort revealed positive relationships for total landings, crab landings and lobster landings in 34F1. This relationship violates one of the assumptions of parameterising Schaefer surplus production models; that CPUE declines with increasing effort. As such the data as it stands is unsuitable for carrying out this type of analysis when used as a complete data set covering 2006-2015. Previous years have carried out analysis based on incomplete records or; by selecting those years when the fishery was experiencing a negative relationship between CPUE and increasing effort. Contemporary data however seems to suggest that in this area catchability of crab is on the increase either for biological/environmental reasons or because of some other driver. As such

it would be unreasonable to base assessments of this ground on past data that does not reliably reflect the current state of populations on the ground.

4.1.5. ICES Statistical Rectangle 35F0

This ground is the most productive for potting fisheries in the district with the highest annual landings despite being fished by a comparatively small number of ports and vessels (Table 9 Appendix 2). This is the main fishing ground for vessels operating out of Wells and is where much of the districts offshore potting occurs. This area is also fished by a limited number of vessels operating out of Lincolnshire as well as vessels from Bridlington under NEIFCA jurisdiction. Only records originating from vessels landing within the boundaries of EIFCA are considered here as data for vessels landing into other districts has not been obtainable.

Table 5: 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	2276	235.4	210.4	25.1
2014	2	11	2022	260.4	237.8	23.6
2015	3	12	2034	356.6	325.0	31.6
Mean	3	14	2252	277.9	249.7	28.3

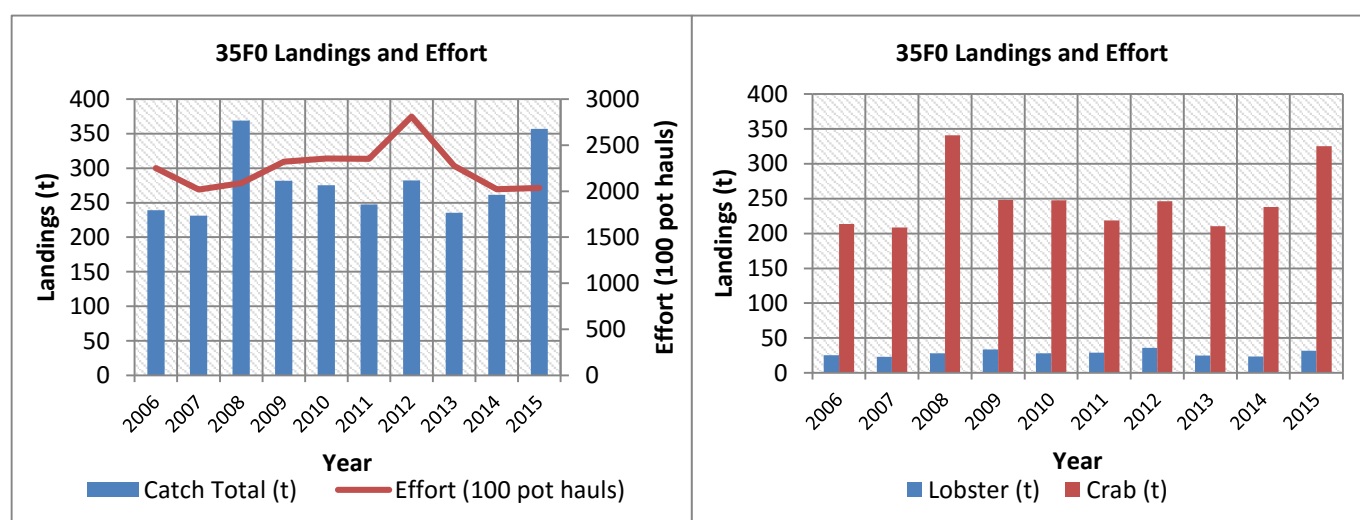


Figure 16: 35F0 annual summary of total landings and effort (I) and landings by species (II).

Reported landings have remained fairly stable in this area for both target species with only minor fluctuations around the mean (fig 16). Peaks in landings have occurred in 2008 & 2015 where ~ 100 tonnes above the mean have been landed. As with 34F1 crab is the major component of landings in this area and drives the fluctuations in total landings. Effort has expressed a declining trend since 2012 however this has been accompanied by an increase in landings since 2013.

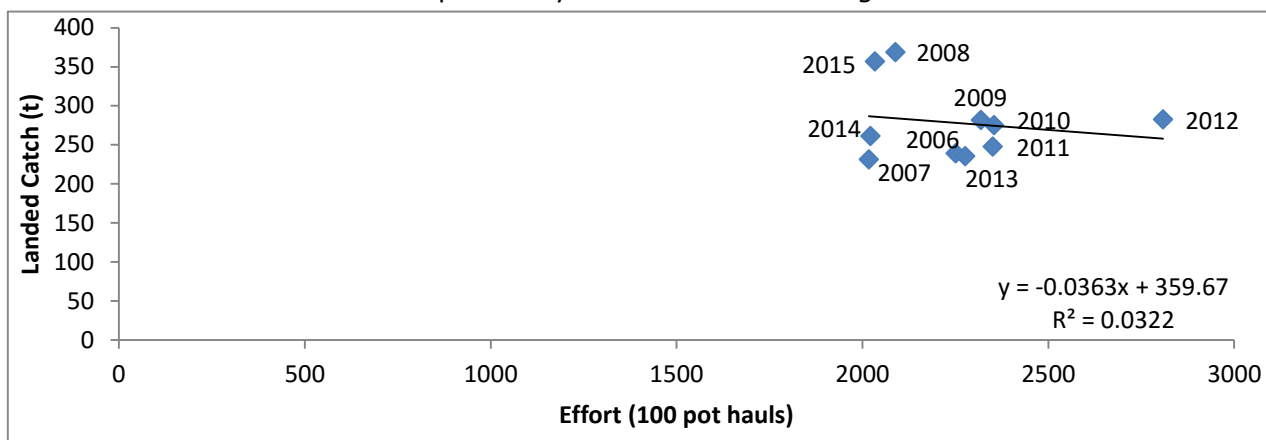


Figure 17: Correlation of landings against effort for ICES statistical area 35F0.

There is no appreciable correlation between landed catch and effort in this area (fig 17) though effort has not varied considerably during the course of the dataset. It is worth noting that both the highest and lowest reported landings are found at similar effort levels and that the reported peaks in landings (2008 & 2015) both occur at the lower end of the spectrum of effort.

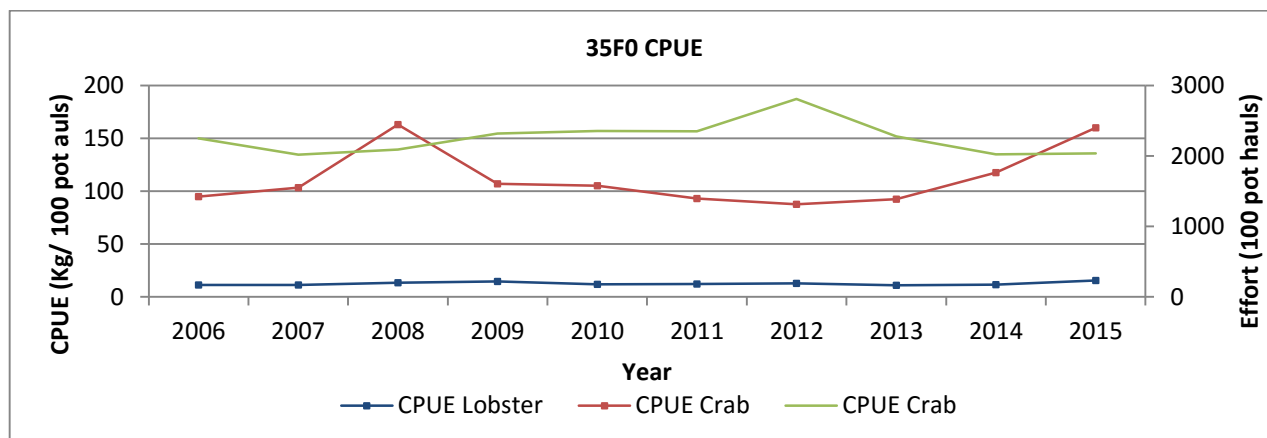


Figure 18: 35F0 Annual CPUE for *H.gammarus* & *C.pagurus* (Effort included on secondary axis for reference).

CPUE for *C.pagurus* in this area annual has typically been stable at ~1Kg of landed catch per pot. Peaks in landings during 2008 & 2015 are accompanied by increases in CPUE for *C.pagurus* to 1.5Kg/pot (fig 18). CPUE for *H.gammarus* have remained relatively stable throughout the course of the dataset peaking this year (2015) at 12.6kg/100 pots.

Surplus Production Model

Regression analysis of 2006-2015 data revealed negative relationships between CPUE and effort for Total landings, crab and lobster however; this relationship was very weak for lobster. Resulting slope and intercept parameters were used to construct the models presented below (fig 19) and provide estimates for MSY and fOpt. The model indicates that the fishery has operated at effort

levels beyond the optimum for *C.pagurus* in the past and coincides for the most part with reduced yields during these years (2012 is an exception. Contemporary records from 2014 & 2015 along with past records from 2007 & 2008 show that the fishery has operated at effort levels close to estimates of f_{Opt} however; 2008 & 2015 have produced yields that exceed those predicted for this amount of effort while 2007 & 2014 have produced less.

Due to the weak negative relationship between CPUE and effort for *H.gammarus* MSY of 123411kg (123 tonnes) is estimated to be reached at 1839700 pot hauls. This figure is exceptionally high and likely a gross overestimation of actual optimum effort.

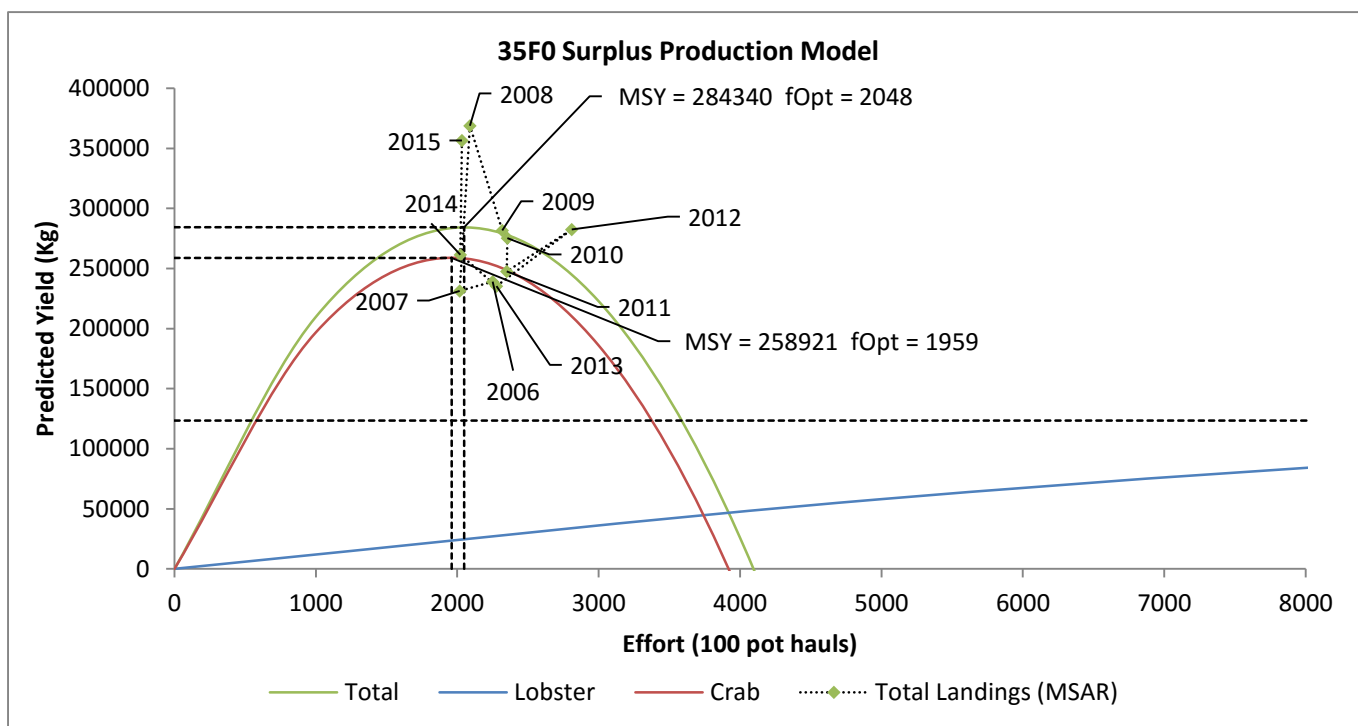


Figure 19: Surplus production model for area 35F0 using parameters from regression of effort/CPUE between 2009 and 2015. Recorded Total landings from MSAR included for comparison.

4.1.6. ICES Statistical Rectangle 35F1

This is the third most productive ground in the district the majority of which falls outside of the 6nm district limits. Despite this it is still considered in this assessment as it is fished by a number of ports and vessels originating from within the EIFCA district (Table 6); and it is probable that the stock associated with this area is part of a larger stock that includes inshore areas.

Table 6: Statistical Rectangle 35F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	7	11	861	64.6	56.3	8.3
2007	7	10	1187	118.6	108.8	9.8
2008	10	17	1575	183.1	168.6	14.5
2009	9	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	556	46.8	42.9	3.9
2014	6	8	1134	91.9	81.6	10.3
2015	5	9	492	58.5	52.3	6.2
Mean	7	13	1291	118.5	106.4	12.1

Landings and effort have varied considerably in this area, building to a peak in 2009 before dropping off gradually over time (fig 20). For the most part changes to landings are associated with a related change in effort (i.e. when effort goes up so do landings and vice versa) suggesting that effort allocation is the main driver behind changes to landings in this area. As with other areas associated with the North Norfolk Coast the main component of catch is *C.pagurus* it is notable however that landings of *H.gammarus* fluctuate in a similar pattern to those of *C.pagurus* increasing along with increasing effort and decreasing when effort is reduced.

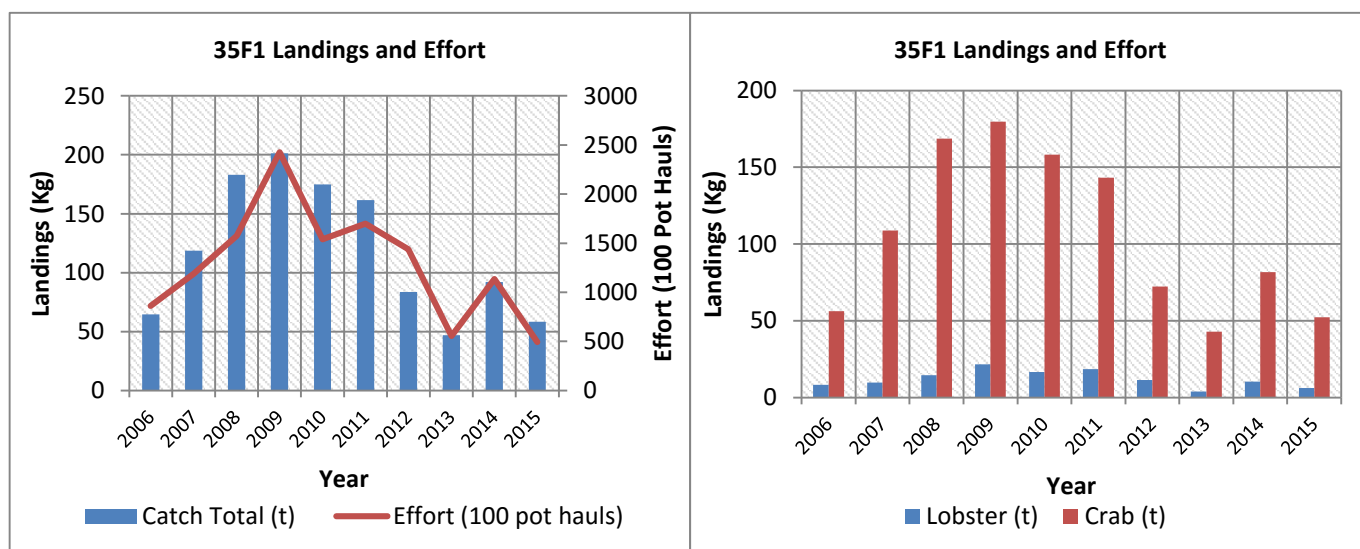


Figure 20: 35F1 annual summary of total landings and effort (I) and landings by species (II).

Correlation of effort and landings display a strong positive relationship in this area (fig 21), with the trend line accurately describing the relationship ($R^2=0.7958$). This goes some way to explaining the relationship between effort and landings observed in figure 20. Going on this information it is apparent that the main driver for changes to landings in the area is effort allocation. While this ground seems capable of supporting levels of effort much higher than those experienced through the course of the dataset effort allocation is relatively low compared to other areas nearby. This is likely due to comparably productive grounds being within easy reach of vessels operating from the North Norfolk Coast that require less effort and expenditure to reach.

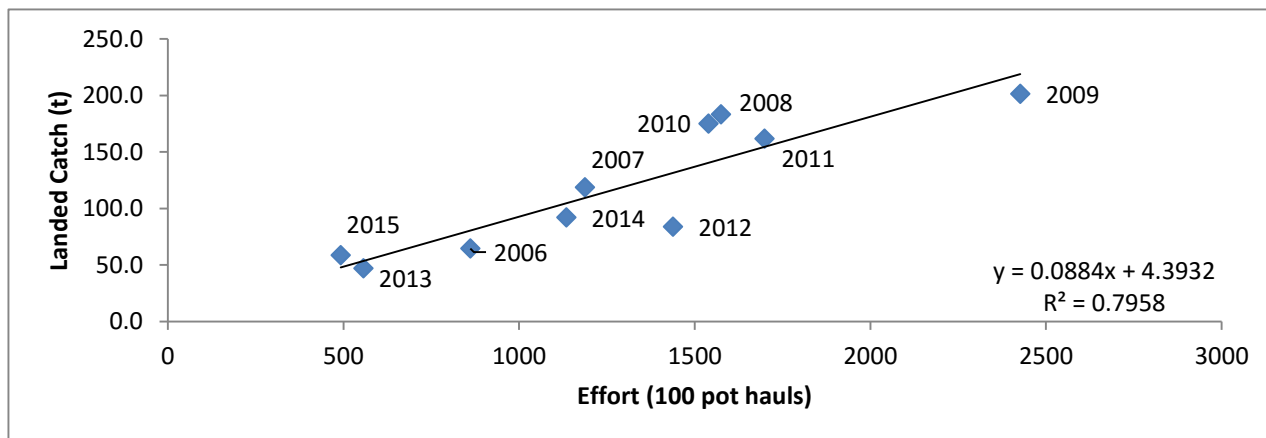


Figure 21: Correlation of landings against effort for ICES statistical area 35F1.

Following the trend observed in other grounds associated with the North Norfolk Coast this area has seen recent increases in CPUE for *C.pagurus* (2012-2013, 2014-2015). Where these increases occur a concurrent decrease in effort is observed. Peaks in CPUE occur at ~1kg of landed crab per pot in 2008, 2010 and 2015 with an average of ~0.8 kg per pot. CPUE for *H.gammarus* has peaked in 2015 at 12.6Kg landed per 100 pots averaging 9.4kg per pot across the dataset.

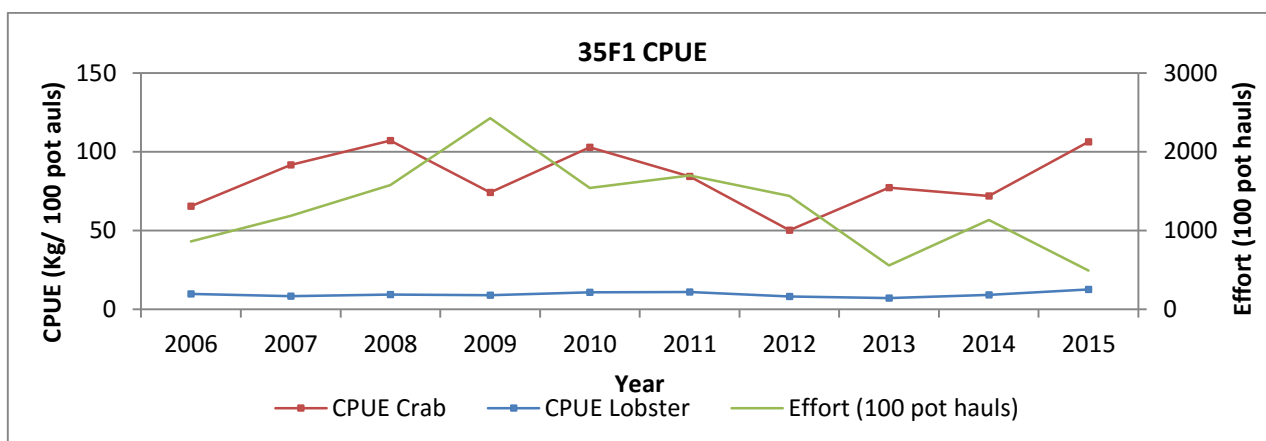


Figure 22: 35F1 Annual CPUE for *H.gammarus* & *C.pagurus* (Effort included on secondary axis for reference).

Surplus Production Model

Regression of CPUE against effort for data points 2006-2015 revealed a weak negative relationship for total catch, crab and lobster in this area. Resulting slope and intercept were used to construct the models presented below (fig 23) and provide estimates for MSY and f_{Opt} . The model suggests that this area is not exploited to a level approaching sustainable limits. As in other cases

where this relationship is weak, MSY and f_{Opt} estimates appear very high. These are likely over estimates, resulting from low rates of exploitation and little influence from fishing on this part of stock.

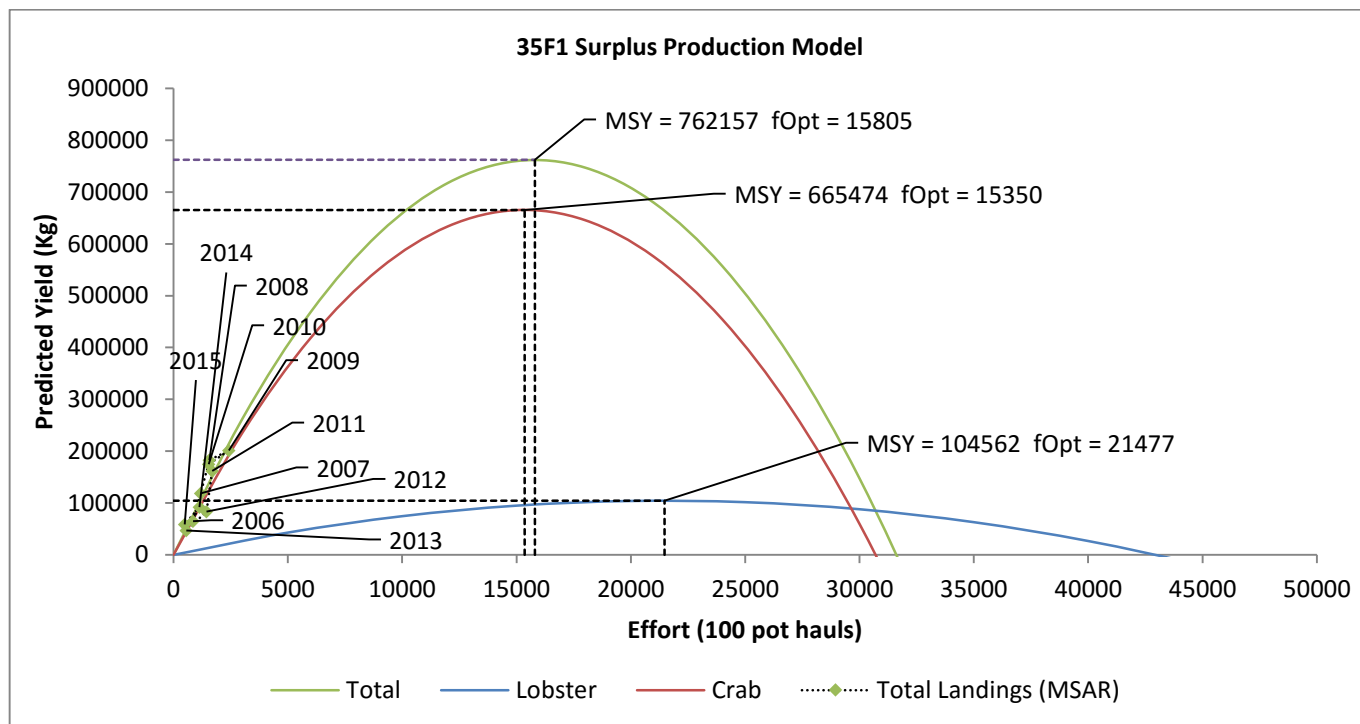


Figure 23: Surplus production model for area 35F1 using parameters from regression of effort/CPUE between 2009 and 2015. Recorded Total landings from MSAR included for comparison.

4.2. Commercial Vessel Surveys

Histograms of size frequency data resulting from surveys carried out during commercial vessel surveys are presented in Appendix 2 (Figure 16) for *C.pagurus* and Appendix 2 (Figure 17) for *H.gammarus*. Catch composition data relating to size selection criteria (MLS) and sex are presented below (Tables 7 & 8).

Table 7: Catch composition of *C.pagurus* sub-samples aggregated by month showing numbers landed < MLS and \geq MLS by sex with percentage contribution shown in parentheses.

	April	May	June	July	Aug	Total
Male < MLS	126 (31%)	63 (27%)	77 (31%)	98 (24%)	116 (33%)	480 (29%)
Male \geq MLS	99 (24%)	78 (33%)	57 (23%)	132 (33%)	80 (23%)	446 (27%)
Total Male	225 (55%)	141 (60%)	134 (54%)	230 (58%)	196 (56%)	926 (56%)
Female < MLS	86 (21%)	37 (16%)	28 (11%)	51 (13%)	50 (14%)	252 (15%)
Female \geq MLS	101 (25%)	56 (24%)	87 (35%)	119 (30%)	103 (30%)	466 (28%)
Total Female	187 (45%)	93 (40%)	115 (46%)	171 (43%)	153 (44%)	719 (44%)

Sex ratios remain relatively constant throughout the dataset for *C.pagurus* with males marginally more dominant in the catch overall. The female component of the catch is consistently dominated by individuals \geq MLS with ratios of \geq MLS : < MLS approaching 2:1 when the data is aggregated. The male component shows more variability with regard to size selection criteria however this is again marginal with ratios of \geq MLS: <MLS consistently close to 1:1. There is little evidence of seasonal selectivity by sex with peak catches for both males and female occurring in April and July.

Table 8: Catch composition of *H.gammarus* samples aggregated by month and in total showing numbers landed < MLS and ≥ MLS by sex with percentage contribution shown in parentheses. Additional data included below is provided on catch of ovigerous females. Percentage data is given as proportion of all females for Total ovigerous and a proportion of all ovigerous females for ovigerous <MLS and ovigerous ≥MLS.

	April	May	June	July	Aug	Total
Male < MLS	19 (23%)	4 (25%)	8 (17%)	35 (32%)	4 (9%)	70 (23%)
Male ≥ MLS	20 (24%)	1 (6%)	12 (26%)	33 (31%)	13 (30%)	79 (27%)
Total Male	39 (47%)	5 (31%)	20 (43%)	68 (63%)	17 (39%)	149 (50%)
Female < MLS	22 (27%)	11 (69%)	22 (47%)	27 (25%)	10 (23%)	92 (31%)
Female ≥ MLS	22 (27%)	0 (0%)	5 (11%)	13 (12%)	17 (39%)	57 (19%)
Total Female	44 (53%)	11 (69%)	27 (57%)	40 (37%)	27 (61%)	149 (50%)
Total Ovigerous	10 (23%)	-	2 (7%)	1 (3%)	2 (7%)	15 (10%)
Ovigerous < MLS	1 (10%)	-	2 (100%)	1 (100%)	1 (50%)	5 (33.3%)
Ovigerous ≥ MLS	9 (90%)	-	-	-	1(50%)	10 (66.6%)

Aggregated data indicates an even split between catches of male and female *H.gammarus* throughout the sampling period. Catch in May & June is dominated by small females (<MLS) while catch in July is composed primarily of males both large and small. Total catch and landable catch of *H. gammarus* (≥MLS) is seen to peak in July as is expected however; an earlier peak in April is also observable. Ovigerous females were most apparent in April, with relatively few being caught in subsequent months. Aggregated data indicates that the two thirds of all ovigerous females caught were ≥ MLS mostly captured in April.

4.3. Length Converted Catch Curve and Yield per Recruit Analysis

Fishing mortality (F) estimates are summarised below (Table 6). These were derived from estimates of total mortality (Z) resulting from length converted catch curve analysis of size frequency data collected from landings into North Norfolk in 2015. Lowest estimate of F was for *C. pagurus* with mortality in females estimated as higher than males. *H. gammarus* was estimated as having high rates of mortality with females again experiencing higher rates than males.

Table 9: Fishing mortality (F) estimates derived from catch curve analysis of 2015 biosampling data for *C. pagurus* male (CM) *C.pagurus* female (CF) *H.gammarus* male (HM) and *H.gammarus* female (HF) with 95% confidence intervals (CI).

Species/sex	Sample Size (n)	Z (Rate)	Z (%)	Z CI (% lower, upper)	F (Rate)	F (%)	F CI (% lower, upper)
CM	1934	0.987	63	57,67	0.787	54	48,60
CF	1555	1.196	70	61,77	0.996	63	52,72
HM	710	1.429	76	70,81	1.229	71	64,77
HF	566	1.662	81	73,86	1.462	77	67,83

The effect of fishing mortality on the stock was estimated via yield per recruit analysis resulting curves are presented below (figs 25 – 27) along with estimates of target reference points Fmax and F0.1.

In all cases current rates of fishing mortality were found to exceed maximum recommended exploitation rates (Fmax) and to be well beyond those predicted to provide the maximum protective effect on the stock (F0.1).

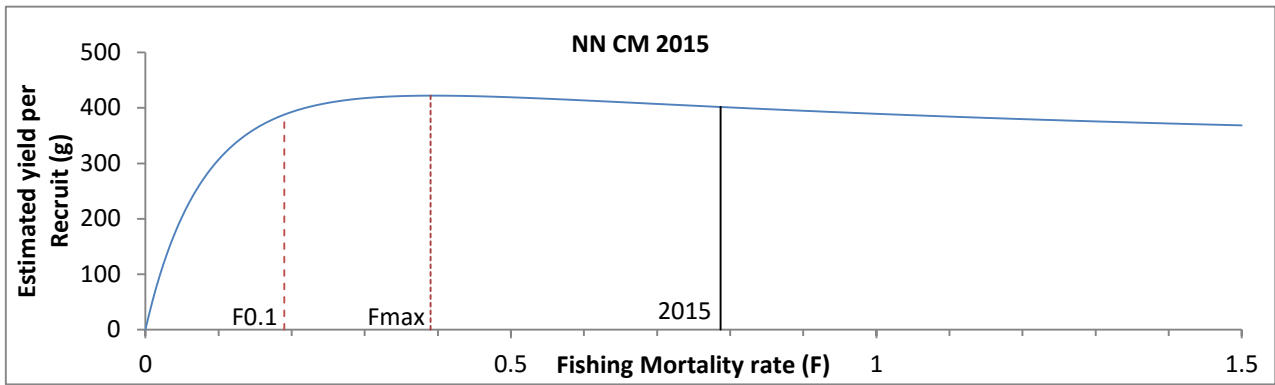


Figure 27: YPR curves for *C. pagurus* males including current estimates of fishing mortality (2015) and target reference points F_{max} and $F_{0.1}$.

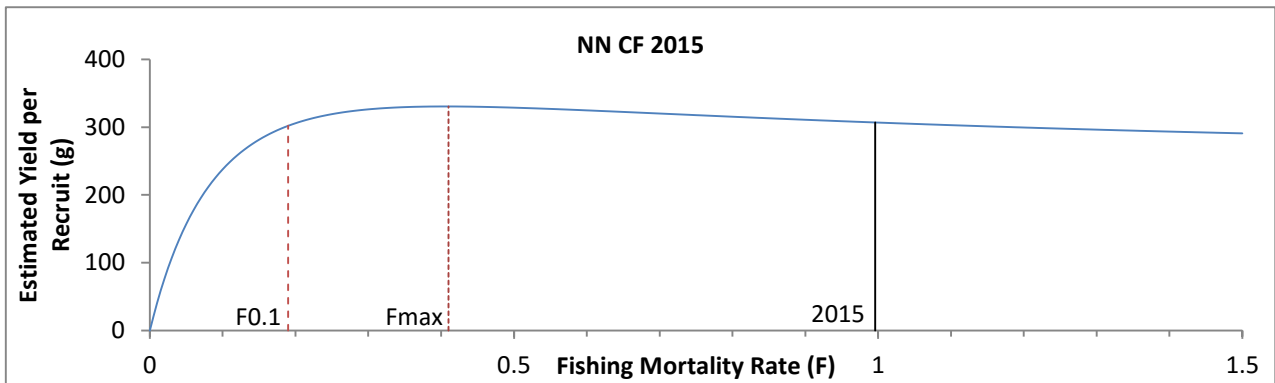


Figure 26: YPR curves for *C. pagurus* females including current estimates of fishing mortality (2015) and target reference points F_{max} and $F_{0.1}$.

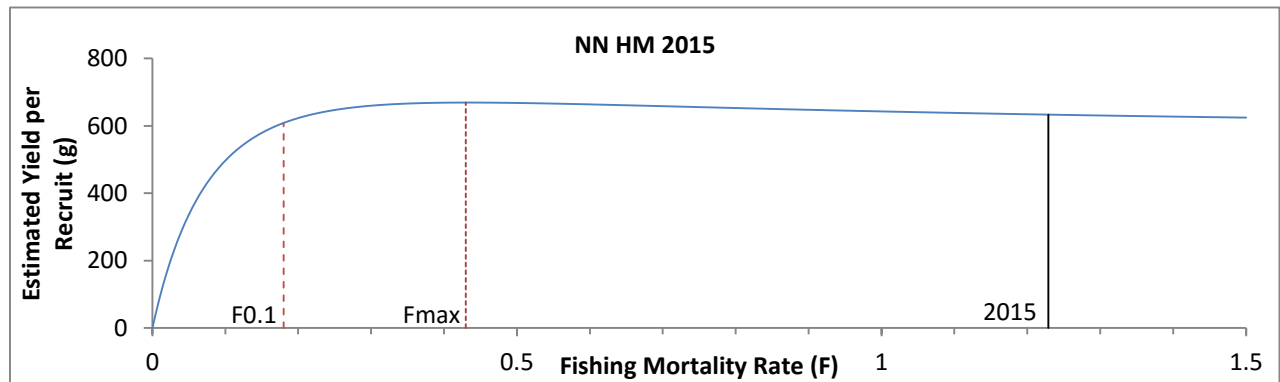


Figure 25: YPR curves for *H. gammarus* males including current estimates of fishing mortality (2015) and target reference points F_{max} and $F_{0.1}$.

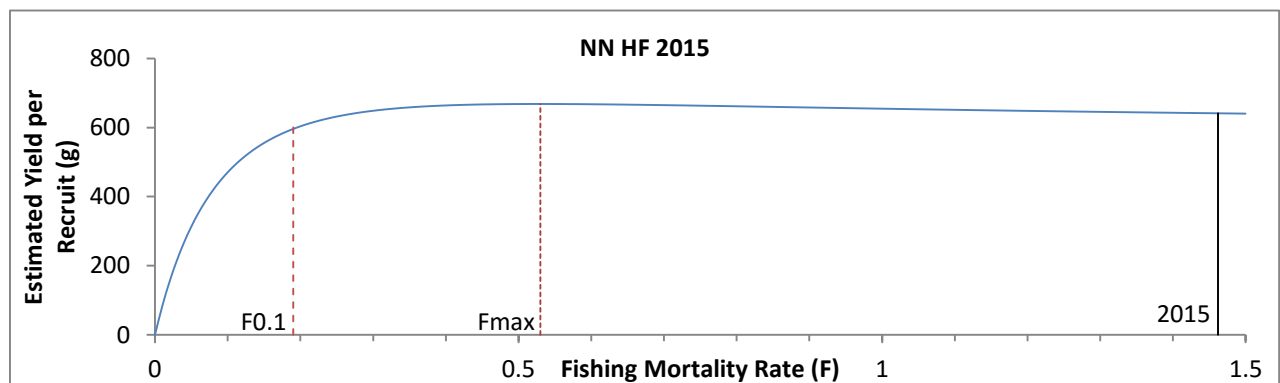


Figure 24: YPR curves for *H. gammarus* females including current estimates of fishing mortality (2015) and target reference points F_{max} and $F_{0.1}$.

Based on current estimates, changes to fishing mortality required to meet target reference points were determined, these are presented below (Table 7). As would be expected those components of the stock estimated to be experiencing the highest mortality rate require the greatest change in exploitation rate 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 7. Estimated changes in fishing effort (F) required to meet reference points Fmax and F0.1 and resulting change to yield per recruit.

Year	Species/Sex	Fmax Rate	% Reduction in F Required	%Yield per Recruit Change	F0.1 Rate	% Reduction in F Required	%Yield per Recruit Change
2015	CM	0.39	-33.4	+5.1	0.19	-46.8	-3.44
	CF	0.41	-47.4	+7.7	0.19	-59.1	-1.6
	HM	0.43	-58.7	+5.7	0.18	-71.7	-3.89
	HF	0.53	-71.0	+4.2	0.19	-82.0	-6.34

5. Discussion

5.1. Landings Effort and Spatial Distribution

Trends in aggregated annual landings and effort for the district have remained relatively stable through 2006 – 2015. Only minor inter-annual fluctuations are apparent, typical of many fisheries however; there does appear to be an increasing trend in landings of *C.pagurus*. The prevalence of *C.pagurus* in the landings and relative paucity of *H.gammarus* is clear and is likely a consequence of species habitat preference and the corresponding scarcity of hard habitat typically associated with *H.gammarus* (Howard 1980, Linnane et al 2000 & 2001), rather than a direct response to fishing pressure. This being said it is apparent from mortality modelling that *H.gammarus* stocks within the district may be experiencing high rates of exploitation relative to the size of the local population. It is however unclear whether this is attributable to fishing, or that the grounds assessed here lack the refugia necessary to support larger animals and as such they are migrating out of the area to find suitable habitat elsewhere.

Reported landings from the main fishing grounds in North Norfolk (34F1, 35F0 & 35F1) suggest a general trend of increasing returns in these areas over the most recent years. Only area 35F1 differs from this with recent landings falling below the average for the area however; this is accompanied by a significant reduction in effort in the area. In all three of these areas LPUE for *C.pagurus* has seen a steady increase over recent years most significantly in 34F1. It is unclear what is driving this change in the fishery, whether biological or economic. Pot fishers are currently reporting that the abundance of crab on the ground in recent years has improved, with pots being hauled full of good-sized landable crab. Such reports would suggest that the area has seen a high influx of juveniles in recent years which are now recruiting to the fishery. The closure of the Cromer Crab factory (2012) has been suggested as having impacted landings in the fishery however; this event is not detectable in the data. The establishment of a new processing facility in 2013 (Jonas Seafoods) and the development and expansion of its trade may go some way to explaining recent increases in landings. As the facilities markets have expanded and developed so too would the demand for locally caught shellfish.

MSAR data has proven useful in the broad-scale definition of spatial patterns of fishing activity. At the port and vessel level it has helped identify where the majority of activity is taking place and clearly indicates that the North Norfolk coast is the focus for this type of fishing activity in the EIFCA district. It is less useful in determining the origin of landings in respect to fishing grounds due to the low resolution to which this information is reported. ICES statistical rectangles cover a relatively large area (1800nm²) and often straddle the 6nm limit. As such it is difficult to accurately gauge where effort is being focused at sea. Although a method of subdividing is available (Appendix 1 Figure 6) this scale is only rarely used in reporting and even still the areas are relatively large at 200nm². It would be useful to encourage reporting to this level from fishermen however; mapping fishing activity from patrol vessel sightings using the method employed to define potting fisheries in Northumberland (Turner et al 2009) may be more useful.

Reporting of effort as pots hauled is also of limited utility. While it provides the information necessary to derive LPUE from landings figures, it gives no real indication of the amount of gear being fished. It would be appropriate to support this data by quantifying the number of pots being fished by vessel. Such information would be infinitely more useful in informing management decisions, particularly if it becomes necessary to apply effort limitation.

5.2. Population Trends

Surveys carried out aboard a commercial fishing vessel in 2014 successfully provided information on the size structure and sex ratios of populations of *C.pagurus* and *H.gammarus* in inshore grounds close to Cromer. However, the method of the surveys and the nature of the gear used to obtain samples limit the reliability of the data obtained. Fleets hauled were being fished commercially and as such did not conform to any standard design (they comprised a mix of traditional wooden pots and modern steel framed parlour pots), and many of the pots contained escape gaps which would skew selectivity in favour of larger animals. In addition, the vessels operator has many years of experience of the grounds surveyed, and is able to target those areas known to provide a high proportion of landable catch at any given time of the year.

Previous surveys carried out in North Norfolk have suggested that catches of *C.pagurus* and *H.gammarus* in the area are largely dominated by individuals <MLS (Addison & Lovewell 1991). However, the 2014 surveys contradict this. Catches of both *C.pagurus* and *H.gammarus* were composed of more or less equal numbers of animals <MLS and ≥ MLS. The predominance of smaller individuals was used as an argument against changing MLS in *C.pagurus* by Addison and Bennett (1992) who determined that any appreciable increase in MLS would likely have a disproportionate impact on the economic viability of the fishery. Presently pot fishers in the area are in favour of an increase in MLS. Despite the prescribed limitations of the data, the results of these surveys suggest that such a change may be viable. To provide more robust information on populations of *C.pagurus* and *H.gammarus* with lower potential for bias bespoke surveys using standardised methods that are independent of commercial activity are preferable. However, such surveys would require substantial resource investment that may be better allocated to other data collection methods.

5.3 Fisheries Models

Surplus production models have a long history of use in fisheries management. Relatively low data requirements and simple execution ensure they are prevalent in the assessment of data deficient fisheries (Smith and Addison 2003). In the absence of population data, information on landings and effort from MSARS provided an opportunity to carry out an early assessment of EIFCAs potting fisheries. The results varied in their success. Some areas responded better to modelling than others, largely dependent on the availability of suitable data. In those areas where the models assumptions of decreasing CPUE with increasing effort were violated, estimation of MSY and f_{Opt} could not be carried out. Confounding of parameters in this manner, as was the case for 34F1, is one of the limitations of this method (Hillborn and Walters 1992). The most credible models resulted from areas with a long tradition of potting where the negative relationship between increasing effort and LPUE is apparent. Surplus production models have been a useful first attempt to assess the status of the fisheries. They provided insight into some of the more important grounds in the district. However, it is difficult to see how the results may be transposed into management measures, unless a method of translating effort from pot hauls to absolute number of pots is devised. Surplus production models are also limited in their ability to appraise technical measures aimed at imparting a protective effect on a particular component of a stock as they take no account of population data relating to size frequency or sex ratios (Smith and Addison 2003). As such they have little use in monitoring the effects of measures such as changes to MLS or the protection of ovigerous females. For future assessments it is proposed that the data resulting from MSAR records is used to provide an overview of each of the grounds, reporting annual landings, effort and CPUE for each of the defined areas; and that surplus production modelling be dropped as the main method of assessment for these fisheries.

The combination of length converted catch curve and yield per recruit analysis provided an evaluation of fishing mortality and its effect on the stock in more quantifiable terms than those provided by surplus yield methods. Despite indications from MSAR records that pot fisheries on the North Norfolk grounds are experiencing successively better yields and catchability of crab in recent years' length converted catch curve analysis suggests that stocks are experiencing some degree of growth overfishing in all aspects of the stock but primarily in lobster. The observable trend of increasing *C.pagurus* landings from North Norfolk pot fisheries may be indicative of a good recruitment event having occurred, the benefits of which are now being appreciated by the fishery as animals grow on to a landable size. If this is the case, then future assessments may see the overall rate of fishing mortality reduced without intervention as these animals grow on to repopulate the larger size classes and reduce the observed slope of declining numbers with increasing age/size; assuming that is they survive and/or do not migrate out of the area.

Catch Curve analysis is relatively data intensive compared to surplus yield methods, however it provides a more reliable indication of how stock dynamics respond to fishing effort and an estimate of how much change is 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 2015 has seen a change in approach with sampling being carried out at the processors rather than on the quayside. This method allows a greater quantity of

measurements to be taken during a single sampling period covering a wider range of vessels. Quayside sampling can be problematic as fishermen are keen to unload their catch and transport it to the processors with minimal disturbance. As such subsamples of catch are often small and it is difficult to obtain samples from more than a handful of vessels. Sampling at the processors alleviates much of this pressure and allows for more rigorous sampling to be carried out. It would be beneficial to carry on with this sampling methodology and ensure that sampling is carried out on at least a monthly basis to provide time series data on catch throughout the potting season and increase confidence in assessment results.

6. Conclusion

Assessment of crustacean stocks in the EIFCA district offer little cause for immediate concern. Landings are either stable or displaying an upward trend while effort has remained relatively stable with no indication of an imminent crash. Some concern exists around rates of mortality in the fishery which suggest that growth overfishing is occurring and that efficiencies could be made to improve yields and robustness of the stock. Population analysis suggests that potential exists to increase the current MLS of *C.pagurus* in the district bringing it more in line with those in other districts. This would have the benefit of reducing fishing mortality on smaller animals and potentially improve spawning potential of the stock. Catch curve and yield per recruit analysis indicate that a change to exploitation pattern resulting in reduced fishing mortality has the potential to improve sustainability whilst prospectively improving yield.

6.1. Summary of Recommendations

- Continue capture of MSAR data to facilitate the assessment of trends in landings effort and spatial distribution of the fishery.
- Switch from MSAR reliant surplus production models to Length Converted Catch Curve analysis.
- Consider the potential of vessels sightings data to improve the resolution of effort distribution.
- Quantify the current number of pots being fished by district and area and consider linking to effort distribution derived from sightings.
- Continue capturing biosampling data from vessel landings with a focus on sampling at processors. Consider extending this approach beyond Norfolk where feasible.
- Ensure biosampling strategy is rigorous and carried out regularly so as to capture data throughout the course of the potting season.
- Continue to build capacity within the IFCA in the use of fisheries assessment methods.
- Explore potential management measures and consider the implications using cost benefit/risk based analysis.

This body of work has gone some way towards identifying the key issues and areas of concern in the fishery however, continued monitoring and further development of analytical techniques and sampling strategy should be pursued to ensure this important fishery is sustainably managed for the future.

7. Acknowledgements

Thanks to John Davies and his crew for assisting with surveys aboard *Richard William*.

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Appendix:

Byelaw 5:- Prohibition on the use of edible crab for bait.

Byelaw 6:- Prohibition on the landing and requirements for the immediate return to the sea of any egg-bearing or soft shelled crab and lobster.

Byelaw 7:- Prohibition of the removal from the fishery of parts of shellfish (e.g. claws) that cannot be measured to ensure compliance with MLS.

Byelaw 9:- Re-deposition of any shellfish, the removal of which is prohibited, to the sea immediately and as nearly as possible to the place from which they were taken.

Byelaw 10:- Prohibition on the landing of whitefooted edible crab (Those crabs that have not fully regained condition and meat yield after moulting) between the 1st of November and the 30th of June (inclusive).

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

Figure 26: EIFCA byelaws relating to the protection of *C.pagurus* and *H.gammarus* stocks

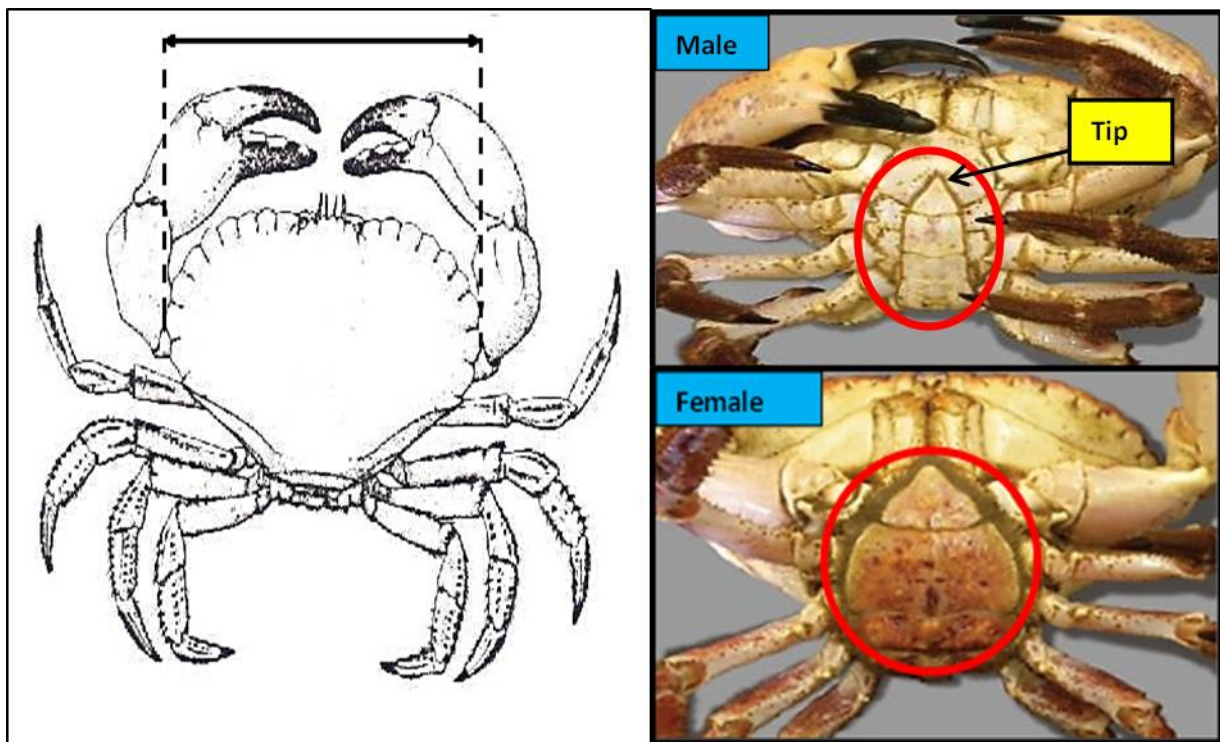


Figure 27: Determining sex and measuring carapace width (CW) of *C.pagurus*. Measurement is taken across the widest part of the cephalothorax.

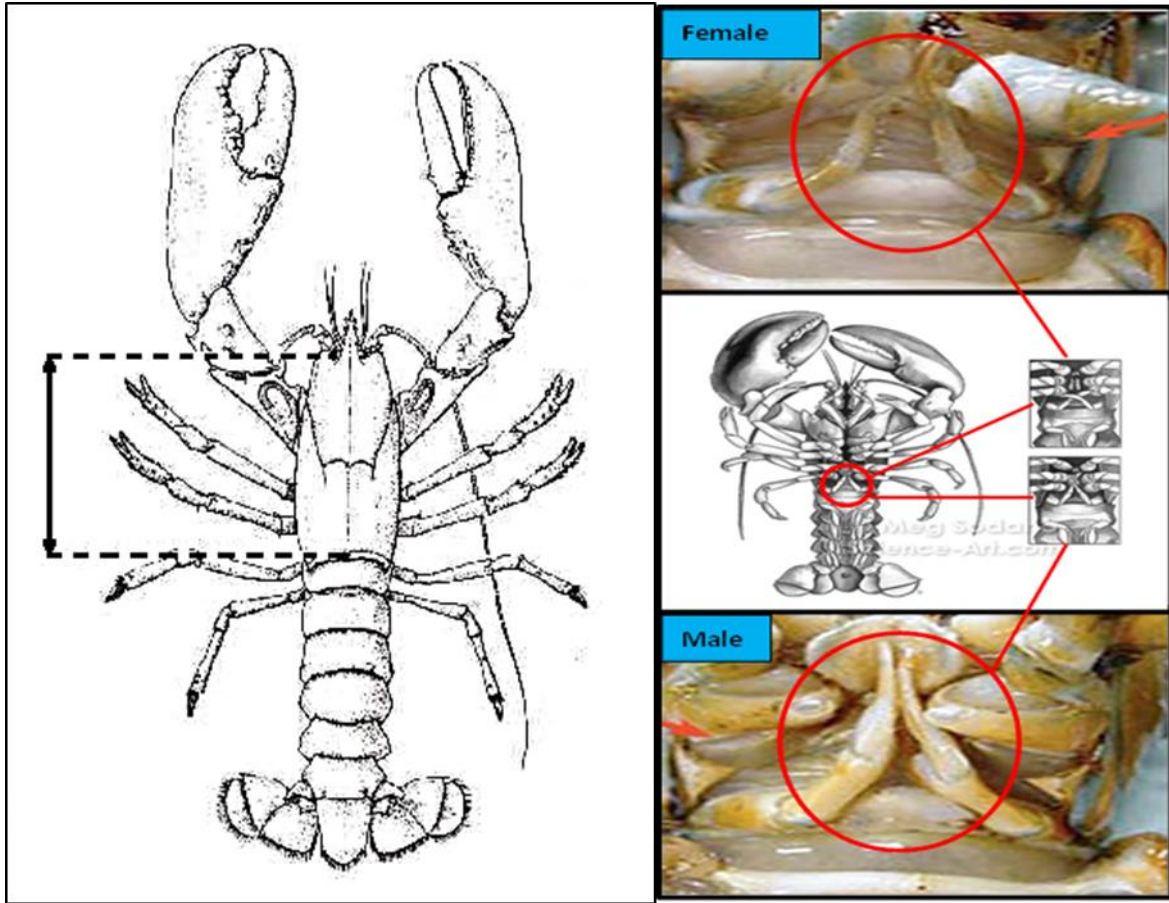


Figure 28: Determining sex and measuring carapace length (CL) of *H. gammarus*. Measurement is taken from the base of the eye socket to the end of the cephalothorax.

ICES statistical rectangles provide a grid covering the area between 36°N and 85°30'N and 44°W and 68°30'E.

Latitudinal rows, with intervals of 30', are numbered (two-digits) from 01 at the southern boundary (latitude 36°00'N) and increasing northwards to 99. The northern boundary of the statistical rectangle system is, thus, latitude 85°30'N.

Longitudinal columns, with intervals of 1°, are coded according to an alphanumeric system, beginning with A0 at the western boundary (longitude 44°00'W), continuing A1, A2, A3 to longitude 40°W. East of 40°W, the coding continues B0, B1, B2, ..., B9, C0, C1, C2, ..., C9, etc., using a different letter for each 10° block, to the eastern boundary of the area covered. Note that the letter I is omitted. The longitudinal column of ICES rectangles and respective coordinates are presented below.

Longitudinal column of ICES rectangle	Coordinates
A	44°W-40°W
B	40°W-30°W
C	30°W-20°W
D	20°W-10°W
E	10°W-00°W
F	00°-10°E
G	10°E-20°E
H	20°E-30°E
J	30°E-40°E
K	40°E-50°E
L	50°E-60°E

When citing an ICES rectangle, the northern coordinate is stated first. Thus, the rectangle of which the south-west corner is 54°00'N 03°00'E is cited as 37F3.

Usually, it is necessary to specify an area with more precision than is possible with a statistical rectangle designation. Therefore, a sub-rectangle designation must be given (as a fifth character) by dividing a statistical rectangle into nine (10' latitude x 20' longitude) sub-divisions, as follows:

1	4	7
2	5	8
3	6	9

For example, the location 58°12'N 10°33'E would, therefore, lie within ICES rectangle/sub-division: 45G05

Figure 29: ICES Statistical rectangle sub-divisions (Taken from Seafish Best Practice guidance for fishing industry financial and economic impact assessments 2012)

Date:		Port:		Species:		Vessel ID:		Shank number:			
ICES sub-rectangle:				Lat:				Pot no/pots in shank:			
Long:				Soak time:							
Bait type:				Soak time:							
Carapace length (lobster) or width (crab) to nearest mm below											
mm	Male	Female	Berried	mm	Male	Female	Berried	mm	Male	Female	Berried
_5				_0				_6			
_6				_1				_7			
_7				_2				_8			
_8				_3				_9			
_9				_4				_0			
_0				_5				_1			
_1				_6				_2			
_2				_7				_3			
_3				_8				_4			
_4				_9				_5			
_5				_0				_6			
_6				_1				_7			
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_9				_4				_0			
_0				_5				_1			

Figure 30: Sample sheets used to capture port based biosampling and survey at sea data. When used for port based sampling figures in mm column are filled in before sampling commences starting at 115mm for *C.pagurus* and 87 mm for *H.gammarus* animals at size are then recorded using barred gates. During Surveys at sea mm column is ignored with size in mm of animals written in the box of relevant sex/ovigerous state.

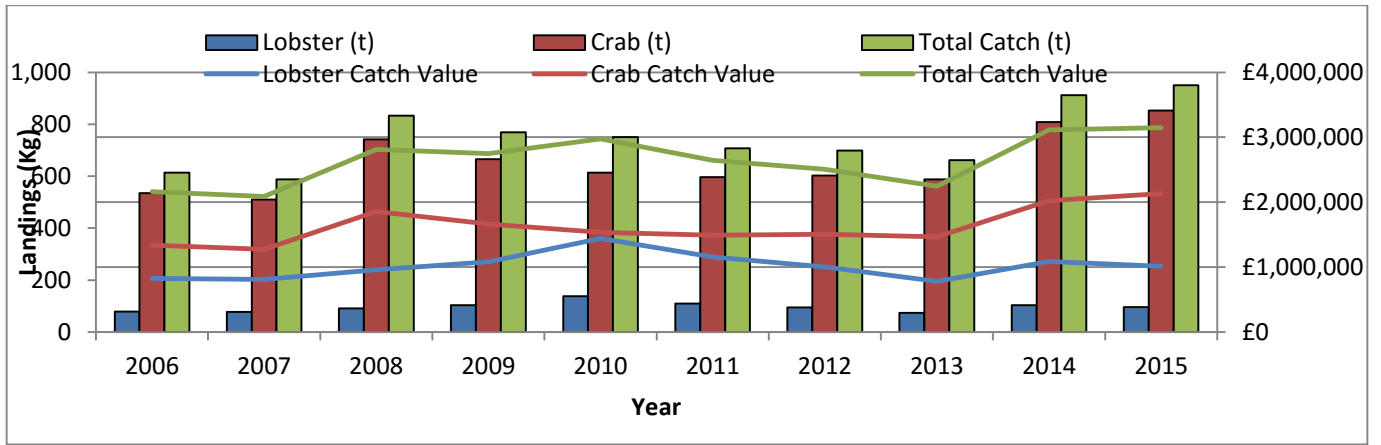


Figure 3128: EIFCA District crab (*C.pagurus*) and lobster (*H.gammarus*) landings by weight and estimated value (2006-2015). Source - EIFCA MSAR Database.

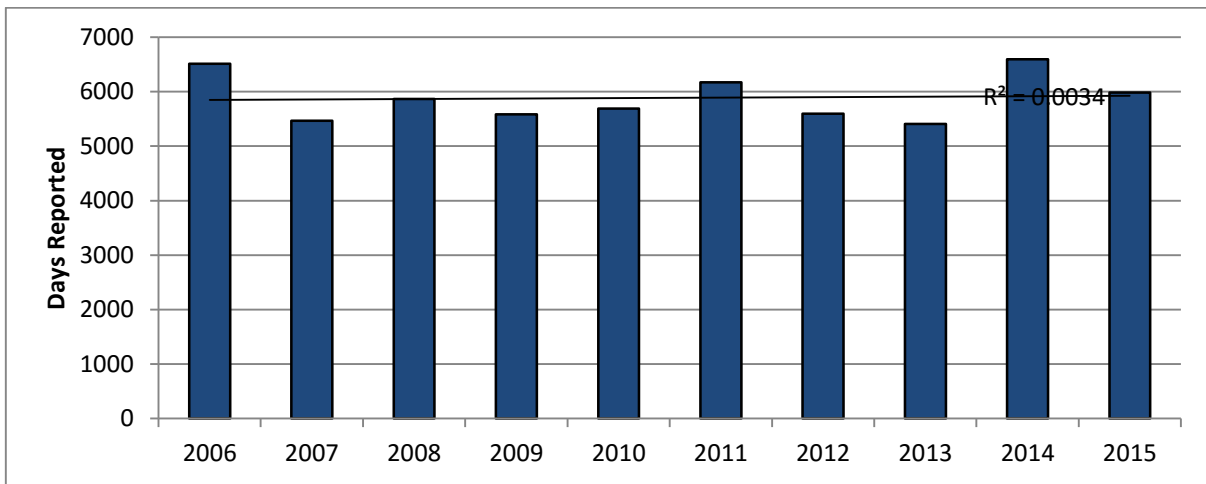


Figure 32: Annual fishing days reported by MSAR form 2006-2014. Source - EIFCA MASR Database

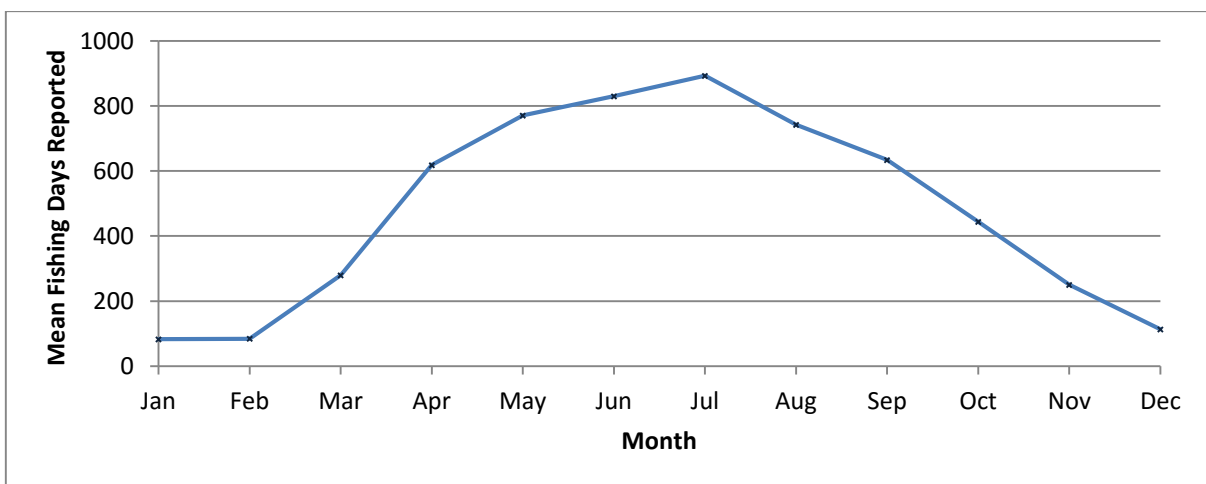


Figure 33: Mean Monthly Reported Fishing Days 2006-2014. Source - EIFCA MASR Database

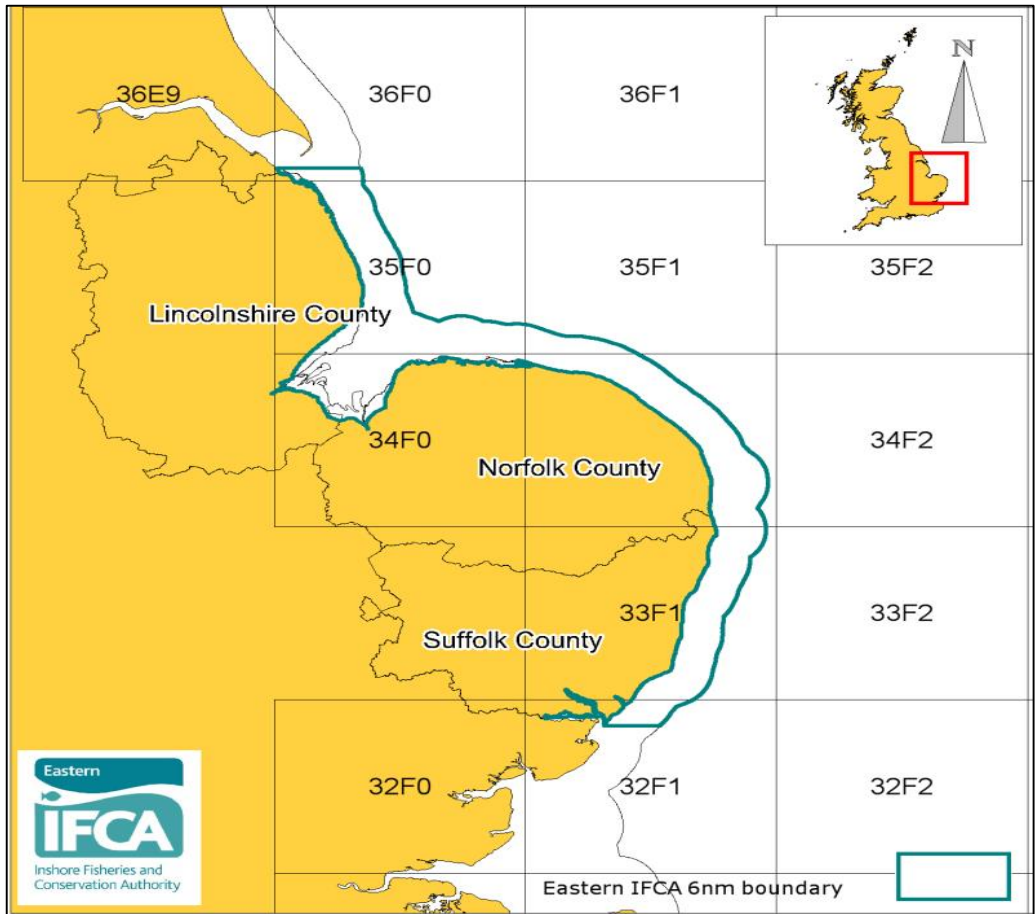


Figure 34: Map showing the extent of the EIFCA district along with ICES statistical Rectangles falling within its boundaries.

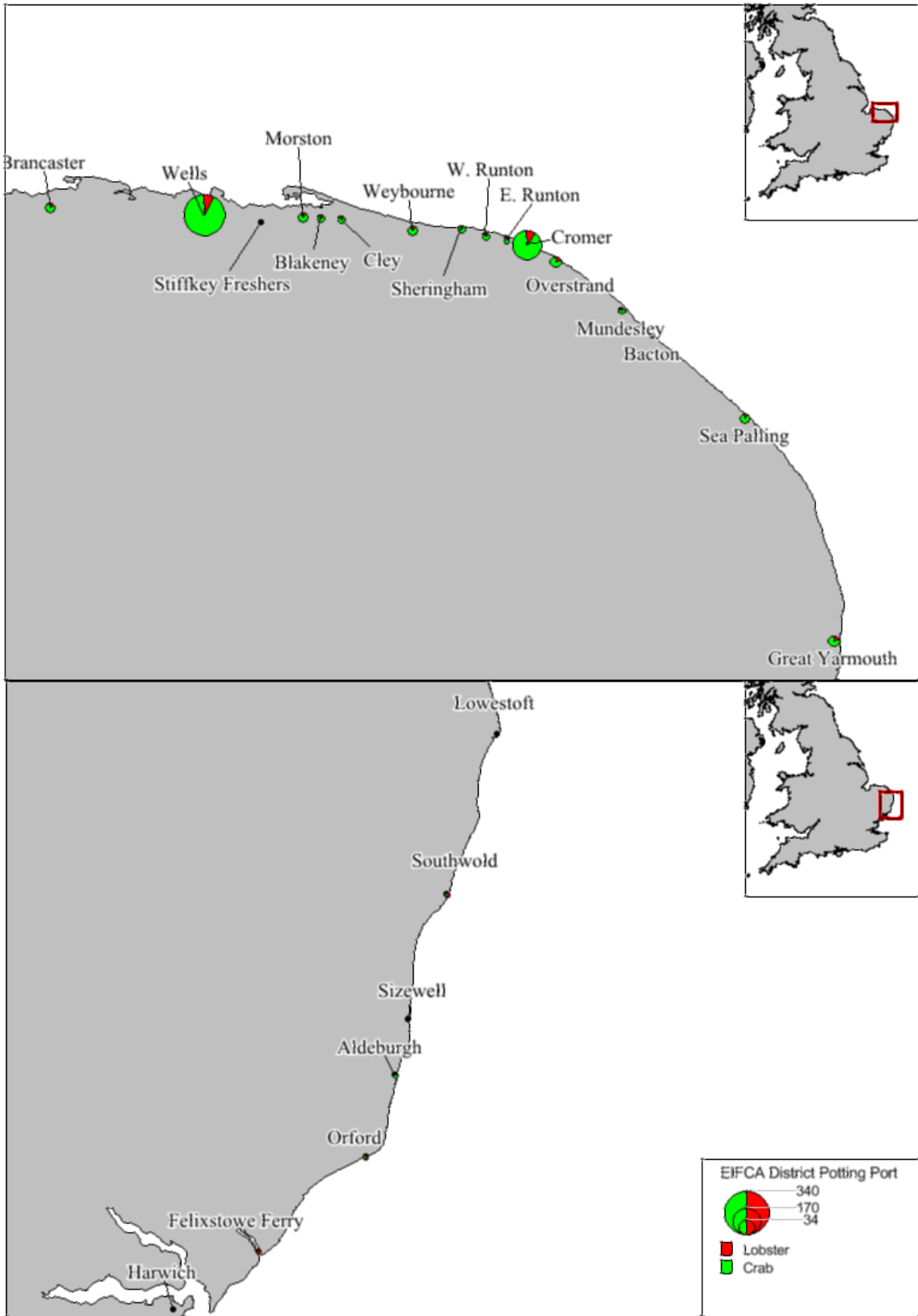


Figure 35: Map showing the distribution of ports engaged in potting and relative contribution to landings for the Norfolk (upper window) and Suffolk (lower window) coast.