RESEARCH REPORT

2014

Crab and Lobster Stock Assessment

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Contents

1. Introduction

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

Landings figures taken from Monthly Shellfish Activity Returns (MSAR) reveal average annual landings (2006-2014) of ~700 tonnes with a mean value of ~£2.5 million. Total landings have increased by 24% from 636 tonnes in 2013 to 787 tonnes in 2014 with only a 5% increase in effort. This appears to be attributable to the mild winter in 2013-2014 allowing an early start to the N.Norfolk inshore crab fishery with sustained catches throughout the season.

This report sees the second year of utilising data from MSAR records to analyse crustacean fisheries in the district using surplus yield models. The conclusions drawn from these are similar to last year as should be expected with no major changes occurring in the fishery. Overall the models predict no major concerns for the majority of the areas assessed however; certain areas along the N.Norfolk coast may be exhibiting signs that fishing pressure is approaching or exceeding recommended limits.

Concerns exist around the suitability of these models which is discussed in the latter part of this report. At present the models provide a means of assessment that is fairly simple to carry out despite the current deficiency in data. More sophisticated methods that align with those used by Cefas to produce their annual stock status reports are currently being investigated. This should allow for direct comparison between local and stock level observations whilst also providing trigger level reference points to inform management.

Conclusions of this report are that while fisheries in the district as a whole appear to remain healthy certain areas in the district may require close scrutiny to ensure that sustainable levels of effort are met.

2. Biology

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

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

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

2.1 European Lobster (Homarus gammarus)

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

Figure 1 A juvenile European Lobster (*Homarus gammarus*) found on chalk reef at Sheringham .

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

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

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

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

2.2 Edible Crab (*Cancer pagurus*)

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

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

Figure 2 Edible crab (*Cancer pagurus)* caught by fishermen operating from Cromer. Image Courtesy of Ady Woods

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

3. Fishing

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

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

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

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

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

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

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

4. Management measures

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

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

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

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

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

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

5. Defining the fishery

The aim of this section is to define the crab and lobster fisheries operating in the EIFCA district in quantifiable terms using data from MSAR forms. These returns detail information about daily fishing activities including; Port of landing, area fished (categorised by ICES statistical area), gear set/hauled and landed catch (kg/species). The resulting dataset (covering 2006-2014) has yielded information that can be used to facilitate the assessment of the fishery and provide focus for the study.

5.1 Data Reliability

The number of fishing days annually reported has remained consistent over the years (Figure 3) with a mean of 5665 fishing days reported each year (2006-2014); submissions do fluctuate throughout the year, reflecting peak periods of fishing activity. Analysis of Variance (ANOVA) revealed no significant differences between the number of submissions received each year (p=0.998) Consistency in the number of returns received each year gives confidence that any trends identified are likely due to tangible changes in the fishery, rather than changes in the number of returns submitted.
It remains to be noted that information generated through the analysis of this data is only as reliable as its source. MSAR forms are often filled in from estimates rather than precise figures. False reporting, either accidentally or with intent can also cause issue in the data. During the course of this analysis any obvious discrepancies in the data have been investigated and any exclusion/alteration of such entries to address this has been documented.

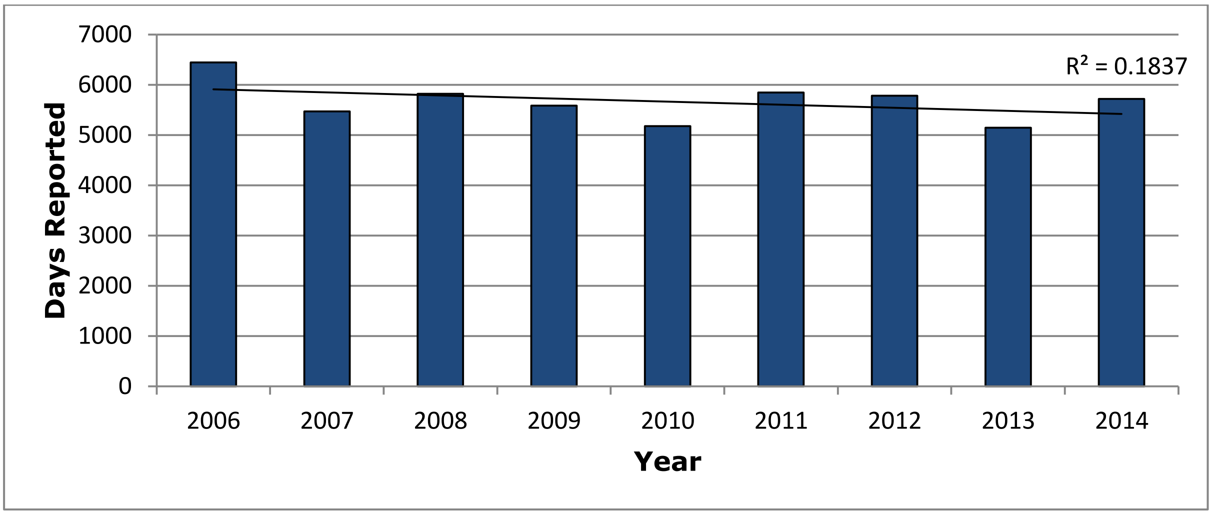

Figure 3 Annual fishing days reported by MSAR form 2006-2014. Source - EIFCA MASR Database

5.2 EIFCA District Landings

Catches of edible crab account for the majority of total annual crustacean landings in the district (mean 86%) with lobster accounting for less than a quarter of total landings each year (mean 13%) this has not changed significantly in 2014. Despite significant difference in landed weight, contribution to estimated value of the two species are more similar (mean crab 54%, mean lobster 46%) due to the higher market value of lobster.

Landings for the fishery have remained relatively stable throughout the period of the dataset fluctuating around a mean of ~710 tonnes for total landings, ~615 tonnes for crab and ~95 tonnes for lobster. Whilst these fluctuations are apparent in figure 4 ANOVA reveals no significant difference in landings between years (p=0.96, 0.949 and 0.77 for total, crab and lobster landings respectively).

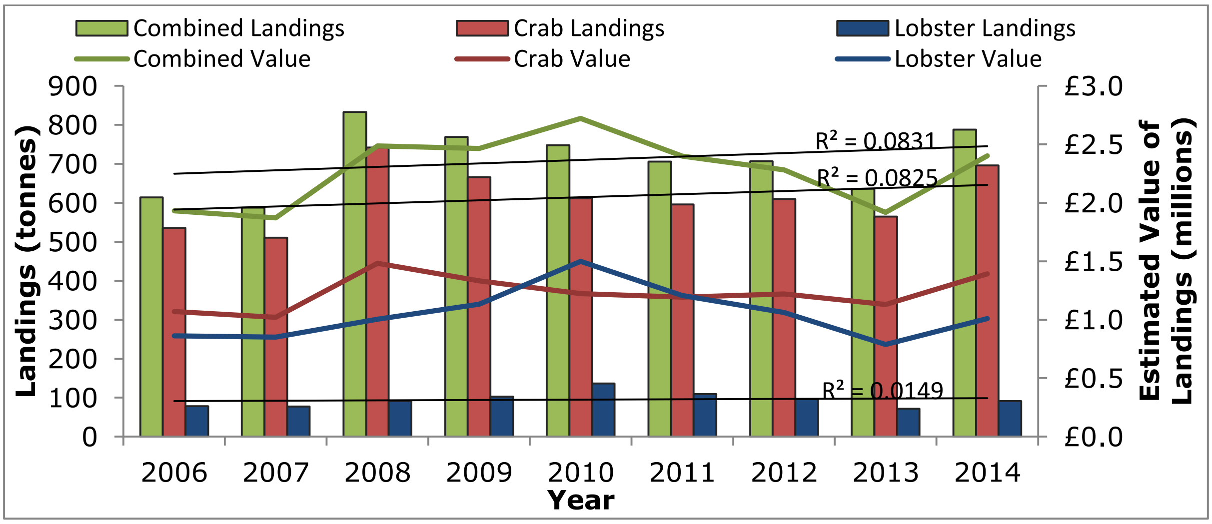

Figure 4 - EIFCA District crab and lobster landings by weight and estimated value (2006-2013). Source - EIFCA MSAR Database

5.3 EIFCA District Effort

Individual vessel effort is recorded as both pots set and pots hauled on MSAR forms, for the purposes of this report and In the interest of accuracy only the latter has been considered due to a lack of consistency in the way that pots set is reported.

Annual effort for the district is summarised in Figure 5 along with CPUE for each species both separately and combined. Effort fluctuates around a mean of 8824 (100 pot hauls) with a relatively large reduction in effort reported from 2006 to 2007. As with landings, effort in terms of annual pot hauls has remained relatively constant across the period of the dataset besides the noticeable decrease 2006-2007 decrease. Despite this ANOVA detected no significant difference in effort between years (p=0.857).

CPUE is seen to vary more for crab than for lobster (Fig 5). Fluctuations in total landings mirror crab landings (Fig 4) and the same is apparent for CPUE as this species is by far the major driver in this fishery. An ANOVA test of CPUE total, CPUE crab and CPUE lobster returned p=0.0038, 0.0032 and 0.857 respectively, suggesting significant differences between some years for Total and crab but not lobster. Post hoc analysis using TukeysHSD revealed these differences to be between 2008-2006 (p=0.003 total & p=0.003 crab), 2008-2011 (p=0.036 total & p=0.013 crab), 2008-2012 (p=0.030 total & p=0.017), 2008-2013 (p=0.048 total & p=0.039). These differences coincide with observable changes in effort suggesting some relationship. Two arguments present themselves to explain this relationship first; that those periods where CPUE peaks represent times in the fishery where potting effort is at such a level as to maximise catch per pot, extra effort is not being exerted to dilute the numbers of crab caught with each pot and so CPUE is elevated. The second possibility is that those years with poor CPUE but relatively higher effort may be as a result of reduced catchability of crab, encouraging fishermen to increase effort in an attempt to compensate for low catch per pot.

Given that changes to effort have not been significantly different it is difficult to believe that such small changes could influence CPUE in the way that the first argument suggests especially over such small temporal scales. It is also difficult to justify why such fluctuations in effort would occur without evidence of external drivers such as fluctuating market demand. The second argument suggests that drivers outside the fishery are responsible for changes to CPUE and that catchability of crab varies for reasons besides changes to effort. Exceptional recruitment years, response to changing environmental conditions or other less obvious drivers could all result in increased numbers of crab on fished grounds causing improved CPUE.

Some evidence to support the second argument comes from anecdotal accounts given by fishermen engaged in potting. They suggest that the fishery follows a cyclic pattern, with exceptional years of landings occurring every 6-8 years. This appears to be supported by the MSAR data which seems to follow a similar pattern. If this is the case then it is probable that the cause of these exceptional years is driven by increased numbers of crab in the fishing grounds, likely as a result of high recruitment of crab to the fishery in those years.

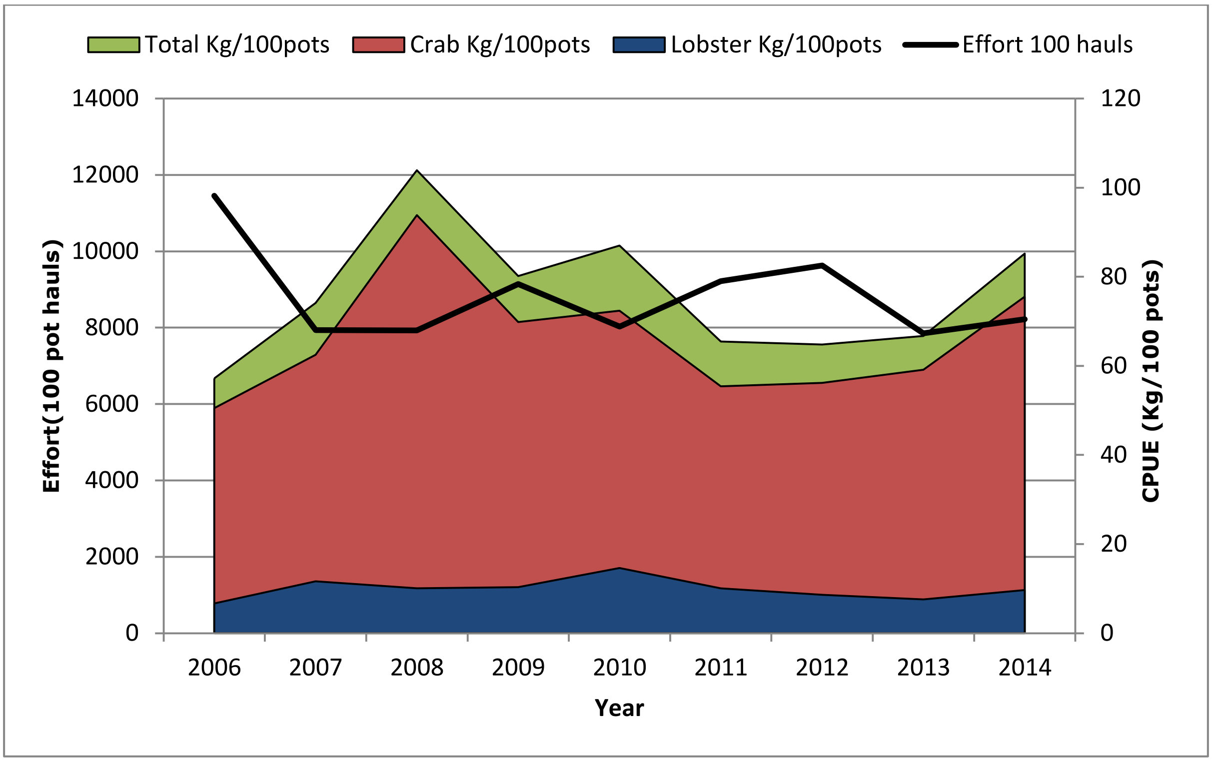

Figure 5 - EIFCA District annual effort and CPUE (by total catch and by species) 2006 - 2014. Source EIFCA MSAR Database

5.4 Ports Engaged in Crustacean Fisheries

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

There has been no noticeable change in the distribution of the fishery this year with the same ports reporting landings as in previous years.

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

Table 1 lists those ports that have submitted MSAR forms over the period of the data set and includes information on the number of vessels submitting returns. Again North Norfolk is most heavily represented in terms of vessels deployed with Wells and Cromer deploying the most vessels in the county.

Trends in total crab and lobster landings by port can be seen in figures 6 with figure 7 giving greater resolution for those ports landing less than 100 tonnes on average across the dataset.

Distribution of productivity is far from even with Wells and Cromer being the major producers, each contributing in excess 100 tonnes to total landings each year (Figure 6). Wells evidently contributes the most to landings in the district accounting for an average of 48% (49% last year) of mean total landings (mean = 334 tonnes/year (down from mean = 342 tonnes/year last year)); Wells contribution to landings is so high that they strongly influence the records for district total landings. When compared to each other total landings for Wells and the district as a whole share a very similar pattern of trends as a result of Wells heavy involvement in the fishery.

Cromer records the second highest mean landings (24% of mean total landings (up from 22%), mean = tonnes/year 164 (up from 152 tonnes/year last year)), but still contributes less than half the mean landings of Wells despite deploying more vessels.

While Wells may produce more landings than Cromer averaged across the years covered by the dataset, this year has seen the first instance in these records where Cromer has matched Wells in terms of production of crab recording its best year of crab landings in the history of the MSAR dataset.

Reasons for Cromer's success this year are likely linked to favourable weather conditions experienced over the course of the year. A mild winter followed by an early spring saw crabs being caught in much higher numbers earlier than would usually be expected. These catches appear to have been sustained throughout the year and combined with favourable conditions have allowed crab fishermen in this part of the district to carry on fishing later into the winter months. Whist this has been an exceptional year for Cromer due to an abundance of crab Wells has not benefitted so greatly for some reason.

Table 1 – Ports and vessels operating in the potting fishery in EIFCA's District 2006 - 2013.

Port	County	'06	'07	'008	'09	'10	'11	'12	'13	'14	Max	Min
Skegness	Lincs	0	1	1	0	0	0	1	2	0↓	2	0
Kings Lynn	Lincs	1	0	0	0	0	1	2	3	3	3	0
Boston	Lincs	0	0	0	0	0	1	4	7	4↓	7	0
Wells	Norfolk	9	8	11	9	9	9	14	8	8	14	8
Cromer	Norfolk	13	14	17	14	15	17	16	18	15↓	18	13
Morston	Norfolk	2	2	5	5	5	4	2	1	2↑	5	1
Brancaster	Norfolk	3	2	3	4	3	3	4	3	3	4	2
Weybourne	Norfolk	2	2	2	2	2	2	2	2	4↑	2	2
Sea Palling	Norfolk	2	2	2	2	2	2	5	3	4↑	5	2
Great Yarmouth	Norfolk	5	7	8	7	6	8	10	8	13↑	13	5
Overstrand	Norfolk	3	3	2	2	2	2	2	2	2	3	2
Sheringham	Norfolk	8	6	5	6	6	6	7	6	7↑	8	5
Mundesley	Norfolk	3	3	2	2	2	3	1	1	2↑	3	1
Blakeney	Norfolk	2	2	3	1	2	3	2	1	1	3	1
West Runton	Norfolk	2	0	1	1	1	1	1	1	1	2	0
Cley	Norfolk	1	1	1	0	0	2	4	5	4↓	5	0
East Runton	Norfolk	2	2	1	2	1	2	3	3	5↑	3	1
Bacton	Norfolk	2	1	2	2	2	1	1	1	1	2	1
Stiffkey Freshers	Norfolk	0	0	0	0	0	1	1	1	1	1	0
Felixstowe Ferry	Suffolk	10	8	9	6	3	9	10	10	10	10	3
Southwold	Suffolk	5	3	4	1	3	5	7	6	10↑	7	1
Lowestoft	Suffolk	6	5	2	2	2	4	3	6	4↓	6	2
Sizewell	Suffolk	1	1	1	1	1	1	1	1	1	1	1
Harwich	Suffolk	0	6	4	0	2	1	0	5	3↓	6	0
Aldeburgh	Suffolk	6	5	5	7	5	5	7	7	8↑	8	5
Orford	Suffolk	4	4	3	3	4	2	3	2	2	4	2
Unidentified	N/A	2	0	1	0	1	0	3	0	5↑	3	0
Total		94	88	95	79	79	95	116	113	118↑		

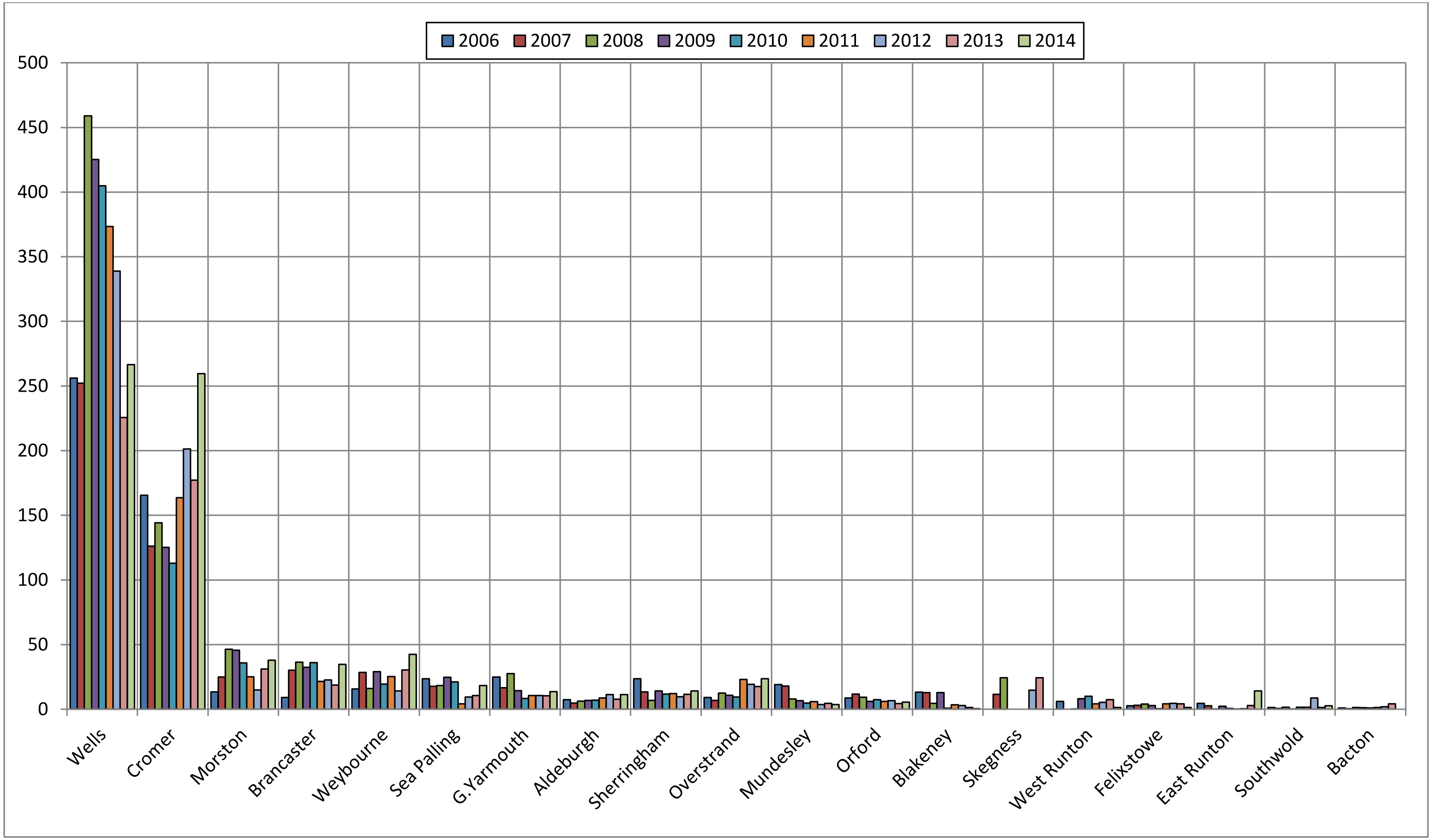

Figure 6 Annual Landings by Port, mean >1 tonne (2006 - 2014)

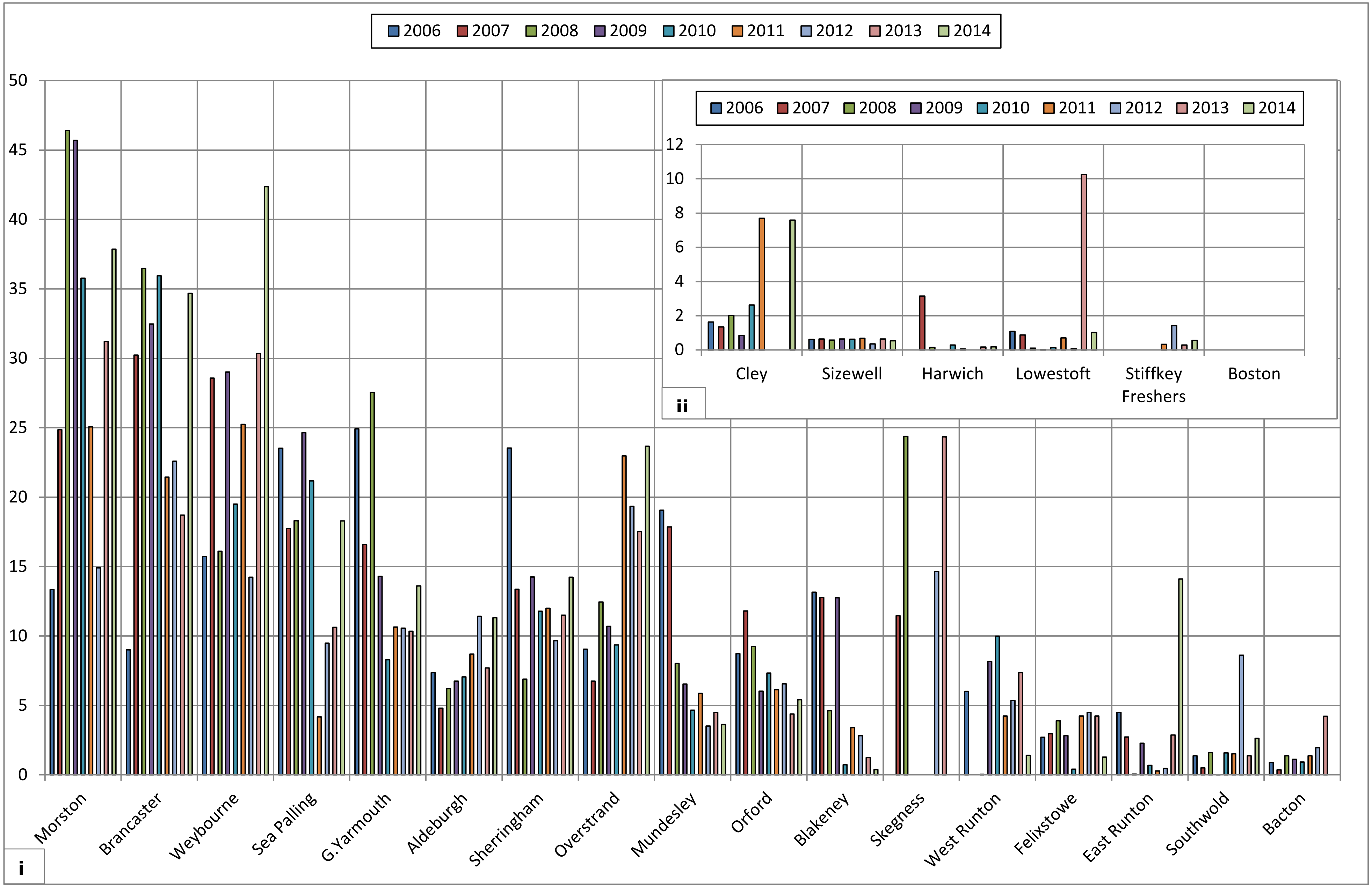

Figure 7 - Annual Landings by Port (i) mean >1 tonne < 100 tonne (ii) > 1 tonne (2006 - 2014).

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

Figure 8 divides the district by county to show where the major potting fisheries are located. Figures are based on mean annual landings converted to percentages to visually describe where the majority of landings are taking place by county.

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

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

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

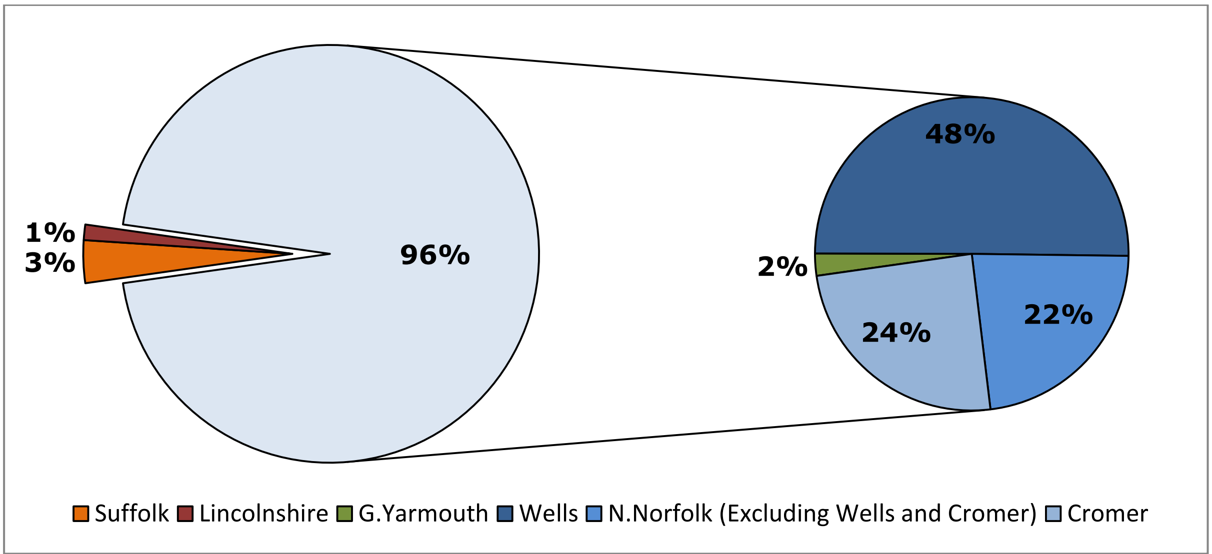

Figure 8 Relative contribution to total landings for each county within the district including a break down of ports operting out of N.Norfolk

5.5 Grounds Fished

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

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

In this study Statistical Rectangles have been used to define the boundaries of grounds fished by operating in the district and carry out analysis on a site by site basis. This delineation is facilitated by the requirement for fishermen to report ICES Statistical Areas they have fished on any given day. Those areas falling within the boundaries of EIFCAs authority are presented below (Figure 9).

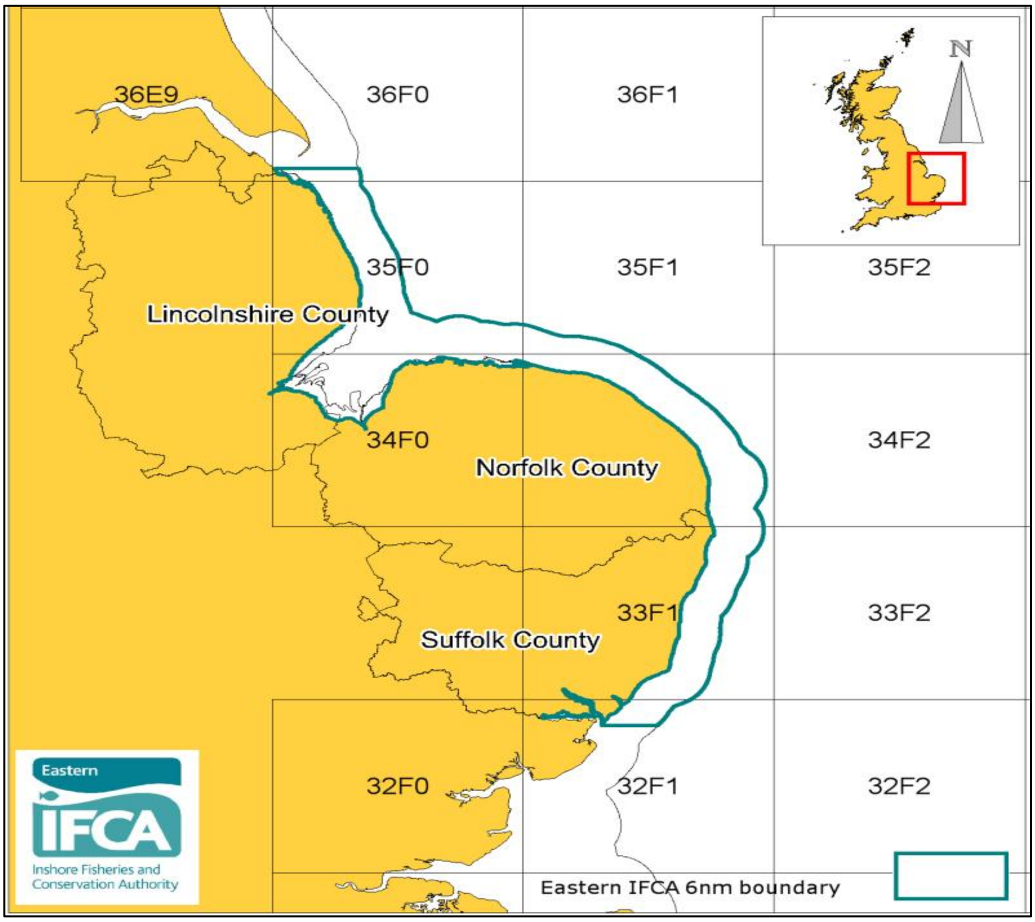

Figure 9 Counties and ICES Statistical rectangles falling within the EIFCA district boundaries.

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

Figure 10 shows landings and effort data for those grounds falling within the bounds of the EIFCA district, highlighting where effort is concentrated and where the majority of landings originate. From this it is clear to see the importance of areas 34F1, 35F0 and 35F1 of the North Norfolk coast which each contribute on average >100 tonnes to combined landings annually.

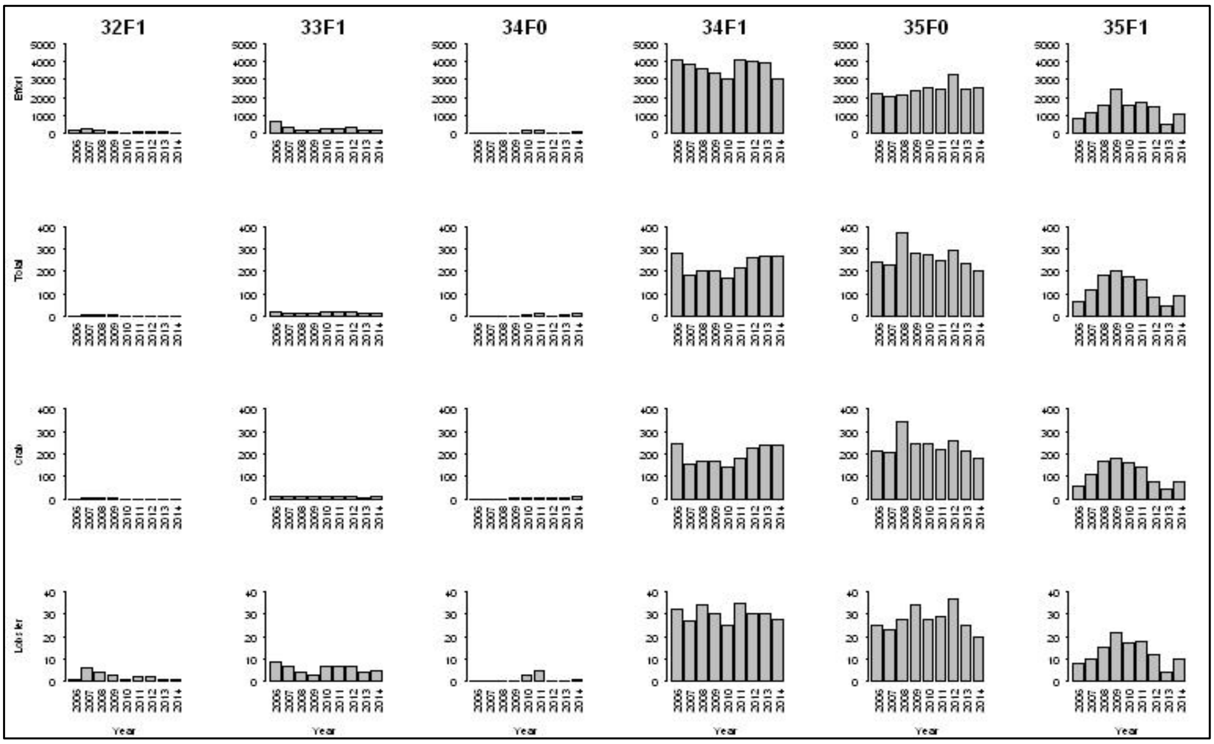

Figure 10 Annual effort (100 pot hauls) and landings (Tonnes) for the main potting fishery grounds in the EIFCA district 2006-2014.

Statistical analysis (ANOVA) revealed significant differences in effort between areas (p=<0.001) post hoc analysis using TukeysHSD revealed that this was the case for all areas except 33F1-32F1 (p=0.1067) and 34F0-32F1 (p=0.9996). Similar comparison of total landings revealed differences in all but 33F1-32F1 (p=0.9757), 34F0–32F1 (p= 0.9861), 34F0-33F1 (p=0.9821), 35F0-34F1 (p=0.2618)

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

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

6. Fisheries Assessment

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

6.1 32F1

6.1.1 Overview

This area overlaps significantly with Kent & Essex IFCA being located at the southern limits of the EFICA district. It is fished by a relatively small number of ports and vessels from our district which is reflected in effort and landings (Table 2).
Lobster accounts for a greater proportion of catch in this area than crab; however this difference is not significant, indicating that this area operates as more of a mixed fishery than areas such as those along the North Norfolk coast that are more reliant on a single species.

Table 2 Statistical Rectangle 32F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	11	189	2.1	0.7	1.4
2007	3	13	223	8.8	2.8	6.0
2008	5	13	165	6.6	2.8	3.8
2009	2	6	96	4.6	1.7	2.9
2010	5	7	36	1.7	0.5	1.2
2011	1	6	95	2.2	0.6	1.6
2012	1	8	112	2.3	0.4	1.9
2013	2	10	134	2.1	0.7	1.5
2014	2	6	41	1.0	0.5	0.6
Mean	**3**	**9**	**121**	**3.5**	**1.2**	**2.3**

Landings and effort are positively correlated in this area (R^2=0.486) as indicated in Figure 11; particularly in the period covering 2007-2010 where landings are seen to decrease relative to effort in a linear pattern. This trend is affects both crab and lobster landings (Fig 12 (ii)) suggesting that effort is the main driver of landings in this area.

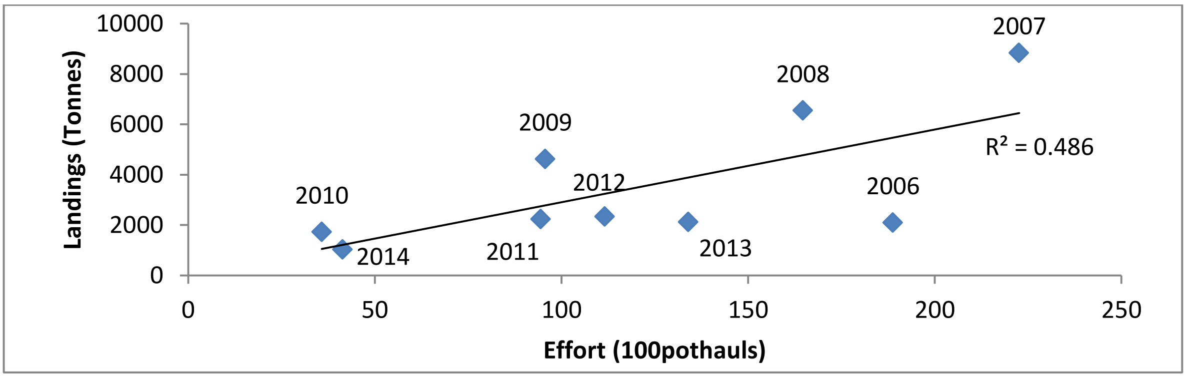

Figure 11 Correlation of landings against effort for area 32F1

Of some concern is the time period from 2010 onwards, where effort begins to increase again without a corresponding increase in landings. It is apparent that something is having a negative effect on the fishery from this point limiting productivity relevant to previous years. The cause of this uncertain at this point and will require further investigation. It is possible that the fluctuations observed here are artefacts of the MSAR recording process. Returns are received to the MMO direct from fishermen and then distributed to the relevant IFCA depending on port of landing. It may be that much of the returns generated from this area are either mistakenly being forwarded to K&EIFCA or that landings are occurring in ports outside of the EIFCA district.

Despite the lack of certainty in the completeness of this dataset there is confidence that this area operates differently to those on the N.Norfolk coast. Lobster forms the greater proportion of the catch here with less dependence on crab (fig 13 ii), whether this is a consequence of less crab on the ground or fishermen selecting lobster over crab is uncertain.

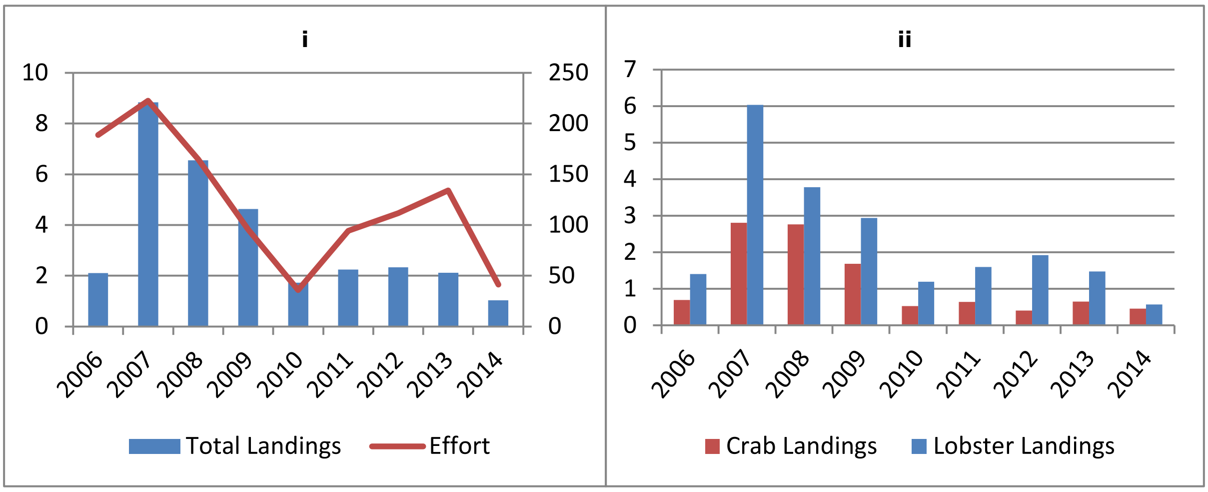

Figure 12 Statistical Area 32F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

6.1.2 CPUE

Regression analysis of CPUE (catch per unit effort) against effort highlights the disparity between pre and post 2010 data (Fig 13) which falls into two distinct groups when plotted. During the period between 2007 and 2010 CPUE is elevated compared to other years. Despite this disparity there seems to be little indication of a relationship between effort and CPUE in either group. This lack of observable trend suggests that in this area fishing effort is not having a detrimental effect on abundance (CPUE would be expected to fall as effort increased if this was the case).

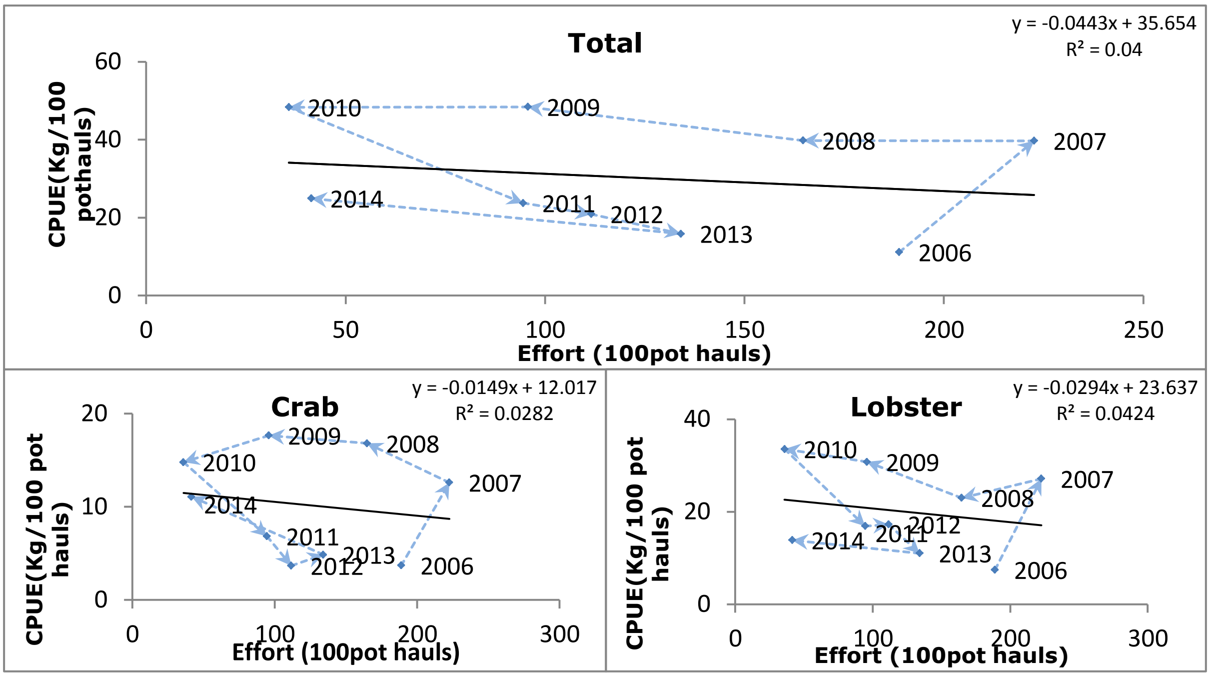

Figure 13 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 32F1 2006-2014

That said CPUE drops dramatically from 2010 to 2011 suggesting that something has impacted the catchability of animals. It is possible that something outside of the fishery has had a negative impact on the abundance of animals on the ground or has otherwise reduced the efficiency of the fishery. This is followed by a steady decline in CPUE despite increasing effort which should have seen landings returning to 2008/2009 levels.

6.1.3 Surplus Yield Models

The surplus yield model produced from parameters derived from the above regression is presented in figure 14. This model suggests that that MSY and fOpt have not been reached during the period covered by this dataset and that additional effort in this area would produce increased returns for both species. Optimum effort is near enough the same for both species unlike in other areas where crab becomes the limiting species. This is likely explained by the lower dependency on crab in this area, probably as a result of lower abundance of crab on this ground. While this may seem counter intuitive the reduced catchability of crab in this area brings them more in line with lobster populations. Despite this it is worth noting that the predicted MSY for crab is still much lower than the N.Norfolk crab grounds.

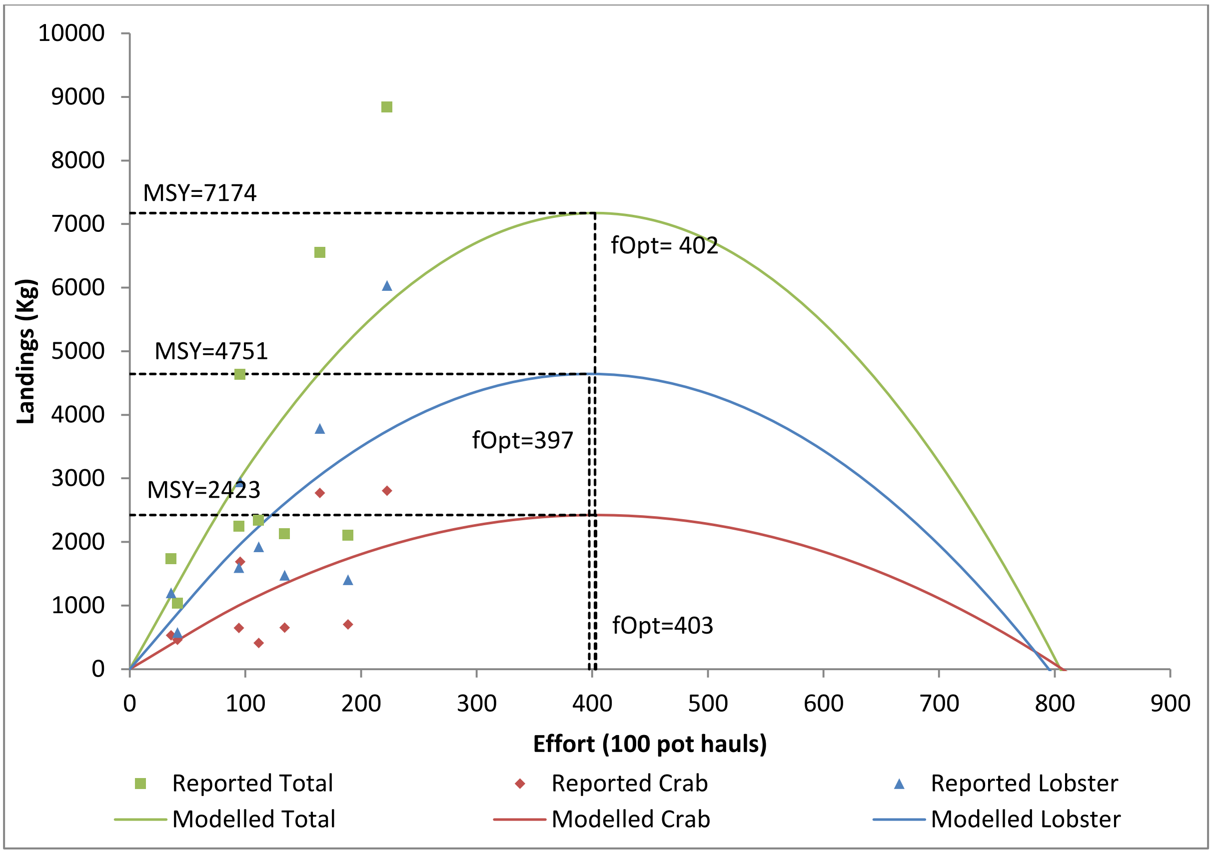

Figure 14 Statistical Rectangle 32F1 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2013)

Indications are that this area has been underexploited in the past and could have been subjected to higher levels of effort however; there are concerns that something has had an effect on the productivity of the fishery in recent years reducing its capacity. It may be that this is simply an artefact of the MSAR reporting process however; it may be also ne the result of environmental or anthropogenic induced changes outside of the effects of the fishery. The cause remains unclear at this point and warrants further investigation.

5.2 33F1

5.2.1 Overview

This area is situated off the Suffolk coast covering an area between the Orford and Lowestoft. Again it is fished by a small number of ports and vessels compared to other areas in the district which is reflected in landings and effort (Table 4.3).

Table 3 Statistical Rectangle 33F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	8	19	665	20.9	11.5	9.4
2007	7	20	364	15.5	9.0	6.5
2008	7	17	215	15.9	11.4	4.4
2009	7	14	170	12.0	8.8	3.2
2010	7	18	230	17.2	9.9	7.2
2011	6	16	232	18.8	12.1	6.7
2012	8	21	344	19.1	11.8	7.3
2013	8	20	213	12.2	8.0	4.2
2014	6	18	203	15.4	10.6	5.1
Mean	**7**	**18**	**293**	**16.3**	**10.3**	**6.0**

Landings and effort are again exhibit positively correlation in this area (fig 15) with effort having seen a substantial reduction after a peak in 2006. In the period after 2006 effort and landings remain relatively stable forming a loose cluster to the left of the plot indicating that only minor changes are occurring in the fishery at present.

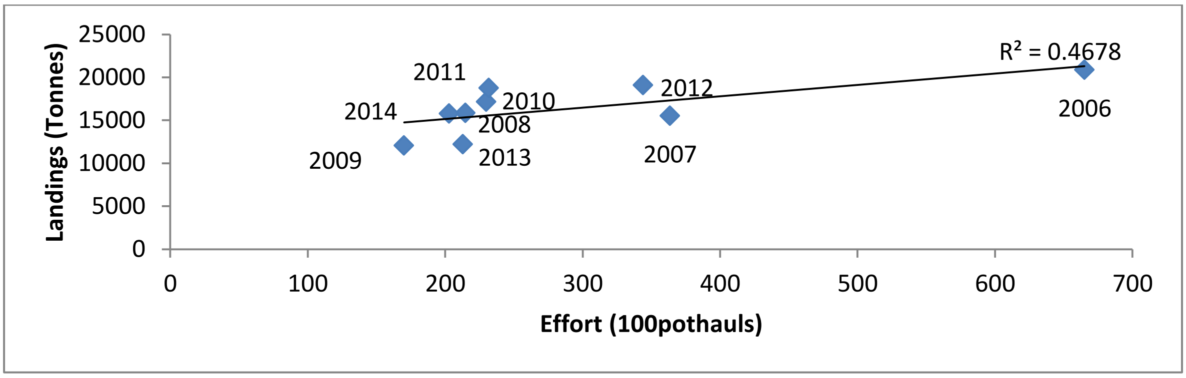

Figure 15 Correlation of landings against effort for area 33F1

Landings have remained fairly stable across the period of the dataset however there is an observable reduction in effort between 2006 and 2009 (Fig 16 i). Crab composes the majority of catch in this area with lobster playing a lesser role (fig 16 ii). Landings have increased this year while effort has fallen though only slightly.

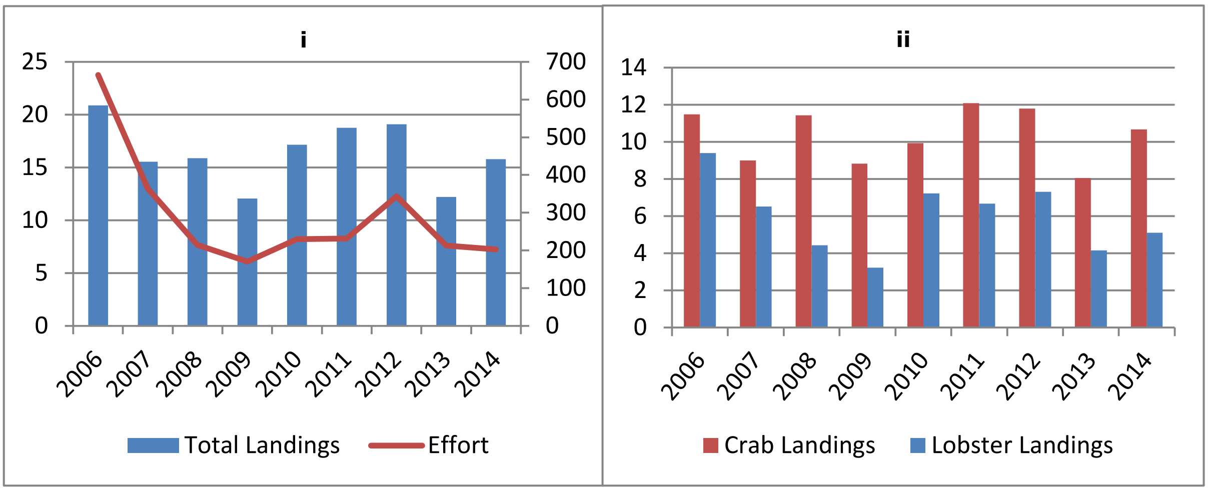

Figure 16 Statistical Area 33F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

5.2.2 CPUE

Regression analysis revealed a strong negative correlation between increasing effort and CPUE for total catch and for crab (R^2=0.73 and R^2=0.75) with a weaker negative correlation for lobster (R^2= 0.32). All data points fall into one group along the regression line and no apparent outliers (Fig 17). The spread of data provides good coverage of different levels of effort and CPUE for this area and a good fit of the regression line (R= gives confidence in the reliability of the models generated from it.

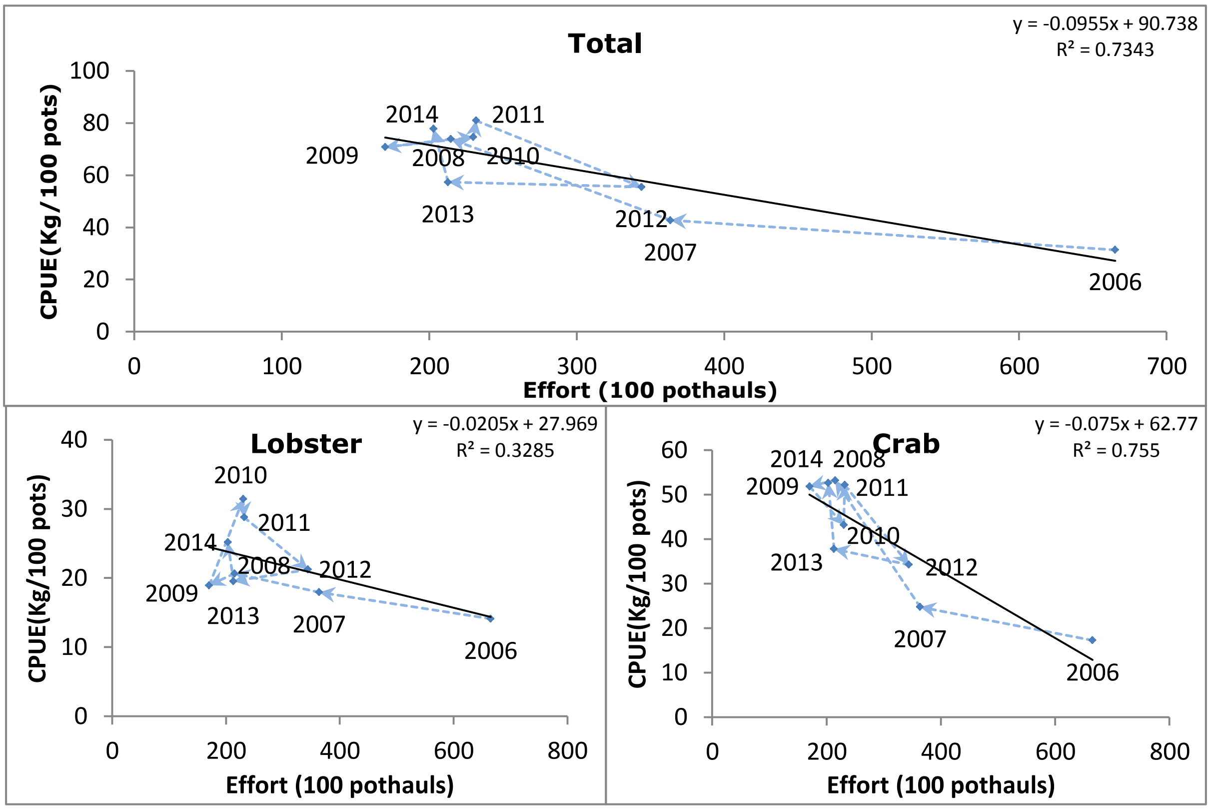

Figure 17 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 33 F1 2006-2014

5.2.3 Surplus Yield Model

Figure 18 presents surplus yield models for this areas fishery generated from all points on the regression analysis. Indications are that this fishery may have been subjected to unsustainable levels of effort (2006 data point) but that a subsequent roll back of effort has brought exploitation levels down below the recommended MSY of ~21.5 tonnes preventing any long term damage to the viability of stocks.

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

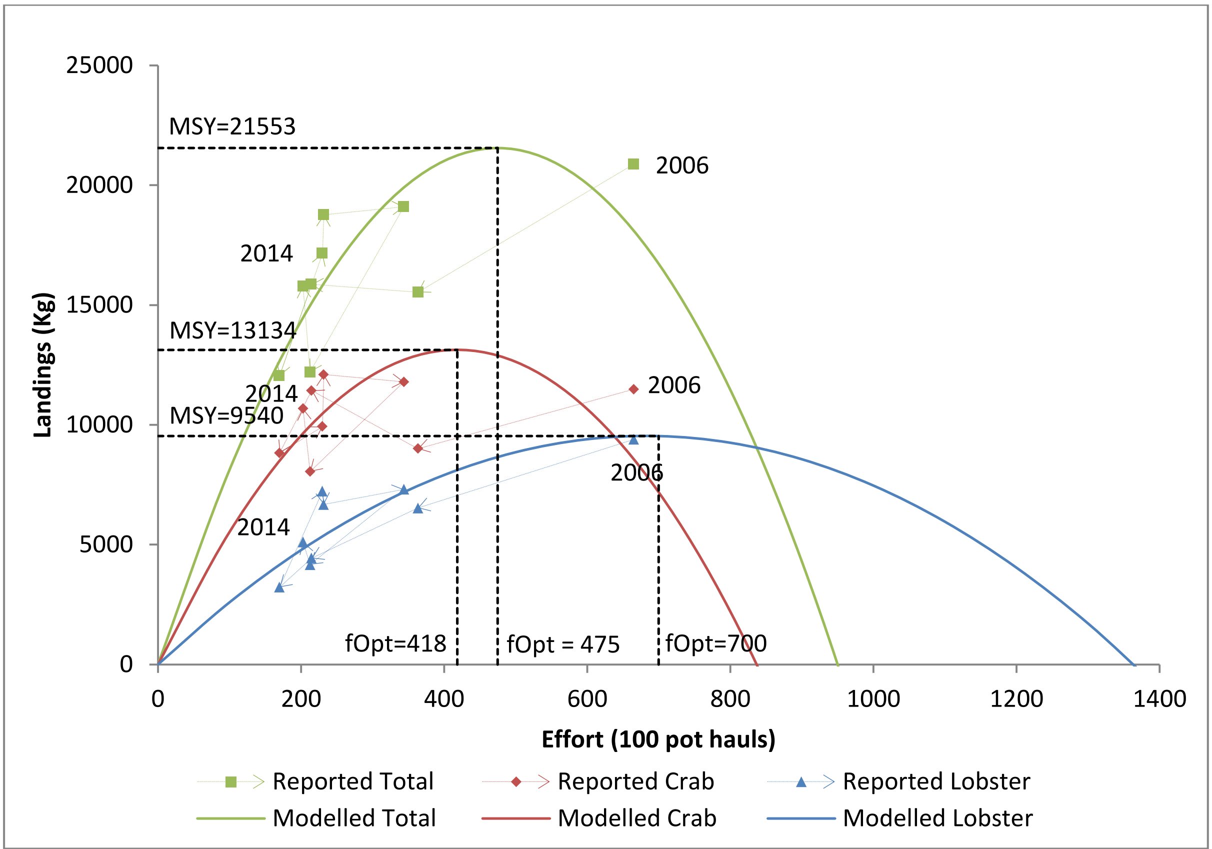

Figure 18 Statistical Rectangle 33F1 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2014)

5.3 34F0

5.3.1 Overview

This area straddles the border between Norfolk and Lincolnshire and is composed mainly of The Wash and a short section of the North Norfolk coast. It represents a developing fishery with very little in the way of effort currently dedicated to crab and lobster fishing (Table 4).

Table 4 Statistical Rectangle 34F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	1	1	0	0.0	0.0	0.0
2007	0	0	0	0.0	0.0	0.0
2008	1	1	0	0.0	0.0	0.0
2009	2	3	22	1.8	1.6	0.2
2010	3	3	151	7.7	4.5	3.2
2011	5	7	176	11.5	6.9	4.7
2012	6	6	31	3.3	3.0	0.3
2013	5	5	49	5.2	4.9	0.3
2014	3	4	112	9.8	9.1	0.6
Mean	**3**	**3**	**60**	**4.4**	**3.3**	**1.0**

Landings and effort are strongly correlated for this fishery and observe a pattern typically expected in a developing fishery where increasing effort produces higher returns (fig 19).

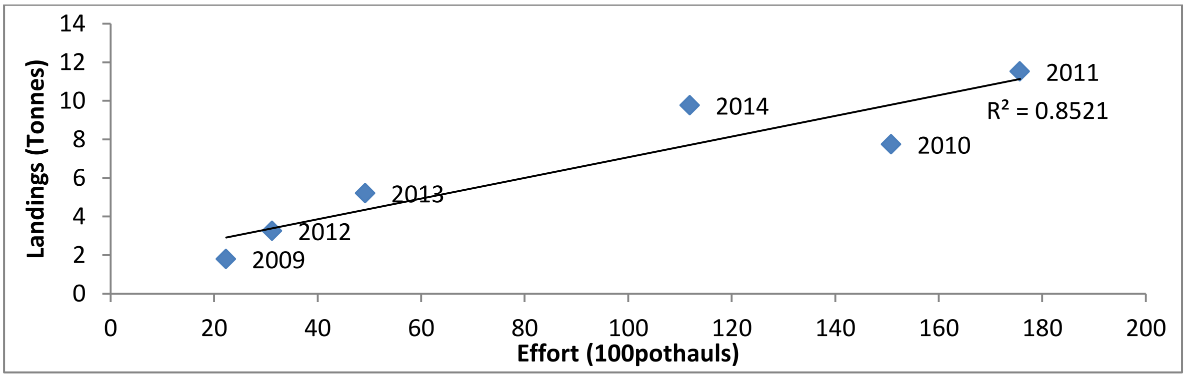

Figure 19 Correlation of landings against effort for area 34F0

Crab constitutes the majority of the catch however the difference between crab and lobster catch is not statistically significant (Figure 20). This area has seen an increase in reported effort and landings this year however statistical analysis (ANOVA) did not find this significant.

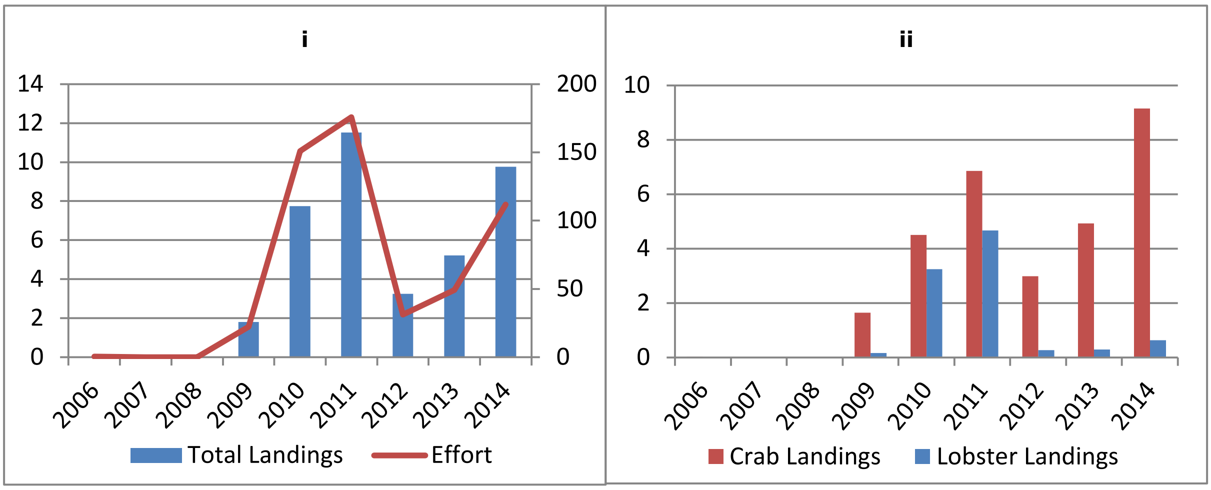

Figure 20 Statistical Area 34F0 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

5.3.2 CPUE

Unlike other areas in the data set fishing activity has only been recorded for six years starting in 2009. Regression of CPUE against effort does reveal a negative correlation between the two (Figure 21) however this is only apparent for crab. Regression of CPUE against effort for lobster reveals a positive correlation which suggests that the fishery has not yet been fully or over exploited for this species at this time. While this is good news in terms of the fishery likely having no negative effect on populations of lobster in the area as of yet it does mean that this data cannot be used to model the fishery effectively, as this type of model relies on parameters from a negative correlation to function correctly. For this reason only the model for crab should be considered here, the model for lobster and for the total fishery have been included here however this it is highly likely that these represent gross overestimates of the capacity of the fishery.

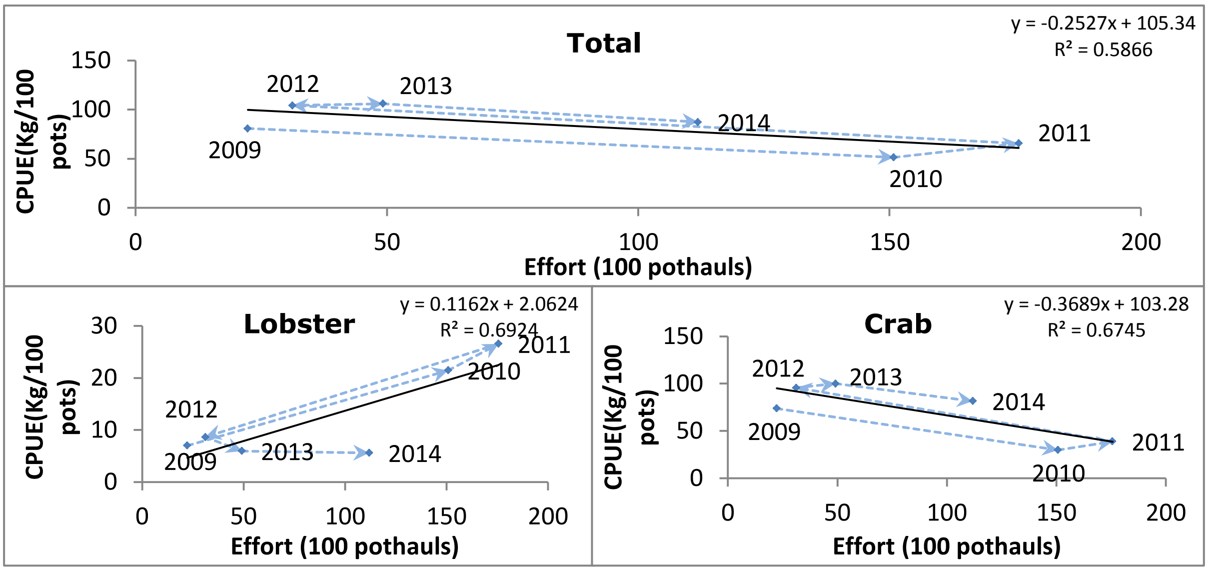

Figure 21 Regression Analysis of Crab CPUE vs. Effort for Statistical Rectangle 34F0 2009 -2014

5.3.3 Surplus Yield Model

Figure 22 models the fishery for crab and includes curves for both the total fishery and lobster however; parameters for this part of the model are unreliable for use as indicators of MSY and fOpt. As increasing effort has only ever resulted in increased landings of lobster the curve for this species displays an exponential increase in landings with increasing effort taking it out of the visible portion of the graph. As there has been no downturn in CPUE with increasing effort for this species the model can only predict ever increasing returns with increasing effort, natural logic would bring this prediction into question as no fishery operates in this manner, eventually fishing effort would reduce populations below a level where reproduction can sustain it. As the curve for the total fishery is based on CPUE for both species it is likely that the poorly modelled lobster curve is having the effect of shifting the peak of this curve (MSY) up and to the right, essentially overestimating MSY and fOpt for total catch in the fishery. While this is the case the fit of curve for the crab fishery in this area is good and it is highly probable that crab is the limiting species in this fishery (i.e. the first to suffer from overexploitation of the ground). While the model for the crab fishery is certainly more reliable than that for lobster catches of crab have been at their highest on record for this area this year falling way above those predicted by the model for the level of effort and MSY as predicted by the model. This throws into question the reliability of this type of model for this area and by extension for crab and lobster fisheries within the district. This type of model only takes account of the effect of fishing pressure on stocks and it is becoming clear that variables outside of the influence of the fishery may be having a greater impact on stock distribution and abundance.

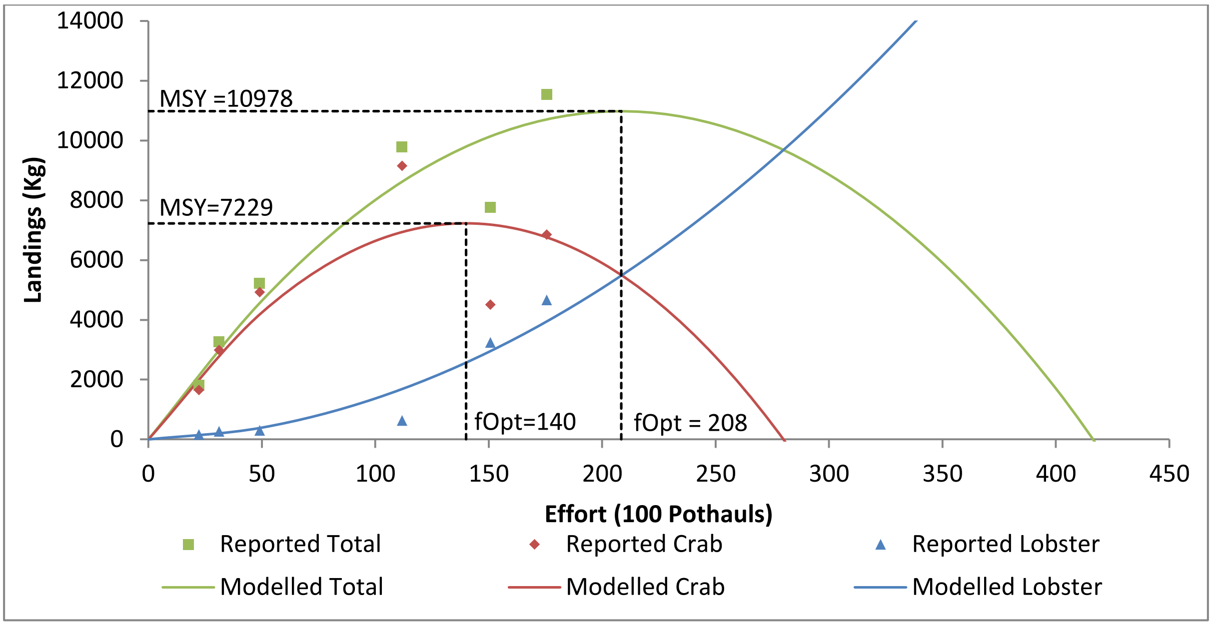

Figure 22 Statistical Rectangle 34F0 Surplus Yield Model for Crab Using Parameters Derived from Regression of Data Points 2009 – 2014.

5.4 34F1

5.4.1 Overview

This area is one of the most productive for potting in the EIFCA district. Situated off the North Norfolk coast it is the primary fishing ground for vessels operating out of Cromer. This area is fished by a large number of vessels from numerous ports along the North Norfolk coast, mainly consisting of day going vessels launching from beaches and fishing close to shore. The high number of vessels fishing this area is reflected in the effort and landings which are the second highest for any area in the district (Table 5).

Table 5 Statistical Rectangle 34F1 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	17	49	4123	278.8	246.5	32.3
2007	12	37	3837	183.3	156.0	27.3
2008	13	35	3564	203.7	169.8	33.9
2009	14	37	3339	200.1	170.4	29.7
2010	13	35	3046	167.3	142.5	24.9
2011	12	42	4090	213.0	178.4	34.6
2012	13	41	3989	258.1	227.6	30.5
2013	14	44	3940	268.3	238.7	29.5
2014	12	36	3024	270.2	242.0	28.2
Mean	**13**	**40**	**3661**	**227.0**	**197.0**	**30.1**

A positive correlation exists between landings and effort in this district (fig 23) however the relationship is fairly weak (R^2= 0.127) suggesting that increasing effort is unlikely to result in increasing returns in this area. The area has historically been fished for over a century and it is likely that the effort here has reached the maximum sustainable capacity for the area. These grounds are highly productive with regard to crab and it is likely that this area represents a catchment area for recruitment of larvae.

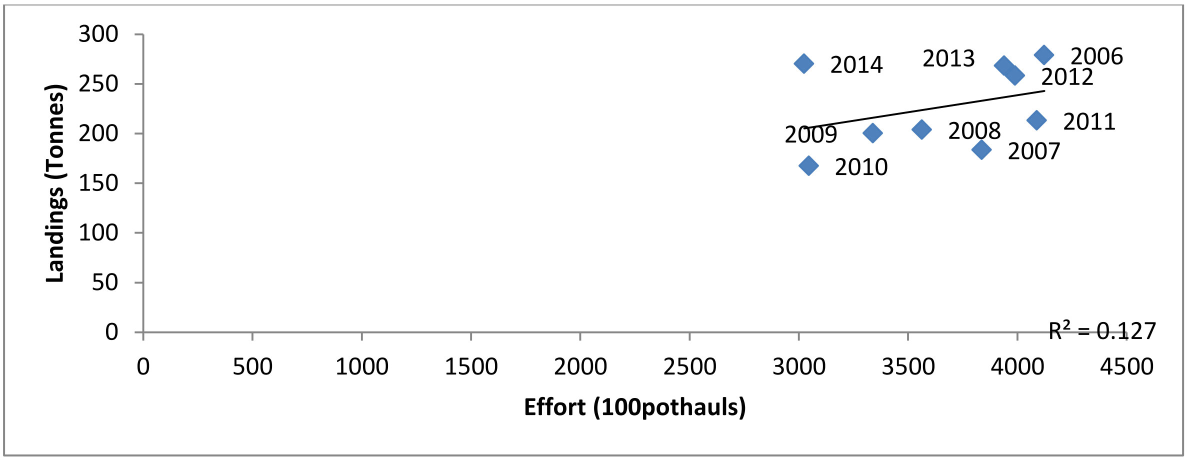

Figure 13 Correlation of landings and effort for area 34F1

This fishery is very much centred on fishing for crab with large numbers being landed each year. Landings of lobster are significantly lower than crab in this area (Figure 24) however; lobster landings are still significantly higher here than in most other areas in the district. 2014 has been an exceptional year for Cromer, with mild weather allowing the fishery to begin early and landings sustained throughout the course of the year.

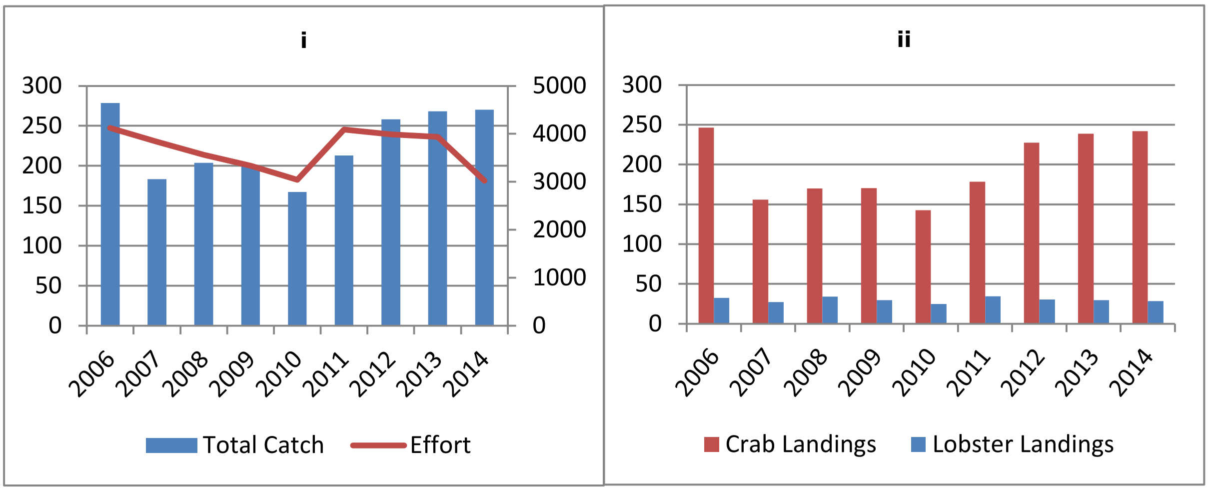

Figure 24 Statistical Area 34F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

5.4.2 CPUE

With the addition of the 2014 data regression analysis of data points now results in negative correlation between effort and CPUE for all species, though the relationship still remains weak (Figure 25). Data points form two groups for crab but are tightly clustered for lobster. In the regression analysis for crab the two groups lie almost parallel to each other with CPUE for the years 2006, 2013 and 2014 elevated above the other years (2007-2012). Both groups show the same relationship with CPUE decreasing as effort increases however the top group suggests higher CPUE at similar levels of effort to the lower group. This appears to be due to a few years (2006, 2013 and 2014) where CPUE has increased without any appreciable increase in effort. Whether these years represent the status quo or can be considered exceptional becomes increasingly less apparent with the addition of the 2014 data. It may be that this ground is a naturally dynamic system, able to produce high abundance of crabs in the right conditions but with fewer animals on the ground when such conditions are not met. Unfortunately it is not possible to ascertain what may be causing this dynamic flux from the MSAR data and it is likely that the answer to such a question remains outside the scope of the authority to answer. Despite this management decisions that ensure the area is sustainably exploited are still possible if the precautionary approach is employed. Such measures would set limits at the lower threshold of what the system is capable of sustaining, with years producing higher abundance of crab seen as a boon to the fishery.

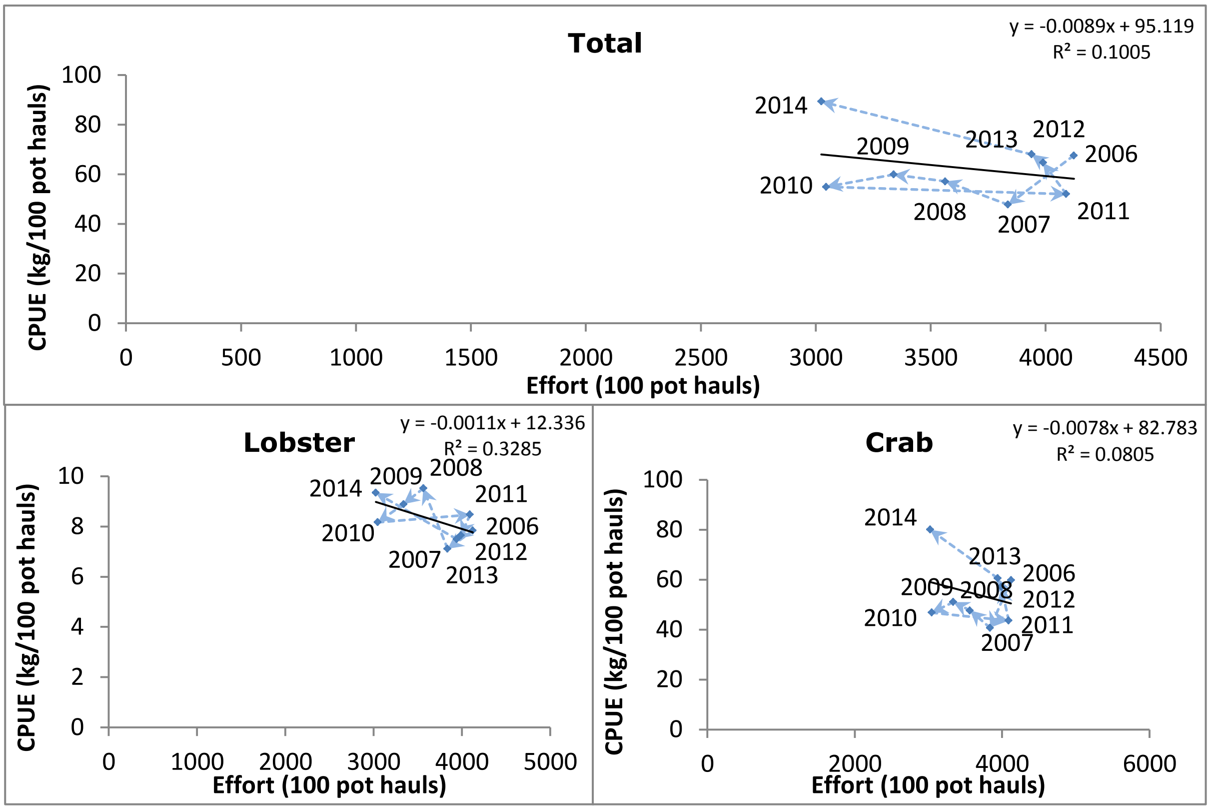

Figure 25 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 34F1 2006-2013.

5.4.3 Surplus Yield Model

Using parameters derived from all data points in the regression produces the model presented in figure 26. This model differs from the previous model presented in 2014 as it uses all points in the regression rather that those only from the lower grouping mentioned earlier (2007 – 2011) That being the case this model considers both "exceptional" and "standard" years in its estimates of MSY and fOpt whereas last year's only considered "standard" years, as a consequence it strikes a balance between truly precautionary and overly optimistic in its estimates. The model suggests similar fOpt's for both species considered though the MSY they produce for each species differs. Separate models could be constructed for both of these states however they are not presented here. While the model is not overly optimistic in its estimates it can still be noted that a number of points representing reported landings fall well above the line of estimate. This further reinforces the concept that these years represent exceptional circumstances in the fishery where for whatever reason recruitment of animals into the fishery is higher than the norm. It does not appear that this fishery has yet reached unsustainable levels of exploitation however; the model suggests that current effort is approaching the maximum recommended levels. 2006, 2012 and 2013 2014 appear to be exceptional years for this fishery, where no appreciable increase in effort has produced higher yields than in other years. It is not clear from the available data as to what is causing these exceptional years or if indeed they are part of a natural pattern of abundance within the fishery that cannot be detected within the scale of data being analysed; further investigation and monitoring of the fishery would be recommended to fully explore what is happening. Concerns may arise if this represents a change in the dynamics or behaviour of the crab population. It may simply be that conditions have become more favourable, increasing the carrying capacity of the area resulting in more crabs on the ground however and of greater concern; it may be a response to some unidentified driver resulting in crabs spending more time in areas that are subjected to fishing pressure. If the latter is the case this may have a detrimental impact on the population as a whole as a higher proportion of the stock is subjected to fishing pressure. Again and unfortunately it is beyond the scope of this report to draw solid conclusions about this.

That said it would be advisable to monitor effort in this fishery as it does appear to be approaching the maximum recommended levels based on available data. As this is one of the most economically important crustacean fisheries in the district further study to investigate population dynamics in the fishery were also carried out this year, the results of which will be presented in a separate report.

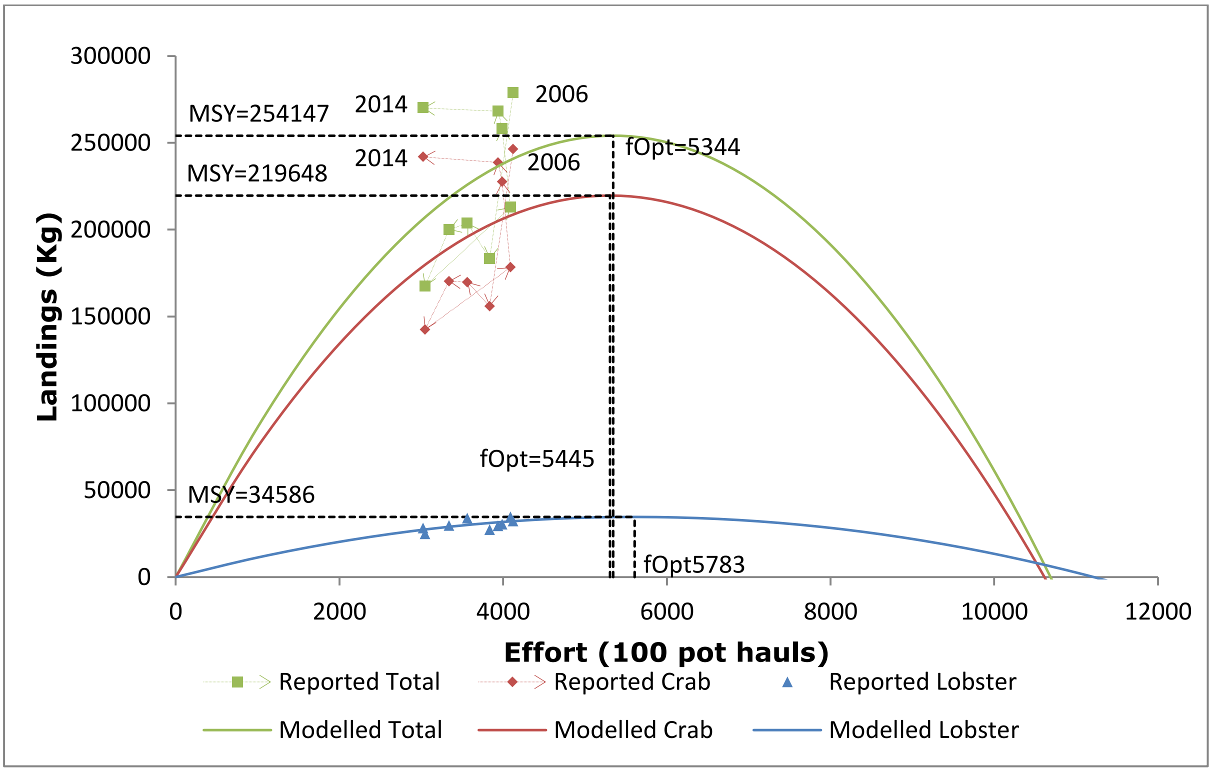

Figure 26 Statistical Rectangle 34F1 Surplus Yield Model Using Parameters Derived from Regression Data Points 2007-2011.

5.5 35F0

5.5.1 Overview

This area is the most productive for potting fisheries in the district with the highest annual landings despite only being fished by a small number of ports (Table 6). This is the main fishing area 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 off the Linc's coast, and vessels that travel down from Bridlington. As such while this area falls completely within the boundaries of EIFCA it is fished by vessels falling under the authority of NEIFCA and as such can be considered as a straddling site in terms of distribution of effort.

Table 6 Statistical Rectangle 35F0 Summary of Vessels, Ports, Effort (100 pot hauls) and Landings (tonnes).

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	3	13	2251	239.2	213.7	25.4
2007	4	12	2040	231.4	208.4	23.0
2008	3	14	2105	368.8	340.6	28.2
2009	3	13	2374	281.8	248.2	33.6
2010	3	14	2507	274.5	246.7	27.9
2011	4	15	2439	247.7	218.8	28.9
2012	4	18	3207	292.6	255.6	37.0
2013	4	13	2471	236.2	211.1	25.1
2014	2	10	2528	203.7	183.3	20.4
Mean	**3**	**14**	**2436**	**264.0**	**236.3**	**27.7**

Landings and effort do not exhibit any relationship in this area producing a trend line that is for all intents and purposes flat (figure 27). This suggests that in this area landings have plateaued and that increasing effort is unlikely to result in higher returns. Rather catch is likely to be diluted between gears resulting in reduced CPUE. The bottom line of this is that potting for crustaceans on this ground appears to be at or beyond maximum productive capacity at current levels of effort.

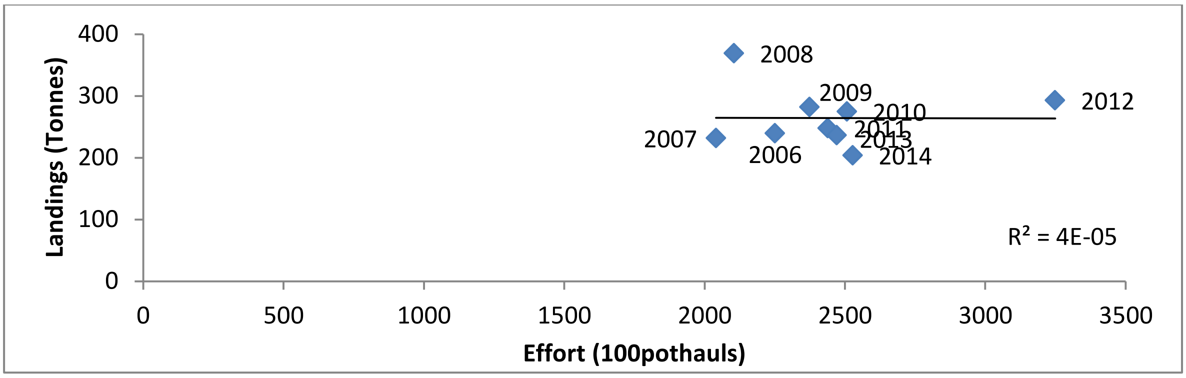

Figure 27 Correlation of landings and effort for area 35F0

As figure 28 demonstrates crab constitutes the majority of the catch for this area being significantly higher than lobster. Despite being ancillary to the main crab catch however; as with 34F1 lobster landings are still significantly higher from this area than most others in the district. Landings are fairly consistent and appear to follow effort quite closely with changes in effort coinciding with a related change in landings. There has however been an observable trend of decreasing landings over recent years though this is also apparent in previous years followed by partial recovery. 2008 stands out as a noticeably productive year for this area with elevated landings that does not coincide with any appreciable increase in effort. This year has seen the continuation of a declining trend in returns from 2012 with 2014 being the lowest point in the MSAR records for this area.

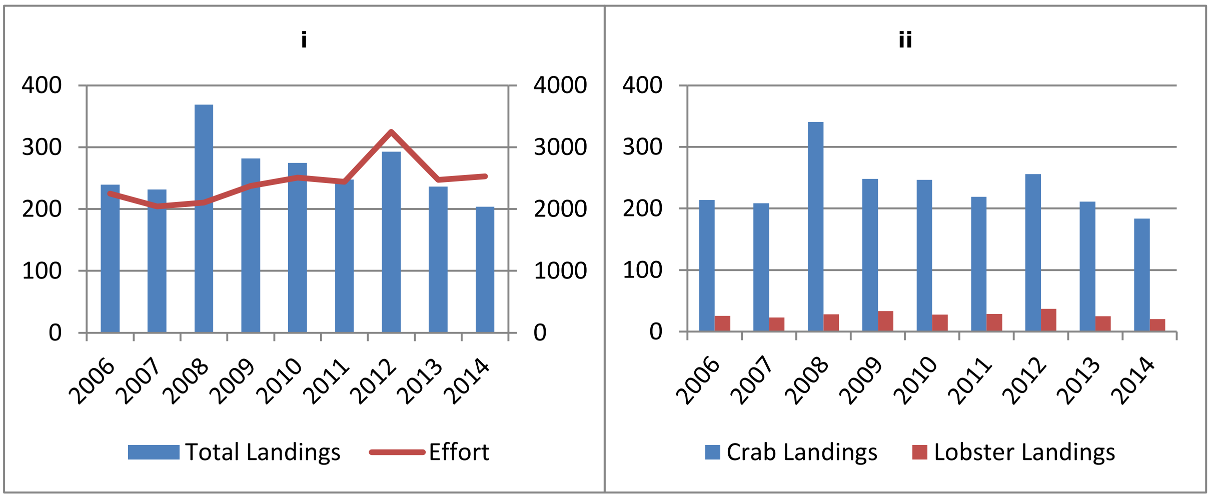

Figure 28 Statistical Area 35F0 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

5.5.2 CPUE

In this area CPUE and effort are negatively correlated for both species and for total landings (figure 29). 2008 appears to be an exceptional year where for some unidentified reason landings and hence CPUE was elevated compared to other years.

Statistical analysis Of landings and CPUE between years (ANOVA) Revealed no significant differences in landings between years however; changes the elevated CPUE in 2008 was found to differ significantly compared to all other years except 2009 (TukeysHSD p= <0.05 for all years except 2009)for crab and consequently total catch. As such 2008 appears as something of an outlier compared to other years when CPUE is regressed against effort. Despite this the trend of declining CPUE with increasing effort still remains in this area.

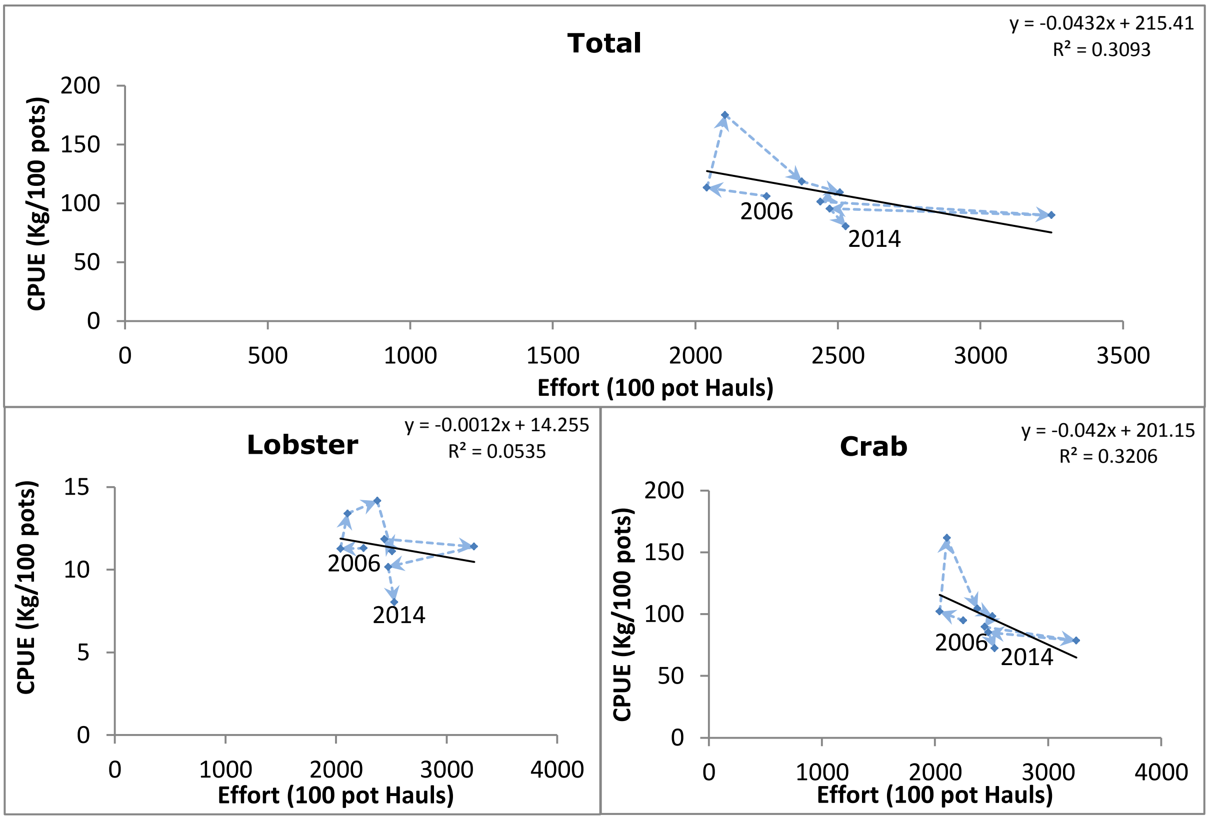

Figure 29 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 35F0 excluding 2008

5.5.3 Surplus Yield Model

Figure 30 indicates that crab is the limiting species in this fishery. Despite this MSY for crab is significantly greater than for lobster at ~240 tonnes compared to ~42 tonnes. Lobster appears to be able to sustain much higher levels of effort than crab in this model and this is explained by the regression of CPUE against effort for this species. Increasing effort is observed to have a lower effect on exploitation rate for this species producing a flatter trend line in the regression analysis.

Crab then is the limiting species for this fishery and it is apparent from the model that effort in this area is at the upper limit of sustainability. Ideally effort in this area should be rolled back to avoid localised depletions to this component of the stock. The area does seem to show some degree of dynamism with variability in landings and CPUE that cannot be fully explained by the data presented. Consequently this ground may be capable of producing landings and levels of CPUE on par with 2008 in the future however; the level of uncertainty associated with this assumption would caution against any increase in effort in this area and would preferably see the exploitation rate decrease.

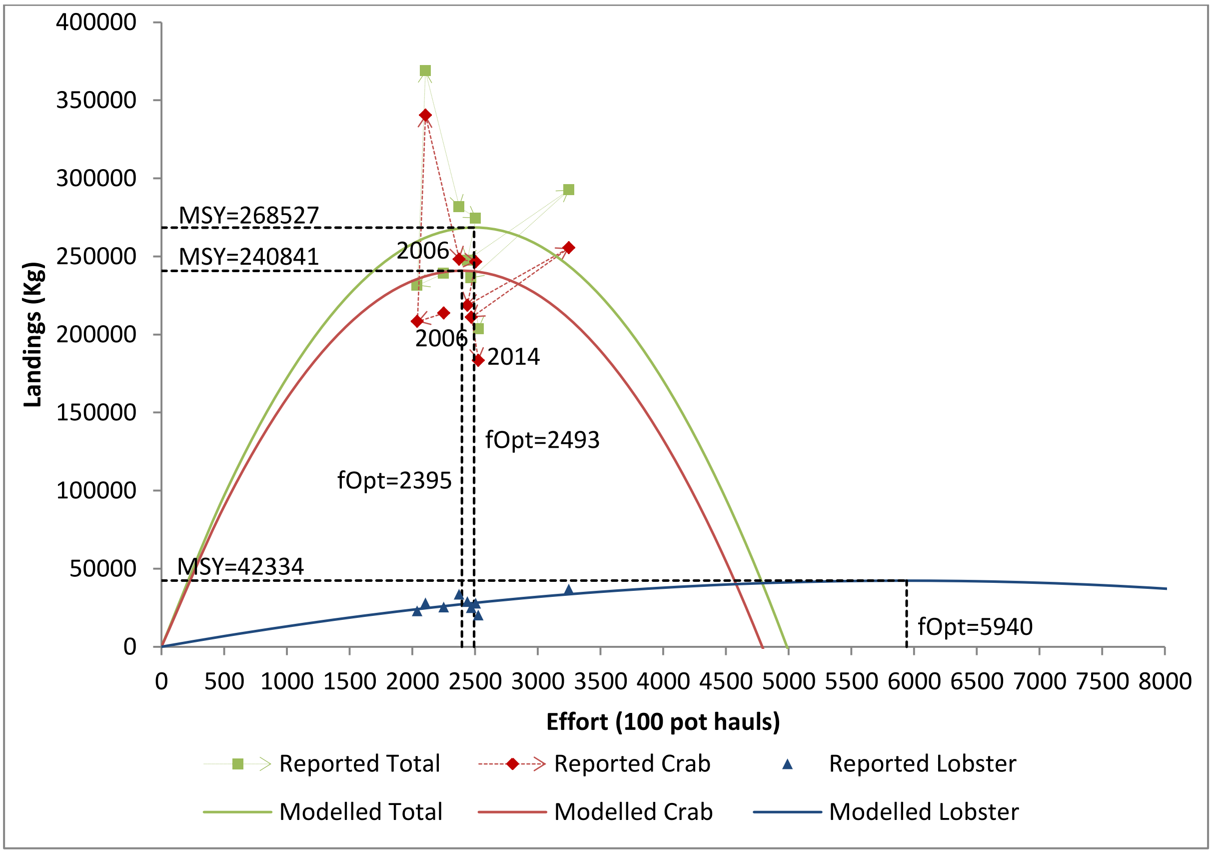

Figure 30 Statistical Rectangle 35F0 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2013)

5.6 35F1

5.6.1 Overview

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

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

Year	Ports Fishing	Vessels Fishing	Effort	Combined Landings	Crab Landings	Lobster Landings
2006	7	11	861	64.6	56.3	8.3
2007	7	10	1187	118.6	108.8	9.8
2008	10	17	1575	183.1	168.6	14.5
2009	9	16	2427	201.3	179.7	21.6
2010	9	17	1539	174.8	158.2	16.6
2011	6	13	1691	160.9	142.4	18.4
2012	6	12	1454	86.7	75.2	11.5
2013	6	8	534	46.2	42.3	3.9
2014	6	9	1063	88.6	78.5	10
Mean	**7**	**13**	**1370**	**125.0**	**112.2**	**12.7**

Plotting landings against effort reveals a strong positive correlation with higher levels of effort producing greater returns for this area (Fig 31). The implication of this relationship is that productivity of the area could be has potential to be increased by applying more effort. This gives this ground potential for the redirection of effort from grounds that are being pushed to their maximum sustainable capacity.

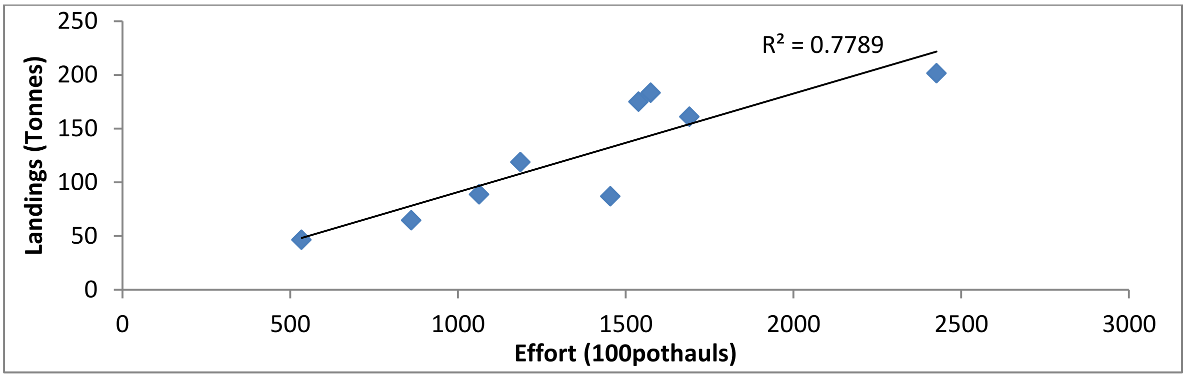

Figure 31 Correlation of landings and effort for area 35F1

Effort and landings have seen a steady increase from 2006 to 2009 with landings increasing by ~50 tonnes each year, before steadily falling back down to 2006 levels again in 2013 following decreasing effort. 2014 has seen effort and landings pick up again for this area (table 7). Crab constitutes the main catch with landings considerably higher than lobster (Figure 32).

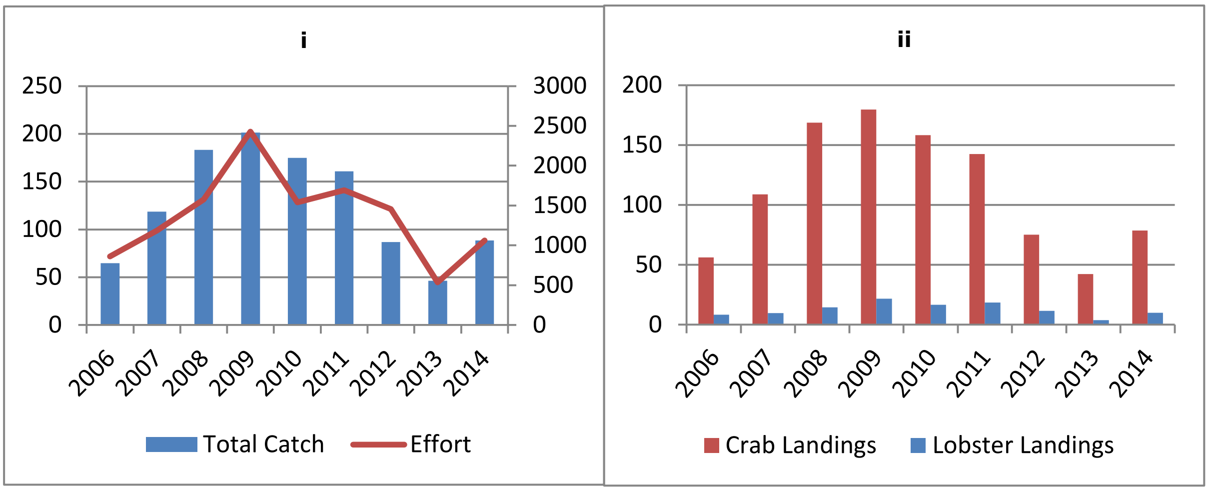

Figure 32 Statistical Area 35F1 (i) Annual Landings in Tonnes (left axis) and Effort in 100 pot hauls (right axis) (ii) Landings by Species in Tonnes.

5.6.2 CPUE

Regression of CPUE against effort for total catch (figure 33) revealed a weak positive relationship between increasing effort and CPUE supporting the suppositions made from the correlation of landings and effort (figure 31) that this area has the potential to support a higher rate of exploitation. While this is the case the relationship between increasing effort and CPUE is very weak producing almost flat trend lines. This suggests that the relationship between increasing effort and CPUE is beginning to plateau and is likely approaching the level at which MSY would be met. Without further increasing effort and observing the effects on CPUE it is uncertain where the tipping point in this relationship would lie.

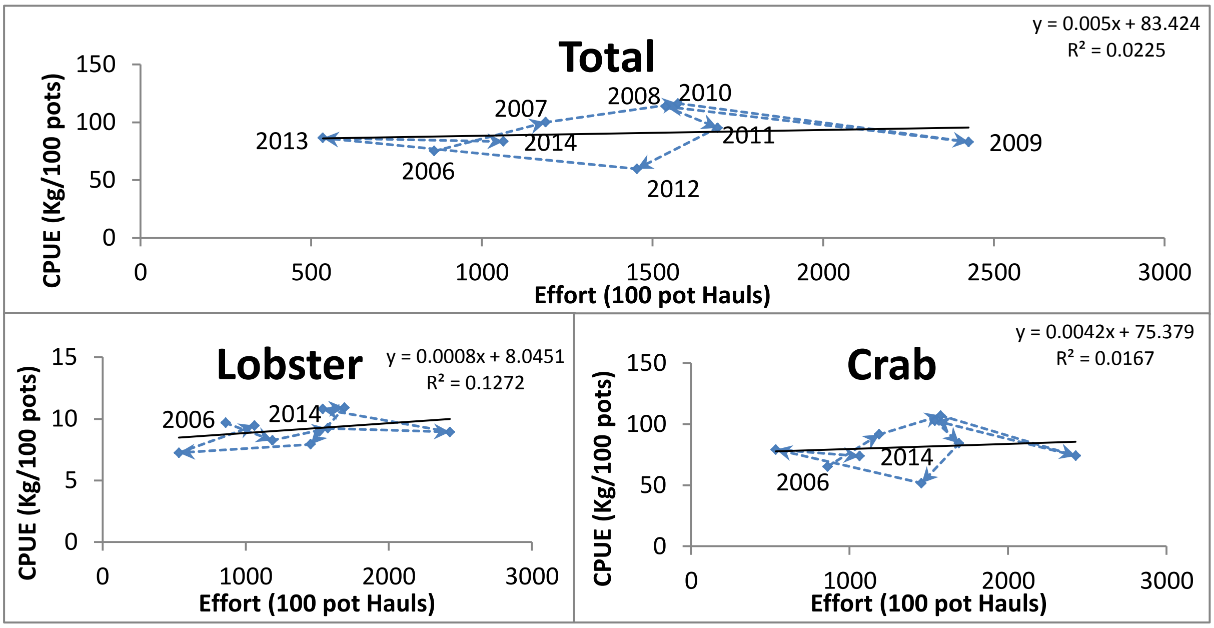

Figure 33 Regression Analysis of CPUE vs. Effort for Statistical Rectangle 35F1 2006-2014

5.6.3 Surplus Yield Model

The surplus yield model in this example (Figure 34) is based on a set of modified parameters that differ from those produced by regression of CPUE against effort. As such this model is heavily caveated as it is based on assumptions as to how this ground would respond to further increases in effort. The cerebration behind this is outlined below.

Deviation from the standard procedures in constructing this model stem from the observed relationship between effort and CPUE. For this type of model to work an observable negative relationship between CPUE and effort is required for the creation of parameters. These parameters are based on the slope (rate at which CPUE decreases with increasing effort) and intercept (theoretical CPUE when effort is effectively zero) of the trend line. In a fishery where the point at which a negative relationship between CPUE and effort has not yet been encountered (i.e. increasing effort results in increased CPUE) the slope instead predicts the rate at which CPUE increases with increasing effort.

The Use of such parameters results in a model whose curve predicts an exponential rise in landings as effort increases (as seen for lobster in figure 22). This relationship is observed for all of the regressions in this area.

To rectify this, the inclined slope in this set of regressions is simply inverted to produce a negative number based on the following assumption about the fishery;

1. That the flattened trend line observed in the regressions represents a level of effort that is approaching the optimum.
2. That the initial rate of decline in CPUE beyond the optimum will be close to the observed increase seen in the regression.

Therefore slope for each change from;

- 0.005 to -0.005 for Total Landings
- 0.0008 to -0.0008 for Lobster Landings
- 0.0042 to -0.0042 for Crab Landings

The original intercept has been retained in each case essentially forming the pivot point of the transformation.

The model that this conversion produces is presented in figure 30. Predicted MSY is not too far removed from that given by the models constructed for adjacent areas (34F1 and 35F0) considering the parameters used are based on the estimated response of CPUE as effort passes the tipping point. That said the MSY presented here is probably somewhat of an overestimate given that the slope it is based on is very shallow. If a stronger relationship between increased effort and declining CPUE beyond the tipping point exists then the effect would be to reduce these predicted MSYs. As such this model is indicative only and this area is likely to perform similarly to adjacent areas 34F1 and 35F0 in terms of productivity. That said evidence from MSARs suggests the area is relatively lightly fished at present and has potential to absorb some of the surplus effort from these other areas.

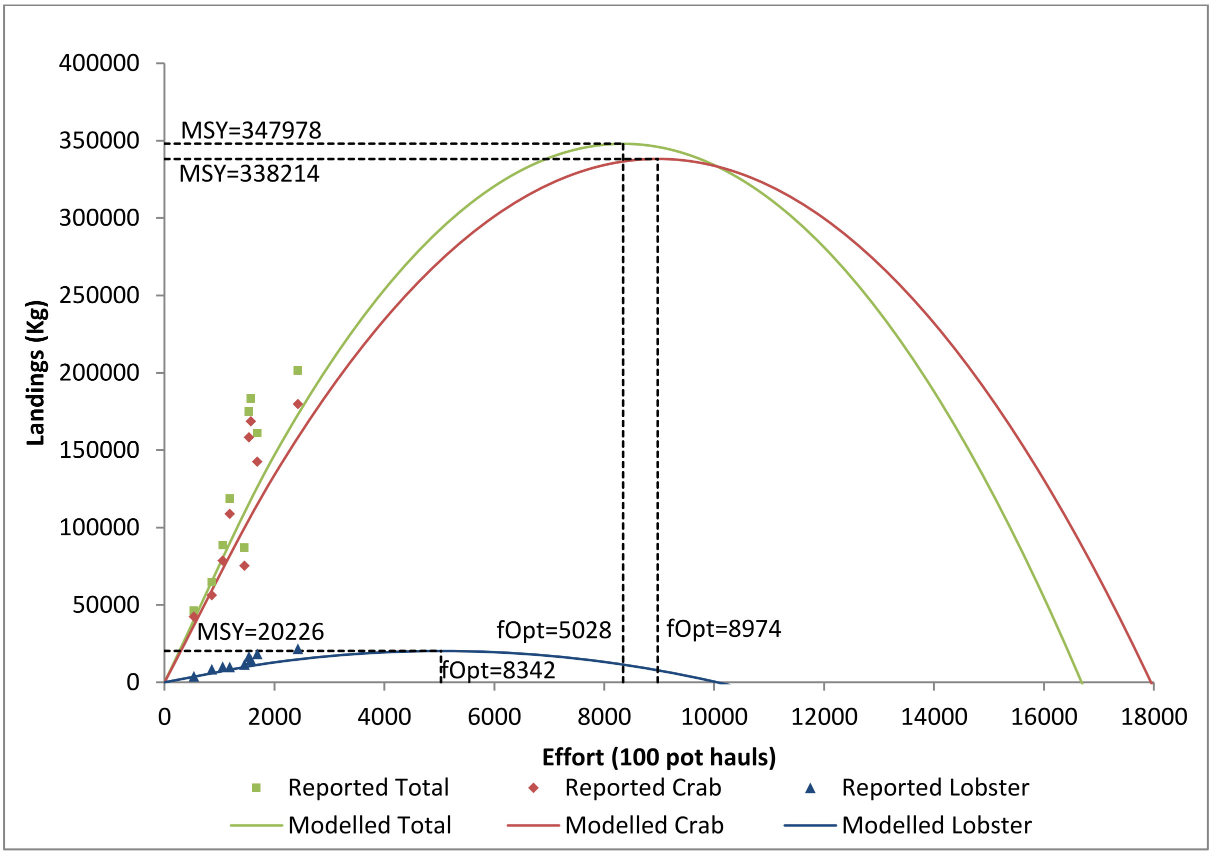

Figure 34 Statistical Rectangle 35F1 Surplus Yield Model Using Parameters Derived from Regression of all Data Points (2006-2014)

6. Discussion

6.1. Analysis Results

The above analysis represents the second year of applying surplus yield methods to the data collected from MSARs. The addition of the 2014 data has improved the stability of a number of the models with all available data points being used for each of the assessment areas. The general overview produced by these models is good suggesting that there are no areas where effort is overly exceeding the productivity of the grounds however; there are some areas which may be showing early signs of cause for concern. The Suffolk grounds (32F1 & 33F1) both appear to be operating well within the bounds of the predicted MSY/fOpt estimates given by their respective models. There is however some small concerns regarding reporting in area 32F1 as the majority of this area falls outside the EIFCA district and it is likely additional ports falling under the jurisdiction of Kent & Essex operate in this area. While this is of some concern the CPUE generated in this assessment is unlikely to be adversely affected by additional reports, rather the volume of landings will be elevated causing the model to produce higher estimates of MSY.

The fisheries operating from the N.Norfolk coast offer greater concern and it is apparent that in two of the areas assessed effort and landings are approaching maximum recommended limits as predicted by the surplus yield models. Area 35F0 is of greatest concern, as in the past six years effort in this area has been maintained at or surpassed the recommended upper limit of fishing effort as predicted by the model. Correlation between effort and landings in this area are produces a flat relationship, indicating that no amount of increasing effort will result in increased returns. Ecological concerns not withstanding a reduction of effort would be highly beneficial in this area. The analysis presented suggests that the available fish are being distributed between gears with less being landed per gear (reduced CPUE) for similar overall returns. This type of overfishing has economic as well as ecological implications as the extra effort affords higher running costs for no additional profit to the fishery as whole.

The traditional N.Norfolk inshore area (34F1) also presents some concern, though not so great as that posed by 35F0. Fishing effort in this area appears to consistently fall in the portion of the model that would be expected to produce maximum economic yield (A yield that falls somewhere below MSY in most surplus yield models but that produces the maximum net profitability when running costs are considered.) suggesting long term stability both in terms of economic and ecological viability. The concern then lies in how this ground is utilised in the future. It would be advisable to at least maintain effort in this area at current levels and prevent any increase in pressure on this ground. Threat lies in latent effort and displacement from other areas that may see the productivity of this area and be drawn in to fish there from areas with higher competition for space or with perceived declining returns. This area also appears to exist in two different states with productivity being elevated for some years for no immediately obvious reason. Occurrence of elevated CPUE and higher landings has been the prevalent trend for the past 3 years (2012 – 2014) with another instance at the beginning of the dataset and it is possible that this is linked to milder winters and earlier access to the fishery. While this may be seen as a boon to the fishery, offering higher productivity and hence profitability it may also carry deeper connotations. Speaking from an entirely hypothetical standpoint this increased abundance of animals may not necessarily represent increased levels of recruitment but perhaps; more animals from the same population using the ground or; animals moving onto the ground earlier in the year and moving away later. Should this be the case what we may be observing is; a population of similar size to previous less productive years being subjected to higher levels of fishing pressure than they would normally otherwise endure. If this is the case then the early access and prolonged fishery provided by milder winters may be a mixed blessing in effect subjecting the stock to increased fishing pressure without the need for additional effort.

The final area covered by the assessment 35F1, does not show signs of overexploitation throughout the history of the MSAR dataset and as such the parameters derived from the regression of CPUE on effort were inappropriate for the effective modelling of this ground. As such modified parameters were used as a proxy to facilitate modelling. While the estimates produced by this model cannot be held to be accurate the supposition is that this ground may be useful for the relocation of effort from other grounds that are experiencing high effort allocation. The feasibility of this would of course be dependent on the ability for vessels to reach this ground while still achieving viable returns (i.e. remaining profitable despite increased costs of reaching the area).

6.2. Analysis Methods

The surplus yield models presented above represent the achievement of long term goals for the authorities crustacean research programme and provide a simple method of assessing the status of fisheries within the EIFCA district at the simplest level and utilising readily available data sources. The models are not without their limitations however and do not marry well with the more sophisticated methods used by other organisations such as Cefas in their stock level assessments, offering little in the way of direct comparison of results.

These models are fairly simplistic, only taking into account the fishery effect on the stock, and do not take of stock abundance or biology into consideration. Such models are unsuitable for the estimation of stock status, spawning stock biomass, mortality rates or a number of other metrics useful in the assessment and management of fisheries.

Traditionally these models have been associated with the assessment of finfish stocks where data required for more in depth assessment has not been readily available and management measures have focused around effort limitation. In such cases the metric for fOpt generated is often in a form that can be easily managed (e.g. days at sea or trawl hours) however in these models this is not the case. Pot hauls whilst useful for the determination of CPUE are a fairly abstract concept when it comes to translation into management measures. Unless this metric is transformed into a more tangible format such as total numbers of pots fished then managing effort is a difficulty. In addition to this limitation such a measure of the fishery may be unsuitable in monitoring or detecting the effect of technical measures such as the introduction of escape gaps or changes to MLS.

Population data collected from surveys aboard fishing vessels carried out during 2014 begin to fill in some of the gaps in data that currently limit what we are able to achieve. This additional data should provide the baseline information required to carry out assessments that align more readily with those used to assess stocks on a national basis. These assessments provide references levels based on rate of fishing mortality that are not readily monitored by the use of surplus yield based analyses so the adoption of the methods used to define these parameters is highly advisable. This would allow a better comparison of results between assessments carried out on a local level with those undertaken on a broader scale opening the forum for discussion on where attention needs to be focused to address issues and concerns in the fishery.

This is particularly pertinent in light of recent recommendations for the reduction of fishing effort in crustacean fisheries nationwide as proposed by Defra. The basis of these comes from the results of the Cefas assessments and suggests that dramatic reductions in fishing mortality are required to bring these fisheries in line with MSY targets. These recommendations largely contradict conclusions drawn by the assessments presented in this report The ability to directly compare estimates between our own assessments and our those carried out by Cefas would put the authority in a much better position to contest such recommendations or at least make it more obvious where our own commitments to effort management should be focused.

7. Recommendations

In continuation of this project a number of objectives should be realised in the coming year;

- Adoption of Length Based Cohort Analysis as used in the Cefas stock assessments.
- Implementation of a rigorous at port sampling regime to inform assessments.
- Collection and consolidation of pot numbers and grounds fished
- Investigation of pertinent management measures e.g. escape gaps, changes to MLS, Effort limitation.

Primarily the assessment methods utilised by Cefas should be adopted and emulated to provide a more coherent comparison of results observed on a local scale with those presented by their annual stock assessments. This is work that is currently in progress but is unavailable at this point in reporting.

Initial data for this has been collected over 2014 from surveys carried out at sea aboard fishing vessels and will form the basis of initial assessments however; the resource requirements for these surveys is relatively high compared to the value of the data they produce. Consequently targeted biosampling at points of landing would provide a compromise, providing a less detailed but more accessible source of data. It may be desirable to carry out further at sea surveys to refresh the data collected in 2014 at some point in the future however it is not a priority for 2015.

With work being undertaken to review current bylaws and interest from the industry to improve regulation in the crustacean fishery a review of potential management measures would be beneficial to inform management as to the risks and benefit of a range of technical measures.